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Management Considerations of Fish Production in Cages 1

Andrew M. Lazur[2]

The production of fish in cages has been practiced for many years in various countries worldwide. Many commercial species, including bluegill, hybrid striped bass, carp, channel catfish, salmon, tilapia and trout have been cultured in cages. Specific production characteristics (such as cage design and construction material, stocking rates, feed types and rates and water quality requirements) vary greatly depending on the species and water body. For example, salmon ranching or farming utilizes large cages or net-pens anchored in bays or estuaries; more recently, large flexible self contained systems with walkways are being used in more open, ocean conditions. In these situations, tidal influence and prevailing winds provide essential water exchange through the cages replenishing oxygen levels and removing nitrogenous waste products. Small farm ponds or lakes are a water resource that is commonly used for cage culture. Regardless of the species produced and water body utilized, the confinement of a large number of fish in a relatively small cage environment can increase stress on fish. Special attention to proper fish culture practices including water quality and feeding management are essential.

Characteristics of Cage Culture

The practice of producing fish in cages or floating pens differs from the more widely practiced open pond culture in several ways. Fish can be cultured in cages in bodies of water that do not lend themselves for traditional open pond culture methods. This may be due to obstructions in the pond, such as tree stumps, or water depths greater than 7 feet which make seining difficult or impossible (Figure 1). Due to the crowded conditions of fish in a cage system, special water quality management practices are required to ensure good fish health, survival and growth. There are specific features of cage culture that should be considered prior to producing fish.

Figure 1 .

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2. Andrew M. Lazur, Assistant Professor and Extension Aquaculture Specialist, Fisheries and Aquatic Sciences, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

Opportunities

- Ability to utilize bodies of water unsuitable for conventional pond harvesting methods such as seitung or complete pond draining.
- Ease of observing fish activity including feeding.
- Relative ease of harvest.
- Ability to produce one species in cages in ponds stocked with other species, for example, catfish in cages in a bass and bream pond.

Challenges

- Increased disease susceptibility due to crowded conditions.
- Greater size differentials among fish at harvest due to competition and aggression among fish.
- Greater potential for theft and predator loss.
- Increased incidence of water quality-related stress compared to open pond culture.

Producing fish in a cage presents several key differences over fish production in an open pond which directly influence productivity of cage systems.

Channel catfish are commonly stocked at 3,000-8,000 fish per acre in open ponds with an average depth of five feet. This equates to one fish per 360-540 gallons, or one fish per 48-72 cubic feet. Production yields are generally 3500-5000 pounds per acre in aerated ponds. Aeration by mechanical means, such as electric paddle wheels, has proven to increase oxygen levels and fish production in open ponds. Stocking densities for cages are considerably more dense ranging from 0.6 to 2 fish per cubic foot, or 5 to 12 fish per gallon. Fish production in cages has ranged from 0.3 to 0.75 lbs per gallon. Recommended pond stocking rates for cage production are up to 2000 fish per acre without aeration and up to 4000 fish per acre with aeration. Wild fish populations in the pond should be considered when determining stocking rates. Stocking rates for tilapia and hybrid striped bass in cages are 6 fish per cubic foot. Pond stocking rates are 4000-8000 and 3000-5000 fish per acre, respectively, for tilapia and hybrid bass.

Fish stocked into open ponds can utilize a significantly greater portion of the water column than caged fish. Pish in ponds are able to utilize natural foods as part of their diet, whereas many species produced in cages, including Bream, hybrid bass, catfish, trout and salmon, are completely dependent on the commercial diets they are fed. Filter-feeding species, such as some carp and *Tilapia* species, can derive nutritional benefit from phytoplankton that enter the cage in addition to commercial diets.

In the event of a low oxygen occurrence, fish in the open pond can migrate to areas of higher oxygen concentration. On the other hand, fish raised in cages are dependent on oxygen levels within the small space of the cage. The ability of pond fish to utilize the entire pond volume is a distinct advantage over the confinement of caged fish.

