Proceedings of the Midwest Regional Cage Fish Culture Workshop

August 24-25, 1990
Holiday Inn
Jasper, Indiana

Sponsored by:
Indiana Aquaculture Association, Illinois-Indiana Sea Grant Program,
Purdue University and University of Illinois Cooperative Extension Services, and Southern Illinois University at Carbondale
A WORKSHOP

ON THE

MIDWEST REGIONAL CAGE CULTURE

D. L. Swann and P. B. Brown

Editors

Presented at

Southern Indiana Purdue Agriculture Center
and
The Holiday Inn
Jasper, Indiana
24-25, August, 1990
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WELCOME

LaDon Swann,
Aquaculture Extension Specialist
Illinois-Indiana Sea Grant
Purdue University
West Lafayette, Indiana

Good morning: I cordially welcome each of you on behalf of the Illinois-Indiana Sea Grant Program, Southern Illinois University at Carbondale, and the Indiana Aquaculture Association to Indiana's first of many Aquaculture Extension Workshops. I also welcome you to Southern Indiana, which is the heart of Indiana's farm pond region. Many of the ponds in this region, like those in Southern Illinois, offer the potential fish farmer a means of learning essential fish husbandry skills at a relatively low cost.

I have great expectations for the aquaculture industry in Indiana and Illinois. These two states are historically agrarian, and are fortunate to be situated in the center of one of the largest marketing regions in the United States. One-half of the U.S. population lives within 500 miles of us. With this tremendous market for aquaculture products and the growing interest in aquaculture, universities like Purdue, University of Illinois and Southern Illinois University at Carbondale are mandated to provide educational and supportive services that will directly benefit our growing industry.

In response to our obligation, we sincerely hope that this cage culture workshop spawns similar industry directed programs through increased awareness of our services.

Before getting started with our first presentation, I want to remind you that this workshop is yours, so please feel at home and by all means ask questions during the next day and one-half. I feel that our speakers are experts in their fields and love to talk about fish farming. If at any time during the course of this workshop I can provide assistance to you, let me know.
MIDWEST REGIONAL CAGE CULTURE WORKSHOP
August 24-25, 1990
Holiday Inn, Jasper, Indiana
and
Southern Indiana Purdue Agriculture Center

FRIDAY, AUGUST 24, 1990

8:30   Welcome
       LaDon Swann

8:45   Species Selection --
       "What Can I Grow in Cages"
       Dr. Joe Morris

9:30   Nutrition and Feeding --
       "The Most Important Thing
       A Farmer Does Each Day"
       Dr. Paul Brown

10:15  Hybrid Striped Bass --
       "Is There an Alternative
       to Catfish?"
       Dr. Brian Nerrie

11:00  BREAK -- Travel to Southern
       Indiana Purdue Agriculture
       Center (SIPAC)

11:30  Site Selection and Water
       Quality -- "Success or
       Failure in Cage Culture"
       Mr. Dan Selock

12:15  LUNCH at SIPAC

1:15   Return to Holiday Inn

1:45   Stress and Diseases --
       "How Not to Kill Your Fish"
       Mr. Rodney Horner

2:30   Harvest and Handling --
       "One Advantage to
       Cage Culture"
       Mr. Charlie Stevens

3:15   BREAK

3:30   Economics and
       Marketing -- "Is it Profitable?"
       Ms. Jean Riepe

4:15   "Cage Culture in the
       Aquaculture Industry"
       Mr. John Morrison

5:00   FREETIME

7:00   BANQUET and Discussion
       "Alternative Agriculture"
       Dr. Steve Lovejoy

SATURDAY, AUGUST 25, 1990

8:00   TRAVEL TO SIPAC

8:30   Small Scale Processing
       Mr. Tim Anderson

9:15   Cage Construction
       "Round or Square"
       LaDon Swann

10:45  BREAK

11:00  Panel Discussion
       Speakers and Farmers

12:00  Closing Remarks/Evaluation
SPECIES SELECTION FOR CAGE CULTURE

J. E. Morris
Iowa State University

Cages were probably first used centuries ago for the storage of 'wild' fish. Since those earlier times, cage culture of fish has developed. Cage culture (principally catfish culture) has existed for a number of years in various regions of the U.S. A renewed interest in this form of aquaculture has taken place in the Midwest as part of agricultural diversification.

The selection of the appropriate species of fish is necessary for the future success of any aquaculture venture, including cage culture. Depending on their temperature requirements for growth, fish may be labeled as warm, cool or cold water species. The desired species characteristics for cage culture are: 1. fast growth rate; 2. tolerance for crowded conditions; 3. grows well in regional environmental conditions; 4. is native to the region; and, 5. one that has a market value. Several species are suitable for cage culture. Species that have been raised in the U.S. include catfish, bluegill sunfish, striped bass, walleye and trout. This paper will entail discussion regarding the culture of each of the aforementioned species.

This paper will also discuss stocking rates of cages. These rates are impacted by the quantity and quality of feed being used, and the water itself. In the event that the cages are placed into flowing water (streams, rivers, etc.), then it may be possible to increase the stocking rates listed under each species.

Catfish

Channel catfish is but one of 39 different species in the catfish family Ictaluridae. Closely related species are blue catfish, black bullhead, brown bullhead and yellow bullhead. This paper will concentrate on the culture of the channel catfish in this region.

This species (a warm water fish) has a well established market due to the success of the catfish industry in the southeast. However, to sell this fish in the midwest, the production costs must be below or at least the same as for fish that may be shipped into this region from the southeastern U.S. In addition to the established market, availability of fingerlings, tolerance for variable water conditions and adaptability to cages combine for their suitability to cage culture.

Since these fish are typically found in warmer waters, optimal growth occurs when water temperatures approach 80-85°F.

Growth stops at 45°F, while the upper range of water temperature is 95+°F. The preferred water temperature of this species is the principle reason for the limitation of their culture in this region.

Channel catfish may be stocked into cages when water temperature of this species is the principle reason for the limitation of their culture in this region.

Channel catfish may be stocked into cages when water temperatures exceed 50°F. However, stocking at warmer water temperatures (above 80°F) may adversely stress the fish, and lead to disease and ultimately death. It is often best to stock cages two weeks prior to the anticipated growing season, based on preferred temperatures for growth.
Fish handled during these cooler water temperatures are less active and, thus, are less excitable which reduces the potential for their injury. As with all fish, the individual should buy only high quality fingerlings that are relatively free of disease.

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 4 to 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 to stock at a lower stocking rate. Larger fingerlings must be stocked in the midwest as the growing season is shorter than in the southeast. 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. Also, a fingerling over 10 inches in length may not adapt well to a cage.