Water Quality Considerations

Water quality is extremely important in all fish culture systems. The nature of cage culture creates a need for special attention to particular water quality parameters. A review of the major water quality considerations involved in cage culture are presented below.

Dissolved Oxygen

Dissolved oxygen is one of the most important water quality parameters in fish culture. Oxygen concentrations in a cage environment can drop quickly if water exchange is inadequate. Optimum oxygen concentration should be above 5 parts per million (ppm) at all times for good growth. Frequently, morning oxygen levels can fall below 2 ppm, particularly in fertile ponds (moderate to heavy algae bloom) in summer, causing stress to caged fish. During calm days when water exchange is minimal, oxygen concentrations within the cage can drop to stressful levels even though outside the cage they are adequate. In these situations supplemental aeration is necessary to reduce stress to fish.

Mechanical aeration can be utilized to improve water quality in cages. Paddle wheels, pump sprayers, destratifiers, water circulators and diffused air systems placed near cages to provide greater water movement and aid in faster water exchange which improves water quality (Figure 2)and (Figure 3) . Special attention must be paid to the placement of aerators for aerating cages. An aerator located too close to cages can subject fish to too strong currents and possibly increase stress levels. A gentle current providing water exchange is recommended. Having an aerator adjacent to cages can increase water flow through the cage and may improve oxygen levels. As water is aerated, it is continuously pushed through and away from the cage. A significant increase in oxygen level within the cage environment will occur only after the aerator has had sufficient contact with a large volume of pond water. By simply moving water through the cage, dissolved oxygen levels may be maintained with no additional aeration. It is important to keep fish stocking rates and total pond biomass within the range stated earlier; doing so will reduce the risk of low dissolved oxygen problems.

Figure 2 .

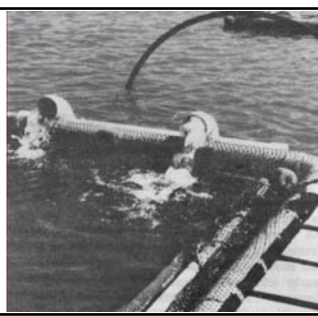

Figure 3 .

There are several major causes of low dissolved oxygen in ponds that a cage producer should understand in order to anticipate problems and implement management strategies. These include:

- Cloudy weather - Since photosynthetic activity is reduced during cloudy weather, pond oxygen concentrations will decline. Ponds with heavy algae blooms can experience greater oxygen declines because of the higher algae respiration rate.

- Summer thunderstorms - High winds and heavy rains can cause a "turnover" or destratification of ponds, especially in deeper ponds which are typically used for cage culture. The wind and rain mix deeper, low-oxygen, bottom waters (hypolimnion) with surface water (epilimnion) causing a rapid reduction in oxygen concentrations. The degree of oxygen reduction depends on the volume of the hypolimnion -the greater the volume of the hypolimnion, the greater the reduction in pond oxygen concentrations. Deep ponds (6 feet or deeper) which typically stratify could benefit greatly from use of an aerator which mixes the layers and improves the total oxygen budget of the pond.

- Plankton die-off - Phytoplankton populations can die for unknown reasons and cause rapid oxygen depletion due to bacterial decomposition of algae and associated respiration. Ponds experiencing a plankton die-off will usually turn from a greenish color to light brown or gray and visibility may increase. Emergency aeration is usually necessary for 2-3 days until algae population and oxygen production increase.

To alleviate low oxygen stress from the above situations, cages should be placed in an area of the pond where emergency aeration, such as tractor driven paddle wheels or pumps, can create a slight flow of water through the cage. For more information on dissolved oxygen refer to IFAS Fact Sheet FA-27.

Temperature

Caged fish will respond similarly to water temperatures as pond fish, but may be exposed to greater temperature extremes depending on the depth and placement of the cage in the pond. It is recommended that cages be at least four feet deep in order for fish to have access to deeper water that is typically cooler in the summer and warmer in the winter.

Optimum water temperature for catfish growth is 78-85° F. Growth declines as water temperature drops to 60°F, and no growth occurs below 50° F. As water temperature rises above 87° F, growth slows and stops at 92° F; in addition, serious stress to the fish can occur at these temperatures. Hybrid striped bass, like catfish, exhibit good growth in the 78-85° F range, but they tend to feed more aggressively in cooler water. Hybrid striped bass have also exhibited signs of stress (e.g., going off feed) at water temperatures above 85° F.

Alkalinity

The alkalinity of water refers to the total concentration of bases expressed as mg/I equivalent calcium carbonate (ppm $CaCO_3$). Waters of higher alkalinity have a greater buffering capacity, which reduces daily pH fluctuations. Caged fish generally exhibit better growth in ponds of moderate alkalinities (>50 ppm $CaCO_3$), and it is recommended that agricultural limestone be added to ponds with alkalinities below 50 ppm $CaCO_3$.

A soil sample of the pond bottom and an alkalinity test of the water can determine if limestone is required to raise the alkalinity. Typical application rates average 1-2 tons of limestone per acre.

Turbidity

The turbidity of water refers to the concentration of suspended particles. Clay particles and suspended organic matter are the usual causes of turbidity in ponds. Sunlight penetration is limited in highly turbid ponds resulting in reduced photosynthetic activity. This situation usually promotes thermal and oxygen stratification which renders deeper waters inadequate for good fish growth due to low dissolved oxygen concentrations.

Unusually clear water poses specific problems. Ponds with clear water tend to have increased weed problems due to light penetration into deeper waters. An overabundance of aquatic plants can lead to management and water quality problems. Also, caged fish in clear ponds are generally more sensitive to nearby activity and may not feed until human activity decreases. Frequent disturbances may be more stressful to fish. Fish from clear ponds may also exhibit a skin darkening which can affect their marketability.

Fertilization with phosphorus-containing fertilizers such as 20 lbs. per acre of triple superphosphate (0-46-0) or 1 gallon per acre of liquid phosphate (10-34-0) will stimulate new phytoplankton growth. Maintaining a desirable phytoplankton population or bloom provides several benefits, including oxygen production, food source for various aquatic life, and natural biofiltration of ammonia; phytoplankton reduce sunlight penetration thus shading less desirable aquatic plants. See IFAS Fact Sheet FA-17 for more information on pond fertilization.

A good index of pond plankton turbidity or visibility is the depth at which your hand or a specially designed white and black plate, termed a Secchi disk, disappears as it is lowered in the water. A desirable Secchi disk reading is 18-24 inches. Visibilities of less than six inches are a sign of a heavy algae bloom which contributes to low oxygen levels at night.

Fortunately, ammonia and nitrite problems are unlikely in ponds with cages if the pond is not overstocked and overfed. However, ammonia concentrations can reach stressful levels in cages if water exchange is restricted and excess feed is allowed to accumulate. Overfeeding and allowing excess feed to build up on cages may raise ammonia levels and should be avoided. If a feeding ring is used it is recommended that it be cleaned periodically. Careful feeding management is required to prevent water quality problems, reduce costs and improve fish production.

Biofouling

The water exchange in a cage can become restricted due to a build-up of algae and other organisms. Certain bryozoan species, jelly-like animals, can attach to the cage and severely block the flow of water (Figure 4). Soft mesh cages can float up if bryozoans. Periodic high pressure washing of cages has been used by a few cage producers with moderate success to reduce the biofouling problem.

Filamentous algae can also accumulate on cages and restrict water exchange. This is aggravated by excess feed build-up on cage which promotes algal growth. This algae can be removed by hind or by periodic pressure washing. Some farmers have used small socks of copper sulfate suspended from the cage to control filamentous algae with varied success.

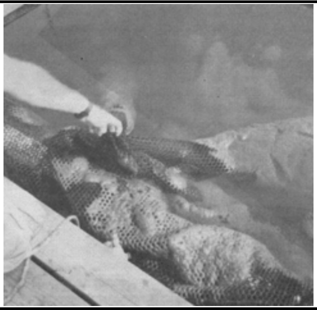

Figure 4 .

Contact your county agent or specialist for information regarding use of aquatic herbicides.