Stocking densities for catfish fingerlings in cages range from 6 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 (7 to 9 per cubic foot) when first attempting cage culture and particularly if supplemental aeration is not present. Do not stock below a density of 6 per cubic foot or catfish will 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 to stock additional cages rather than overstock individual cages to reduce stress. Overstocking individual cages can lead to serious growth and health problems.

Table 1. Suggested stocking rates for cage culture.

<table>
<thead>
<tr>
<th>Cage Size</th>
<th>Stocking Rates</th>
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<tr>
<td>4 x 4 feet</td>
<td>300 - 400</td>
</tr>
<tr>
<td>(cylindrical)</td>
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</tr>
<tr>
<td>4 x 4 x 4 feet</td>
<td>400 - 500</td>
</tr>
<tr>
<td>8 x 4 x 4 feet</td>
<td>800 - 1000</td>
</tr>
<tr>
<td>8 x 8 x 4 feet</td>
<td>1500 - 2000</td>
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Blue catfish and bullheads have been stocked in cages with much success. Blue catfish do not do well in small cages and have a slightly cooler temperature preference than channel catfish. This preference for lower temperature may make this species more appropriate for culture in the Midwest. Additional research needs to be done to address the possibility of culturing the blue catfish in this region.

Bullheads have been raised in cages and appear to do well. Recommended stocking size is a 6-inch fingerling. Bullheads do not grow as large as channel catfish, however, and are only expected to get to 1/2 pound in a growing season. Fingerlings of both bullheads and blue catfish are usually difficult to find and may be expensive. A specially formulated caged catfish diet may be used to feed these fish.
Bluegill

Bluegill and other sunfish belong to the family Centrarchidae. Bluegill sunfish and their hybrids have been reared in cages with some success. Of the variety of crosses, the fry obtained from female green X male bluegill cross are the major hybrids available to aquaculturists. This cross results in fry being approximately 90% males and 10% females, which results in limited reproduction. Temperature tolerances and preferences of bluegill are similar to those for channel catfish (described previously). Bluegill, however, are more aggressive and will take food at lower temperatures than catfish and should be stocked before the water temperatures reach 60°F. Bluegills and associated hybrids are considered to be good candidates for aquaculture in the Midwest since they will feed during lower water temperatures than channel catfish.

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

There are no diets formulated for bluegills. Catfish, trout and salmon diets have been used to feed these fish.

Striped Bass

Striped and white bass are members of the family Percichthyidae. Striped bass and associated hybrids have been successfully raised in cages. Hybrids consist of original cross (female striped bass X male white bass) and reciprocal cross (female white bass X male striped bass). Due to the limited supply of striped bass brood stock, the reciprocal cross is becoming the prominent hybrid used in aquaculture. Both hybrids exhibit 'hybrid vigor' what enables them to survive under more extreme environmental conditions and grow faster than pure striped bass. This fish may be called wipers or sunshine bass.

Much of the potential market is due to the decline of commercial catches along the Atlantic Seaboard. It is hoped that the cultured fish will supplement this open market niche. Since the preferred water temperature of striped bass is 77-80°F, this fish is more suited for culture in the midwest than channel catfish.

Stocking densities recommended are the same as given in Table 1. 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.

To date there are a limited number of diets formulated for these fish. As a substitute, both trout chow and salmon chow have been used with some success. Dietary components still need to be established for these fish.

Walleye

This species has been recently cultured in cages in the Midwest. Current information is limited in scope. Preferred temperature for growth is 68-77°F with the ideal temperature being 73°F.
The greatest losses are due to cannibalism and difficulty training to artificial diets. Thus, a greater density of fish need to be stocked if they are not 'food trained' prior to their placement into cages. Production costs are considered to be high due to the previously stated reasons and because the artificial diets that are available are expensive and limited in supply.

Trout

Trout and salmon all belong to the family Salmonidae. 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 very similar. Rainbow trout will be described here, but the information should apply to other trout species. Salmon have also been cultured in cages, but discussion will be limited to trout.

Trout are cold water species that require well oxygenated waters. 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 activity in the Midwest, 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 midwest to obtain a 1/2- to 1-pound trout by the end of the growing season. Stocking should begin as soon as the water temperature drops below 68°F. Harvesting should begin as soon as the water warms in the spring to 68°F. Failure to harvest in time will mean loss of 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 of Table 1 without concern for aeration and low dissolved oxygen. In fact, densities as high as 15 fish per cubic foot may be acceptable. Trout diets are available for use to feed these fish.

Other Species

The afore-mentioned species are by no means the only species that may be cultured in cages. Selection of other species not listed in this publication should be made with the list of desirable culture characteristics (listed in the first portion of this text) in mind. As interest intensifies and additional research takes place, further information regarding species selection and techniques will develop.

Sources of Information Used in This Publication


FEEDING FISH IN CAGES

Paul B. Brown
Department of Forestry and Natural Resources
Purdue University

If you are going grow fish, you have to feed them. This may sound somewhat simplistic, but feeds and feeding are areas that are often overlooked as aquaculturists begin new operations. One factor that can be overlooked is the relative cost of feed, which is one of the largest operating costs in most aquacultural systems and easily one of the largest costs in cage culture. Thus, purchasing the best quality feed at the lowest price is a vital consideration in terms of economics of your operation.

In pond culture, getting feed to all your fish and reducing wastage can be difficult because of the relatively large area you are working with, but there will be some nutritional contribution from naturally-occurring pond organisms, such as tadpoles, aquatic insects, etc. Feeding fish in cages is simpler than feeding fish in ponds because of the relative ease you can feed a small group of fish in a much smaller area, but the diet has to be nutritionally complete because few pond organisms will find their way into the cage. Thus, you can find diets that are formulated specifically for cage culture where the contribution of pond organisms is minimal.

The two most commonly used feed types are floating and sinking pellets. More and more aquaculturists, regardless of species raised or culture system, are moving to floating or extruded diets. Floating feeds cost a little more to manufacture, but have distinct benefits. When feeding an extruded diet, you can actually see the fish come to the surface and feed, but when feeding a sinking feed, you do not know if the majority of your fish are feeding. This management benefit is important. One of the first indications of sick fish or poor water quality is cessation of feeding. Additionally, floating feeds usually stay intact better than pelleted feeds and retain their form after several hours in water, which is beneficial if fish are feeding slowly. Feed manufacturers are able to make some relatively small floating feeds, but be aware that some feed sizes are manufactured only in pellet (sinking) form.

Nutritional Composition

One of the first steps in deciding which feed is best for your situation and species is selection of the optimal protein concentration which is considered the most expensive major nutrient in animal diets. There are many recommendations regarding optimal protein level and the figures you might here can be confusing. Points that might help you decide which level is best is to understand how we conduct nutritional requirement studies with fish and understand the "natural" feeding habits of the species you want to raise.

Most nutritional studies are conducted with juvenile fish (in the range 2-7 g initial weight or 2.8 cm (1-3 inches)). These fish are growing rapidly and their nutritional requirements are relatively high at this age and size. Further, most of these studies are conducted in aquaria, where the fish has no other nutritional contribution except the diet provided—similar to cage culture. Thus, if the minimum amount of protein required for maximum weight gain in an aquaria system is 30-32%, it should be adequate for similar-size fish fed the same type of diet and raised in cages. For smaller fish, the optimal protein level is usually higher. First-feeding channel catfish grow better when fed a 50%
protein salmon feed, whereas the optimal protein level for grow out is 32%. Another important point to consider are the feeding habits of the fish you are trying to raise.

Channel catfish are omnivores (that is, they naturally eat a variety of feeds), while trout are carnivores (primarily eat smaller fish or insects). These are the two species for which the most nutritional information has been developed, but are not necessarily the species you are raising in the Midwest. The optimal protein concentration for catfish (an omnivore) is 30-32% and the optimal level for trout (more carnivorous than catfish) is 40-45%. Until we establish the optimal levels for other species, you would be wise to consider the natural feeding habits of the species you want to raise and buy the feed that intuitively makes sense, given the optimal levels for catfish and trout. For example, many producers of hybrid striped bass are feeding a 36% protein catfish fingerling diet, while others are feeding 40-45% protein trout diets. Walleye and yellow perch producers are feeding one of the higher protein (40-45%) trout diets, and sunfish producers are primarily feeding catfish-type diets.

There are approximately 55 nutrients required in fish diets; thus, making sure the diet you are purchasing is nutritionally complete can be difficult. Several important points should be considered when you compare diets. For example, make sure that the diet you are considering has good quality protein feedsuff (such as fish or meat meals, soybean meal, etc.), supplemental vitamins, including vitamin C (ascorbic acid), and minerals (including selenium or sodium selenite). These ingredients will be reported on the feed tag in decreasing order of incorporation. For example, the first ingredient listed is incorporated at a higher level than the second, the second is incorporated at a higher level than the third, etc. Fish meal can be an important attractive component in diets, and should be near the top of the ingredient list for certain species.

Many aquaculturists find themselves conducting feed evaluations because relatively few people are raising a particular species (also known as, "trial and error"). Until the research community conducts appropriate studies and can firmly recommend particular feed types, you would be wise to consult with as many people as possible and find the feeds they prefer.

Another important consideration is availability. The best diet for your species may not be manufactured in the Midwest, and transporting that diet to your farm could double the price of feed. If you can buy feed in bulk and store it, you will usually save money. However, several key nutrients (particularly vitamin C) degrade when feeds are stored. So if you buy feed in bulk, make sure you can efficiently store that feed and that the manufacturer uses a stable form of the labile ingredients. Several feed companies located in the Midwest are manufacturing fish diets and several others will be entering this market in the near future; transportation costs should diminish.

Feeding Practices

Now that you have your feed, how are you going to get it to your fish and how often are you going to feed? Hand feeding is feasible when raising fish in cages, however, this requires a good portion of your time. Many aquaculturists with other time commitments or large numbers of fish use one of the automatic or demand feeders. Automatic feeders provide feed at regular intervals, whereas the demand feeders rely on the fish triggering a switch that releases feed from a hopper. Both alleviate the time commitment on your part, but require frequent monitoring and refilling.

Small fish (first-feeding through fingerling size) require feed at frequent intervals; as often as every 15 minutes for some species. Thus, automatic feeders of some type may
be necessary. As fish grow, the frequency of feeding can be reduced. Most larger fish grow better when fed 2-3 meals per day. However, if you have numerous cages, feeding once per day may be all the time you can spare.

Feed rates will vary depending on species and size of fish. For maximal growth of your fish, most aquaculturists feed to satiation, or all the fish will eat in a given amount of time (usually 10-30 minutes). All fish are similar to other animals in that there is some control over feed intake and they will usually not eat excessively when fed an optimal diet.

Conclusion

Feed is a major operating cost in cage culture and protein is the most expensive component in diets. Thus, selection of the most palatable diet that contains the minimum protein level resulting in maximal weight gain will improve the economic outlook of your fish farming operation. Several factors have to be considered, such as availability, and the best advice we can provide is to talk to as many people as possible prior to investing large sums of money in a particular feed. Further, use some common sense in your choice of feed and your feeding practices. Is it worthwhile buying diet A for 50% more money when you can buy a similar formulation for less? Do you get hungry if you skip a meal or a day without eating? Several feed manufacturers are participating in this workshop and we encourage discussions with them regarding your needs and with us regarding questions we might answer for you through research studies.
HYBRID STRIPED BASS
"IS THERE AN ALTERNATIVE TO CATFISH?"

Brian L. Nerrie
Virginia State University

Selection of alternative species for cage culture should be based on economic considerations. Will the rearing of a fish provide a positive return? this return could be in monetary terms, or have value as an alternative activity or hobby. In the United States, the warm water fish most often raised in cages is channel catfish. One alternative fish which has been raised successfully in cages in Virginia is the hybrid striped bass (Nerrie 1990). The USDA (1990) identified the hybrid striped bass as an ideal candidate for aquacultural production. This presentation will focus on the hybrid striped bass as an alternative species for cage culture.

Striped bass originally had a wide natural range from Canada to Florida on the east coast of the United States and into the gulf of Mexico. However, in 1879 and 1882 approximately 430 striped bass were transported by train in two shipments from the Atlantic coast to San Francisco Bay. Today, on the west coast, the range is from Canada down to Mexico. Striped bass are anadromous fish, living in salt water, but moving into fresh water to spawn. Several landlocked reproducing populations of stripers have been established due to extensive reservoir stocking programs.

Hybrid striped bass were first successfully produced by Stevens in 1965 (Bonn et al. 1976). Hybrid striped bass are being used in pond culture rather than striped bass because the hybrid can withstand the warmer temperatures in farm ponds and demonstrates a faster rate of growth than the parent stocks. Additional desirable characteristics of the hybrids are improved disease resistance and survival. A recent summary of culture development of hybrid striped bass can be found in Newton and Nerrie (1989).

Hybrid striped bass are being cultured in cages in many states in varying water quality, salinity and temperature regimes. Cage or net pen culture of hybrid striped bass can be found in Virginia, Maryland, Georgia, Florida, Pennsylvania, Colorado, and North Carolina. The first privately produced and marketed hybrid striped bass in Virginia were from a cage operation. These 18 oz. fish were produced during the 1988-1989 growing seasons and marketed by the farmer directly to restaurants.