Feeding Management

The physical confinement of fish in cages also presents fish nutrition concerns to fish culturists. To minimize fish stress and maximum fish growth special attention to proper nutrition and feeding practices is required.

Nutritional requirements and feeds

It is essential for farmers to use a diet that is nutritionally complete for the cultured species. Since natural food is unavailable to non-filter feeding fish cultured in cages, it is particularly important that diets supply all the necessary nutritional requirements. These requirements include proper protein levels, energy sources, minerals and vitamins. Common catfish diets of 32% and 36% protein are adequate for many fish species. Bream and hybrid bass have exhibited better growth if a higher protein trout or specific hybrid bass diet is used. Some feed manufacturers produce feeds specifically formulated for cage culture. In addition to proper diet formulation, it is important to maintain feed quality by using good feed handling practices. Since heat and humidity can increase the breakdown of certain vitamins in feed, it is recommended that feed be stored in a cool, dry place and that only enough feed be stored as will be used within six weeks. Feed that is moldy or infested with insects should not be used.

The use of floating feed is recommended for cage culture to allow ample time for all the fish to feed. Sinking feed will quickly pass through the cage and be unavailable to the fish. In some cases where a sinking medicated feed is prescribed for treatment of bacterial infections, a metal tray or fine mesh screen is placed on the cage bottom allowing the sinking feed to settle on the cage bottom. For best results the tray or screen area should be large, preferably covering the entire cage bottom with a vertical edge that extends eight inches above the cage bottom. The edge will prevent fish from washing the feed through the cage sides.

Use of the proper feed pellet size is also an important consideration when selecting feeds. A small feed pellet size is recommended for young fingerlings. A 1/8 inch pellet is ideal for bream, hybrid bass and tilapia fingerlings, and a 3/16 inch pellet can be used initially for six-inch catfish fingerlings. As fish grow, the standard 1/4 inch pellet can be used.

Feeding Rates

Initially fish are fed based on body weight. Fingerlings generally are fed 4-5 % of their body weight per day at water temperatures above 70° F. The feeding rate is gradually reduced to 3% as fish grow, and then is reduced to 2% of body weight per day as they near market size. Periodic sampling can be useful to determine average fish weight enabling rate adjustments. An alternative feeding method involves providing fish whatever they can eat in a certain length of time. In many cases the time period is 15-20 minutes. However, this rule of thumb does not always prove true. Some fish will feed intermittently, and a longer time period may be required. Farmers often must determine the necessary time period based on their individual crop of fish. With either feeding method, periodic feeding rate adjustments are necessary. This will help to ensure that fish are being fed an adequate amount for maximum growth.

Feeding caged fish twice per day during the warmer months has shown to significantly increase fish production. Feeding can be spaced about six hours apart; once in mid-morning and again in early evening, for example. Some farmers have observed that their fish will feed best in late evening and have adjusted their feeding schedule accordingly. Sunlight and water temperatures may influence feeding behavior. Once the best times are determined, it is recommended to maintain that schedule.

Feeding activity slows as water temperatures drop below 70°F and is significantly reduced during the cold winter months. Recommended cold water feeding rates are given in Table 1.

Although feeding activity is slow during the winter, feeding remains important during the winter to maintain fish health. The efficiency of fish immune systems is somewhat reduced by the cold water temperatures, and fish that are not fed will experience a greater incidence of diseases. It is common for fish to go off feed for several days during an extreme cold weather period. Immediately following these cold fronts and through the winter, it is helpful to feed during the warmest part of the day.

Feeding Procedures

Feeding rings are commonly used to contain the feed within the cage and prevent it from being splashed out of the cage by fish activity. The feeding ring is usually constructed from a small PVC pipe frame in which a small 118 or 3/16 inch mesh screen is attached so that the mesh extends about eight to twelve inches above and below the water surface. It is recommended that the feeding ring be as large as possible, preferably the same size as the inside dimensions of the cage, and be removable to clean uneaten feed and filamentous algae that can clog the mesh and restrict water exchange.