It may be necessary to provide some term definitions for hybrid striped bass:

Phase I: Hatchlings to when artificial food accepted
Phase II: Remainder of first growing season
Phase III: Second growing season

Regulations

Individual states have regulations concerning the stocking of hybrid striped bass. In Virginia regulations are in place to assure against escapement of large numbers of hybrids which may impact on native fish populations. State agencies responsible for such regulations should be contacted for specifics.
Water Quality

Temperature

The length of growing season is a function of water temperature. Hybrid striped bass can survive in water temperatures ranging from near freezing to over 92°F. However, optimum temperature is reported to be 82°F (Hodson 1987). Vigorous feeding activity is observed when temperatures exceed 59°F (Hodson 1987). With a 180-210 day growing season in Virginia, fingerling (450 fish/pound) hybrid striped bass can reach a market size of greater than one-pound in 16 months.

Overwintering

Hybrid striped bass fingerlings are widely available only in Phase I or early Phase II. Fish must be overwintered to allow sufficient time for market size to be achieved. All cage culture operations in Virginia overwintered hybrids with minimal losses. Successful overwintering of hybrid striped bass was also reported by Harrell et al. (1988). Growth rate is reduced during the cooler temperatures.

Oxygen

The dissolved oxygen concentration in water is the most important parameter for the farmer to monitor. Oxygen should be maintained above 4 ppm for conditions. Many ponds stratify during late summer with an upper layer of warm oxygenated water and a lower layer of cold water which is low in oxygen. Stratification occurs due to absorption of heat by water near the surface of the pond. Algae in this layer will produce oxygen which under these conditions does not easily diffuse throughout the pond. Sunlight is blocked from reaching the lower, cooler waters, where accumulating organic matter uses up oxygen while decomposing. Use of supplemental aeration is advised.

pH

As is the case with many cultured warm water fish, the desired pH range is between 6.5 and 9.0. At higher pH levels (greater than 9), especially at higher water temperatures, ammonia toxicity can effect cultured hybrids.

Hardness and Alkalinity

Hardness and alkalinity are usually related in pond water. Desirable levels exceed 25 ppm as calcium carbonate equivalents. Much of the early research with hybrid bass reported optimal alkalinity and hardness levels greater than 150 ppm. It may be necessary to add agricultural lime or gypsum to ponds to raise the alkalinity and hardness levels. Hybrid striped bass are being caged raised in Virginia ponds with hardness levels less than 20 ppm. However, the fish are not handled until harvest.

Stocking

Two conservative stocking procedures are followed in Virginia for cage operations. To provide practical experience for first time fish farmers and to encourage the growth of hybrid striped bass culture, the Virginia State University Aquaculture Office holds early Phase II fingerlings in ponds for distribution to farmers. In cool early morning hours, fish are harvested and transported to cage operations by standard techniques.
Cage operations without supplemental aeration with 0.5 inch mesh cages are stocked with 5-8 hybrids per cubic foot of cage. These fish will remain in this cage until harvest. Other cage operations without supplemental aeration receive 1000 fish (approximately 2 inches/fish) per cubic yard of 0.25 inch mesh cage. These fish will later be size-rated and transferred to larger mesh cages. Total number of fish stocked should not exceed an expected harvest of 2500 pounds per acre. If supplemental aeration is available, the stocking density should be increased.

Individuals contacting hatcheries for private stockings should be aware that the fingerling supply is the major concern facing the hybrid industry. Stock the largest available uniform size hybrid bass fingerlings from a reputable source before water temperatures reach 70°F in the springtime. Cannibalism can result if fish vary in size and are underfed.

**Feeding**

A commercial feed developed specifically for hybrid striped bass is not readily available in the United States. Successful crops have been grown on both high protein catfish, trout and salmon diets. Feeds of this grade should be available to the farmer at the required size and at reasonable cost.

Competitive commercial diets available at particle sizes appropriate for the mouth size of the fingerlings are nutritionally complete (36-40% protein) and based on years of fish nutrition studies to assure high quality at the lowest cost. Although more expensive, added growth may make it beneficial to feed a diet with more protein. Feed conversions of approximately 2.5 pounds of feed to 1 pound of fish growth can be expected. Ongoing nutritional research leading to a hybrid striped bass diet will improve conversion rates as the specific nutritional requirements for hybrid striped bass are identified.

A shaded feeding area in the cage is recommended for the fish. This could be as simple as burlap bags covering half of the cage to limit direct sunlight. Automatic feeders can be used for Phase II fish because of continuous feeding activity. It is not possible for farmers to be present all the time. Farmers however should make observations concerning feeding activity each morning and evening.

**Sampling**

Not recommended.

**Markets**

The commercial catch of striped bass reached its peak in 1973 when 14.7 million pounds were landed on the Atlantic coast (Norton et al. 1983). Only a fraction of this amount is being marketed during recent years due to fish population management plans to prevent overfishing. Opportunities exist for the further development of a market niche for cage grown hybrid striped bass of approximately one pound size. A renewal of the commercial catch of striped bass will have size limitations, harvest seasons, and perceived consumer concerns about freshness (ocean pollution, length of time from ocean catch to processor, etc.).
Literature Cited


Nerrie, B. L. 1990. Growout of phase II and III hybrid striped bass in Virginia's farm ponds.


### Estimated Production Costs
Phase III Hybrid Striped Bass in Cages
5 Cage budget
210 Days
500 Fish per Cage
10% Death Loss

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
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<td><strong>Variable Costs</strong></td>
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Breakeven Variable Cost per pound: 2.12
Breakeven Total Cost per pound: 2.43
Breakeven Total Cost per pound minus labor: 2.17

### Fixed Asset Worksheet

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This budget is only a guide. It does not include maintenance, pond construction, or marketing costs. It assumes 2250 fish sold at 1.25 pounds each.
SITE SELECTION AND WATER QUALITY: SUCCESS OR FAILURE IN CAGE CULTURE

Dan Selock
Aquaculture Specialist
Fisheries Research Laboratory
Southern Illinois University at Carbondale

Many bodies of water have the potential to serve in multiuse capacity. They may be used for livestock watering, irrigation, recreational fishing, swimming, and, in some cases, aquaculture. Fish can be raised for personal consumption or supplemental farm income. Usually the "open pond" method of aquaculture is practiced, but, due to certain circumstances or by preference, floating fish cages can be used. The success or failure of "cage culture" often depends on proper site selection and the maintenance of adequate water quality.

"Open pond" and "Cage" culture are the most practical methods of aquaculture at this time. Raceways require vast quantities of water and "tank" culture has not been very profitable.

A common problem with "open pond" culture in many existing bodies of water, is the inability to drain and/or seine the pond or lake. Ponds that are deep, irregular in shape, uneven on the bottom, or have trash and stumps do not lend themselves to seineing very well. Floating fish cages thus allow some ponds to be used, however, there is no practical reason to use floating cages in ponds that are drainable and/or seineable, except to sort, grade, or separate different species of fish. Generally, fish experience less stress in an open pond than in a cage, therefore, some degree of risk is taken with "cage" culture.

When a pond is considered for floating fish cages, certain requirements need to be met. Most of these criteria focus upon maintaining adequate water quality inside the cage. The pond must:

1. contain sufficient water throughout the growing season - at least 1/2 to 1 acre in surface area and greater than 5 feet deep in 1/2 to 1/3 of the pond, when the water is at its lowest level. At least 1 to 2 feet of water must be kept below the bottom of the cage at all times in order to flush the wastes away from the cage. Small ponds cannot break down the fish wastes fast enough and almost inevitably have water quality problems (low dissolved oxygen, high total ammonia and nitrite, and excessive algal blooms). Larger ponds have a greater capacity to buffer the effects of fish wastes and feed residues. They also tend to be deep enough to eliminate aquatic plants as a problem.

2. not be located in areas where it can be contaminated by run-off containing high levels of pesticides (can be harmful to the fish and to the people who eat them) or large amounts of livestock wastes (lead to dissolved oxygen problems). Excessive watersheds can also cause rapid water temperature changes and pond turnovers after heavy rains. It is a good practice to inform your neighbors about your fish project, so they can use caution applying chemicals during rainy or windy weather.

3. be able to receive the prevailing winds for overall mixing and aeration. Locate the cages in the pond to maximize any available water movement. Ponds that are low in a valley or deep in the woods usually will not have good water circulation.
4. Be convenient to get to for feeding and inspection. An all-weather access road is usually not necessary, but on occasion, one could be used.

5. Not be heavily stocked with fish. The carrying capacity of a pond is 1,000 to 1,500 pounds of fish per surface acre, if no fresh water or supplemental aeration is provided. This rate applies to both loose fish and/or caged fish. Therefore, the poundage of loose fish already in the pond will affect the number of cages that can be stocked.

Maintaining good water quality in "cage culture" ponds is absolutely essential. Failure to do so will result, at best, in poor growth and high feed conversions or, at worst, a total loss of all the fish. Fish in a pond are living in their own wastes, therefore, the pounds of fish that can be produced is limited by the ability of the pond to provide adequate oxygen. Oxygen is needed to keep the fish alive (respiration), to metabolize the fish food and enable them to grow, and to breakdown the nitrogenous wastes throughout the pond. Decomposition is faster and more complete in an aerobic (oxygen present) environment than in an anaerobic (no oxygen present) one.

The major oxygen sources in a pond are the algae plants (tiny floating plant cells). All green plants manufacture food for themselves by a process called photosynthesis. Plants use nutrients such as nitrogen, phosphorus, and potassium and carbon dioxide plus some water and energy from the sun to make their food. A waste product of this process is oxygen which is given off and dissolved in the water.

The amount of dissolved oxygen (DO) in the pond water normally cycles up and down during a 24 hour period. The DO is lowest at sun-up and highest in mid-afternoon. You want to feed your fish when the DO is high, by the way, since they consume more oxygen during their feeding activity and directly afterwards, and you want to have some sunlight available for the algae to restore the DO level before darkness. During the night the algae are the major consumers of oxygen. Since there is no sunlight for photosynthesis, they must use respiration (take in oxygen and give off carbon dioxide) for energy production. Consequently, if your pond has an excessive amount of algae, the night-time consumption of oxygen by the plants may be enough to stress your fish and eventually suffocate them. The management of a "cage culture" pond involves observing the algae population as well as the fish. If you put your arm into the pond water and lose sight of your fingers before elbow depth (less than 12 inches), your pond probably has too much algae. A freshwater flush or small amounts of algicide may be needed. If you can still see your fingers past your elbow, the algae population in probably adequate.

Diffusion, the movement of air containing oxygen into the water at the pond surface, is of minor importance compared to algae. You can increase the rate of diffusion by agitation (paddlewheel or water fountain), but that is more costly.

The dissolved oxygen should be checked early in the morning as needed. DO should be maintained at 4 ppm and above. In the absence of an oxygen meter or kit, an aquaculturist can observe signs of possible low oxygen that appear several days before the fish are stressed. Indicators of low oxygen are:

1. A sudden change in the color of the algae bloom, from greenish to brown or gray, indicates that some of the algae has died. Dark streaks may also appear in the water.
2. Low DO should be suspected when DO-sensitive fish like golden shiner minnows or tadpoles or crayfish move to the margin of the pond and snails crawl up on emergent plants.

3. A noticeable reduction in feeding by the fish is often associated with low DO.

4. Musty odors or the rotten-egg odor of hydrogen sulfide can accompany oxygen depletion.

The best method to correct a low DO situation is to pump well aerated water from an adjacent pond into the poor one. A paddlewheel can be used to mechanically aerate and mix a pond in an emergency, but it is hard to operate one on a tractor continuously. Air diffusers (blowers) are good to prevent low DO situations, as are air-lift devices, especially around the cages. But, they are not very effective in an emergency.

A routine inspection of the sidewalls of the fish cage for algae or moss build-up is important. Any reduction in water exchange and flushing through the cage can lower the water quality inside the cage.

The alkalinity and chloride level should be checked about three weeks after filling a pond and again if a large volume of water has been added. Alkalinity is a measurement of the buffering capacity against pH swings in the pond. It is the total concentration of bases, carbonates, and bicarbonates available to neutralize any acids. Total alkalinity should be at least 40 ppm, and it is better if it is above 70 ppm. Chlorides should be at least 30 ppm, however 50 ppm and higher is desired. The chlorides appear to counter problems with nitrites and help the fish with osmoregulation.

pH is an expression of the acidity or alkalinity of the water. Less than pH 7 is acidic and greater than pH 7 is basic. The pH should be measured weekly or whenever a water quality problem is suspected. The best range is pH 6 to 9. pH affects the toxic levels of ammonia and carbon dioxide (check hand-out for details).

Ammonia levels correlate to crowding and heavy feeding at warm water temperatures (usually a late summer problem). There are two forms of ammonia; they are ionized (not toxic to fish) and un-ionized (toxic to fish). The pH level and water temperature determine which form of ammonia is prevalent (higher pH and temperature favors toxic, un-ionized form). Un-ionized ammonia at levels of 0.06 to 0.10 ppm can stress fish, so a level of 2 to 3 ppm total ammonia (ionized + un-ionized) is cause for concern. There are several sources of ammonia:

1. The major source is fish feed turning to waste product through the fish; every 100 pounds of feed can create 2.2 pounds of ammonia.
2. Decaying plants and animals in the pond produce ammonia.
3. Uneaten fish food decays to produce ammonia.

High ammonia levels can be corrected by reducing the feeding rate (even to stop), flushing the pond with fresh superphosphate (0-20-0) or 20 pounds of triplesuperphosphate (0-46-0) per surface acre to stimulate algae growth. The algae in turn uses the ammonia as a nutrient source.