It is important to prevent overfeeding. This is costly and can also lead to water quality problems. Any uneaten feed that remains after an extended period should be removed from the cage.

Fish in cages can be sensitive to noise and human activity. Excessive disturbances may cause a reduced feeding response and increase stress, therefore affecting fish health and growth. It is best to limit unnecessary activity near cages. Once fish are trained to a particular feeding time, it is important to keep that schedule.

Production Guidelines

In addition to water quality and feeding management, proper culture techniques are required to ensure good fish production.

Prior to stocking fingerlings in cages, be sure they are in good health and that, when stocked, they are acclimated to the new pond water. This can be achieved by slowly pumping pond water into the transport container to provide a complete water exchange in 20-30 minutes. Check with your county extension agent for a list of fingerling suppliers.

A minimum cage mesh size of 1/2 inch is recommended. This mesh size will hold a five-inch catfish or a two-inch bream, tilapia or hybrid bass fingerling and allow good water exchange through the cage (Figure 5). Smaller mesh sizes can be used to hold young fish, but frequent cleaning is recommended to prevent restriction of water exchange due to biofouling of mesh openings.

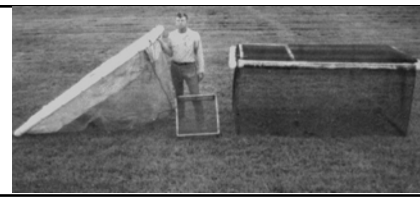

Figure 5 .

Rectangular cages with the long side exposed to the prevailing winds are recommended to maximize natural water circulation through the cage. This is important in removing fish wastes, such as ammonia, and allows fresh water with higher oxygen concentration to enter the cage.

Following the recommended stocking rates for the cultured species and for the pond or lake is of extreme importance. Overstocking followed by heavy feeding and not removing large fish as necessary can lead to severe water quality and fish health problems. Since caged fish are under crowded conditions and the cage is confined to one location of the pond, the volume of water which is available for fish production is significantly lower than that of open pond culture. This is a major reason that production yields for cage culture are lower than open pond culture. Stocking rates for ponds utilizing cages should be limited to 2000 pounds per acre for unaerated ponds and less than 4000 pounds per acre for aerated ponds. The wild fish population in the open pond should also be considered in order to keep biomass or total fish production within the recommended levels.

Cages should be placed in areas of adequate depth. A depth of at least two feet from pond bottom to cage bottom recommended. Cages should be spaced as far apart as possible for good wafer exchange. A minimum distance of 15 feet between cages is recommended. Multiple cages can be anchored to the pond bottom or attached to a rope stretched across the pond, and a boat is used to access cages.

Placing multiple cages next to a pier can limit water exchange unless water circulation is enhanced by a mechanical aerator (Figure 6). If aeration is used, be sure that the water current is not excessive. A gentle current is recommended.

Figure 6 .

Summary

Cage culture is an alternative method of fish production for recreational and commercial pond owners. It allows the opportunity of holding fish of varied sizes and utilizing deep ponds or ponds that are difficult to seine because of stumps or other obstructions. Because of the high stocking rates, crowded conditions, and the cage's fixed location within a pond, special attention to wafer quality and feeding management is required for successful production.

Adequate water circulation through cages is essential to remove waste products and replenish oxygen concentrations. Placing cages in areas of adequate water depth and prevailing winds can ensure maximum natural water circulation. Mechanical aerators, such as electric paddle wheels, airlifts, pump sprayer aerators and others, can be used to provide the necessary water circulation and oxygen supplementation.

Proper fish nutrition and use of sound feeding and culture practices are also essential for good production of fish in cages.

Table 1.

Table 1. Recommended cold water feeding rates.

Feeding rate				
WaterTemp °F	Adults(more than 2 lb)		Fingerling	
	%body wt	Freq days/wk	%body wt	Freq days/wk
45-50	0.5	3	0.5	5
51-55	0.75	5	0.75	6
56-60	0.75	6	1.0	7
61-65	1.0	6-7	2.0	7
66-70	1.5	6-7	2.5	7