Nitrites should also be checked when the pH is greater than 7.5. Fish can be stressed if the ratio of chlorides to nitrites is less than 7:1, and brown blood disease may occur.
The three hand-outs available to you are from Drew Mitchell, a diagnostician in the water quality workshop, Fish Farming Experimental Station, Stuttgart, Arkansas. They are an excellent summary of the water quality parameters used in aquaculture. Good water quality prevents stress, which prevents disease, which means successful "Cage Culture."
HOW NOT TO KILL YOUR FISH

THE ROLE OF STRESS IN FISH DISEASE

Rodney W. Homer
Illinois Department of Conservation

As a preface to my remarks, I should say that I am directing them to the people who, however small they are starting, are doing so not as a hobby, but with the idea in mind of beginning a business.

It is difficult to sell the idea that a major cause of disease in fish is the aquaculturist. We want to have something or someone to blame, other than ourselves. It is so easy to say "Well, the fish got a nasty disease bug that's giving me a big problem and costing me a lot of losses." What do I do about it?" "Well, let's treat 'em," (with chemicals, antibiotics, the kitchen sink, or whatever comes to mind).

Let's back up from this typical money losing scenario for a moment and examine the reason that the fish got sick in the first place.

I have been in this business for a long time, diagnosing fish diseases. During that time, every case of fish disease that I have ever handled confirmed what I was taught by a wise old man, Dr. Stan Sniezko, MOST FISH DISEASES ARE STRESS MEDIATED. FISH DISEASE AND THE ORGANISMS ASSOCIATED WITH IT ARE ACTUALLY SYMPTOMS NOT CAUSES. Although there are exceptions to every rule, bacteria and parasites are rarely so invasive that a healthy fish can't resist them (viruses are another story, but there are only a couple of them that affect warm water fishes and they are rather rare).

What the aquaculturist often fails to recognize is that if he would do his best to minimize stress in his fish, most of the disease which happens would be avoided, and no treatment would be necessary. This failure is so common, it even has a name, PMD. Translated, this means poor management disease. More fish die of it than anything else!

An example of how stress mediates disease is provided by the following, which is an actual case history. It is not intended as an indictment of fish haulers as a group.

Unlucky Fish Company pulls up to farmer Jones pond with a load of channel catfish on board and says, "Have I got a deal for you!" He then proceeds to sell farmer Jones (cheap!) a bunch of catfish for his pond. Somehow, it slips his mind to inform farmer Jones that the fish have been on the truck for 72 hrs. during which time the truck broke down twice and the aerators failed each time.

The next day, farmer Jones notices a few dead catfish. Seven to ten days later, the stocked fish begin dying like flies and farmer Jones shows up at the pathology lab with a cooler full of dying catfish. These channels look like they have been dead three weeks, but are still wiggling weakly. Examination shows that they have 4 different external parasites, any of which would be sufficient to kill them. They also have 2 kinds of bacteria, both highly lethal to catfish, one tearing the hide off the fish and the other causing a blood poisoning.
Farmer Jones says, "What's killing them?" My reply is that something has stressed the heck out of these fish. Every disease organism that happened to be around is lining up like hogs at a trough to see which one can kill the fish first. Farmer Jones says, "Oh my gosh, what's going to happen to all the other channel catfish that are in my pond?"

My reply, and I've never seen it fail is, "Nothing."

The fish on the truck were heavily stressed by crowding, high temperature, and high ammonia levels, combined with low dissolved oxygen. After a few days, they were crawling with bacteria and parasites of all kinds. The fish in the pond, well fed, content, uncrowded, and with plenty of oxygen, resist the introduced bacteria and parasites as though they were not there.

It's different in aquaculture you say? Not really. Naturally there are greater stresses than in an ordinary farm pond, but a philosophy of stress management can save the aquaculturist much money and many headaches on his way to a crop of fish.

What we are talking about here is planning ahead. There are some stresses on fish about which we can do very little. However, there are many that we can head off and deal with before they become a problem. The reason for planning ahead is that once these things become a problem, it is too late to deal with them, and one is doomed to suffer the consequences.

The most common of these is low dissolved oxygen (D.O.). Once your fish suffer an episode of low D.O., it is almost certain that disease will follow. Most often this is within 7 to 10 days. The cost to you will be money, time, chemicals, growth, and poor feed conversion to treat it. The disease will be whatever is available in your pond. The type and severity of disease will differ, depending on the time of year and how stressed the fish were.

It makes much more sense to test the oxygen in your pond often, especially just after dawn in order to catch low trends. You must learn to predict what weather conditions precede a D.O. crash in your ponds. They will not be the same for each pond. Often, a long dry spell followed by a 2" rain signals an all night session with the paddle wheel aerator, perhaps several nights in a row. You must have the equipment already on hand and know how to use it. And, I am sorry, but you must learn that you can't deal with it tomorrow. Tomorrow they will be dead. Your bed may sing you a siren song, but don't listen to it, because it can spell the difference between profit and loss.

Fish in an intensive culture situation must be handled occasionally, which is a stressful experience for them. You can help to minimize this stress by handling them in water which contains 0.5% salt (with no additives). This is about 4 pounds of salt (sodium chloride) per 100 gallons of water. You should also make it a practice to haul fish in this mild salt water.

Fish go into shock by losing chlorides through the gills. Chlorides are one of their most important blood components. When stressed, the fish lose control of their ability to conserve chlorides. Salt in the water at 0.5% almost exactly matches the amount naturally found in the fishes blood. A fish in such water gains chlorides back as fast as they are lost. This acts just the same as an IV following surgery does for people. The fish are prevented from going into shock. When the stressful situation is past, the fish
regains control of its blood chlorides and will perform as though the stress had never happened.

There are many other stresses on fish. Some of them are very subtle and difficult to identify without special equipment. They can place a large burden on the fish which it must overcome before it can use energy to grow. All these stresses may add up to express themselves as disease.

One common one is the frugal farmer who has bought too much feed at one time. To save money, he feeds this feed to his fish regardless of how old it is, or whether it got wet, until he runs out. He may wonder why his fish get sick often, don’t convert feed to fish flesh well and don’t resist other stresses as well as they did before. Feed older than 3 months is suspect for lack of vitamin C and probably has rancid fats and oils. Feed that gets wet accidentally will get moldy within hours in warm weather, and it won’t necessarily turn green. Mold toxins are subtly to acutely toxic to fish.

Raising fish is hard enough without subjecting your animals to this kind of nutritional stress. It doesn’t actually kill them usually. It just makes them harder to raise, and who needs that? All you have to do is adjust your feed order so your feed is always fresh, and discard any feed that gets wet if it cannot be used that day.

The smart fish farmer is always looking for ways to relieve stress on his animals. Not only do they perform better for him, but they will then provide a better product to his customers who will remember and be back next year for more. Aquaculture is simply animal husbandry of aquatic animals. The principles are the same with any species in confinement. Only the specific requirements of each animal differ.

An experienced person in animal husbandry is less likely to attempt to make his animals conform to his wishes. He is more likely to conform his actions to his animal’s needs. A good animal husbandry man learns to speak the mute language of his animals, and he listens to them. A husbandry man must have a feel for his charges and be sensitive to what they are trying to tell him. They will always tell him when something is wrong. They may even tell him what is wrong if he is bright enough to listen. A person who remains deaf to his animals often has “bad luck” in culturing them.

Aquaculture is not a get rich quick proposition. It is a job! It can be a tough job! It is an art! Some people have the touch and some don’t. It is almost a matter of attitude. Many problems in aquaculture are only manageable if one heads them off before they develop (listen to your animals!) Once these problems develop fully, there is nothing that can be done about them, except to use the aquaculturist’s traditional cure for everything, aspirin and Jack Daniels.

The next common misconception is that water is the same everywhere, or, “Water’s water isn’t it?” Well no, it isn’t. There is one fact rarely appreciated by the beginner at aquaculture, but one that holds true in every case. Each and every body of water is unique. There are so many parameters, so many variables in the way that a body of water will react to the fertilizer that one applies or to chemicals used to treat fish disease, that books written about the subject of aquaculture are, and will remain, only approximations. From these approximations (unfortunately through trial and error) the aquaculturist must extract those things which work on his pond, and those things which do not.
Often, only way that one learns what not to do is through the wholesale deaths of the species being cultured. Quote, "But the book said the treatment for this disease is ... parts per million, and that's what I used!" Unquote. Not in your pond its not, or not in your pond at that time of year its not, or not in your pond when the oxygen is that low its not, or not in your low alkalinity water its not, and so on, almost endlessly.

Problems

The first big barrier in aquaculture is oxygen. You must load your ponds, (tanks, cages, etc.) with many pounds of animals per acre (cubic foot, gallon per minute). This loading is well beyond any natural ability of the pond to deal with the waste products produced, or supply their oxygen demands, without occasional wild environmental swings. These swings happen most often when the weather conditions are less than ideal (that is, often). One of the consequences of high loading is the production of large amounts of ammonia. Ammonia is produced as a by-product of the fish’s protein metabolism. This fertilizer results in artificially high populations of one celled plants (phytoplankton) called algae. This is fine you say. Don’t plants produce oxygen and isn’t that what we want more of?

Well yes, to a point. As with all things, one can get too much of a good thing. Your author has seen fish die in droves because the oxygen was too high and before the fish recognized this, they were too buoyant, couldn’t go down and died of oxygen gas bubble disease. The other side of the coin is that the same plants that produce oxygen when the sun is shining, use it when the sun is not shining, or even when the sun is not shining enough, such as a cloudy day.

Since the sun provides the energy that drives the system, lack of sunlight leaves the algae starved for energy. They can tolerate this lack overnight. If this night is followed by a day which is also deficient in light intensity... Only one or two repeats of this scenario is sufficient to cause the collapse and death of the algae population.

This has a twofold effect. In the first place, all the dead algae cells now present the bacteria of the pond with an enormous increase in the amount of food available. They respond to this food with a logarithmic (2 4 8 16 32 64) population increase, all of which use oxygen in the process of growing and dividing. These bacteria then rapidly use up all the oxygen present. At the same time, with most of the algae dead, there are few plants available to generate more oxygen when the sunlight intensity returns to normal. This is serious, since oxygen diffuses poorly in undisturbed water. The rate is so slow that people have difficulty believing it (something like an inch a century!). By the time all this has occurred of course, most of your animals are dead due to lack of oxygen and those that aren’t dead will die later due to stress induced diseases. It is easy to do the above, and it will happen. It is one of the most common occurrences in aquaculture. Because of this, the aquaculturist must have on hand, and be prepared to use, mechanical aeration to restore or attempt to maintain livable oxygen levels in the pond, until the algae populations recover. The trick is recognizing when such a situation is likely to occur and heading it off before it develops. No one will be able to exactly predict for you when this is likely to occur on your ponds. You must learn this through experience. Be watchful. Don’t be too tired and go to bed, trusting to luck. You must do for your animals when they need you and rest later. It is the difference between profit and loss.

Sometimes, events that set off the above scenario do not seem logical. Fish farmers have learned for instance, that a cool rainfall on a summer’s afternoon often spells
oxygen problems that night. This on the face of it does not compute, since cooler water holds more oxygen than warmer water does. Perhaps a discussion of the pond cycle through the year is in order here.

The Water

There is much to know about water, especially your water. Water is your animal's whole world. They live in it, breathe it, excrete their waste products in it. It is their environment. Physically, water has a number of properties of which you as an aquaculturist need to be aware. With the exception of Lake Michigan, the surface waters of Illinois are classified as "warm water". These are waters that have a midsummer surface temperature of 70°F or higher.

Temperature is one of the key factors which govern the lives of fish and regulate the kinds of species which can live in our streams and ponds. The amount of dissolved gases that water will hold varies with the temperature. The warm water of summer holds much less oxygen than cold winter water.

Temperature is the principle regulator of physiologic change in fish, including feeding, growth and spawning. Most warm water fishes grow fastest at temperatures above 70°F and dissolved oxygen content of 5 to 8 parts per million (ppm).

Temperature is also one of the principle factors influencing the pond cycle through the year. Layers of water at different temperatures are layers of water of different weights. The heaviest (densest) that water gets is at about 39°F. Water warmer than this, or colder than this is lighter. If it were not for this fact, life on earth would not exist. If water just kept on getting denser as it got colder until it froze, ice would sink and all bodies of water, including the oceans would be permanently frozen solid! Fortunately for us, the lightest water of all is ice and it floats.

Let us look at the annual cycle of the pond. In the spring just after the ice thaws, the coldest water is on top at 32°F and the warmest water is on the bottom, at about 39°F. As the warm breezes of spring begin to blow, the cold surface layers of water begin to warm. As they get warmer, they get heavier and sink into the depths of the pond, replacing the lighter, colder layers beneath. At some point, all the water reaches 39°F.

Up to this point, there have been layers of water at different temperatures and densities in the pond, making them difficult to mix. Now that the water is all the same temperature and density, it mixes easily and the winds of spring mix the pond thoroughly, bringing the water which has been on the bottom all winter to the top.

Ponds can be thought of as breathing twice a year, once in the spring and once in the fall, breathing out the waste products of respiration of the aquatic life. These are carbon dioxide (CO₂) hydrogen sulfide (H₂S) and other gases. At the same time, the pond is breathing in new oxygen from the air to replace what was used up. So the pond starts the year with its water freshened and a new supply of oxygen from top to bottom.

As the winds warm the surface layer of the pond above 39°F, it becomes less dense and begins to float on the colder waters below. During the summer period, a layering effect called thermal stratification sets up, separating the pond into three zones of differing temperature and density called the epilimnion, the thermocline, and the hypolimnion. These terms simply stated mean the upper lake, the transition zone, and
the lower lake. The thermocline is a layer in which the temperature drops rapidly, at a rate of 0.5°F or greater per foot of increasing depth. Most people who have dived into a pond or lake have experienced the thermocline. Often, they come back up thinking that they have dived into a spring!

The thermocline ends where the temperature ceases to drop rapidly. Once these layers set up in the summer, they are almost as difficult to mix as oil and water and tend to remain stable throughout the warm weather. The upper two layers then effectively seal the lower lake off from contact with the atmosphere. In a deep lake (50-60 feet or more), the temperature of this lower layer may remain in the low 40's during the hottest of summer weather.

During this time, all the aquatic life is gradually using up the dissolved oxygen present in the lower lake, until in about mid-July, in most lakes in Illinois, the oxygen is used up entirely. This is why you can't have trout in your lake over the summer, even though the temperatures on the bottom are plenty cold enough for them. In most Illinois ponds and lakes there isn't any oxygen for them to breath below a depth of 12 feet in the summer.

As fall comes, the warm surface layers of the lake begin to cool off. Being cooler than the layers below them, they are also denser. This cooler, denser water sinks, displacing the lighter, warmer water below. This process breaks up the thermal stratification which has been so stable all summer, and the pond takes its second breath of the year, the fall turnover. The deoxygenated water of the lower layer is brought to the surface, where its oxygen supply is renewed, and all the waste product gases which accumulated in the lower layer during the summer are exhausted to the atmosphere. The process is complete when all the water in the pond is once again at 39°F.

So the pond begins the winter period as it began the summer with its water freshened and oxygen from top to bottom. As the air temperatures continue to cool, water colder than 39°F floats on the warmer water below it. This provides a (relatively) warm refuge for the fish, frogs and turtles of the pond to survive the winter. Believe it or not, many of the our fish would die of what we would call exposure if they were at temperatures below about 35°F for very long during the winter. Ice, being the lightest water of all, forms on the top and the pond is sealed off from contact with the atmosphere.

As winter progresses, snow accumulates on the ice and, depending on the year, lasts for varying lengths of time. At some point, the accumulation of snow is sufficient to shut off sunlight. Aquatic plants need sunlight to renew the oxygen supply, which is continually used by the living organisms of the pond. The plants can do this even under the ice if the sunlight can get to them.

Once the snow blocks off the sunlight, a count down clock begins, ticking off the number of days before the fish run out of oxygen. One factor that determines the number of days on the clock is the water volume. At the time the countdown clock starts, there will be more oxygen available in a deeper impoundment than in a shallower one, simply because the volume of water is greater. In Illinois, a pond 8 to 10 feet deep over 1/4 of its area is deep enough to withstand most winters. When fish are found dead in the spring when the ice thaws, it is referred to as winterkill. The cause of winterkill is not simply low oxygen under the ice. If it were, many more lakes would undergo winterkill than actually do. Other factors enter in, such as the amount of accumulated
organic matter, leaves, dead aquatic woods and so forth, which are slowly decaying under the ice.

Also involved is a simultaneous rise in carbon dioxide from ordinary respiration of fish, plants, and bacteria, as well as H₂S, generated by anaerobic (no oxygen present) respiration of bacteria.

The fish, being cold in the winter, do not require a lot of oxygen to maintain life. However, if the oxygen drops low, if the carbon dioxide (which acts as an anesthetic to fish) rises to an anesthetic level, and hydrogen sulfide rises to a mildly poisonous level, the fish are hit from three different directions at once, and winterkill may occur unless the aquaculturist is prepared, vigilant and takes steps to prevent it. In a very long, cold winter, the problem will be particularly severe.

As spring approaches, in some years, several freeze-thaw cycles take place. These are characterized by partial thawing of the ice over the surface of the pond, which then re-freezes as the weather cools, only to thaw again and so on, until the final thaw occurs. The author has seen severe gas bubble disease in 4" channel catfish induced by thawing ice. This thawing ice had very little snow on it and there was no run off from snow. When the pond refroze, many of the affected fingerling channel cat died from fungus, infecting the places damaged by gas bubbles in the skin.

When the final thaw happens, the pond has its second breath of the annual cycle. As the surface warms, again a point is reached when all of the water in the pond is 39°F. Since all the water is the same temperature, it mixes very easily. The winds of spring then accomplish a second turn over, ridding the pond once again of any noxious gases accumulated over the winter and re-oxygenating it at the same time. The thermocline starts to set up again as water warmer than 39°F begins to float on the colder water below it.

Now, having discussed some of the physical characteristics of the pond water, lets go back for a moment to the pond that experienced the cool rainfall on a hot summer day. You should now have a better idea of what happens. The bottom mud is very rich in nutrients due to feces, uneaten food, and organic matter.

Ponds designed for aquaculture are often shallow and flat bottomed. When the cold rain falls, it tends to break up any stratification which may be present. The cold rain, being much heavier than the rest of the water, sinks to the bottom, churning those nutrients up into the water column.

The bacteria of the pond respond quickly to these nutrients and begin to divide and grow with great rapidity. In doing so, they require large quantities of oxygen, often more than the pond can supply. If the farmer is not prepared for this, the result is often a massive fish kill due to the oxygen content of the water going down to or near zero.

If one goes into aquaculture not expecting problems to occur, one is naive in the extreme (and broke!). As I have said before, it is not sufficient to deal with problems as they occur. By that time, it is usually too late. One must learn to anticipate problems and head them off. One of the prime reasons for doing so is to prevent stress to the animals being cultured. Stress is the number one factor in the development of disease in animals in aquaculture.
As with everything, there are many variations to the sudden cold rain scenario, including one in which the oxygen does not reach zero, but approaches it. For most warm water fish, an oxygen content of 5 parts per million (ppm) or 5 pounds of oxygen per million pounds of water is adequate for good health. Any less than 5 ppm begins to be stressful to the fish. The degree of stress caused by any given level of oxygen, say 2 ppm, depends on the species of fish in question.

Let us say that in our cold rain scenario, the oxygen at dawn has fallen to 1.2 ppm. During the day, it never rises above 3 ppm, and by the next morning, it has fallen again to 1 ppm. The fish respond to low D.O. (dissolved oxygen) in a variety of ways. The first thing the farmer sees is all his fish on top of the water piping when he rises in the morning. This term comes directly from pipe smokers and the sounds and mouth movements that they make sucking on a pipe. The fish do this because regardless of how low the O₂ (oxygen) gets in the pond, the water at the surface is always saturated with oxygen. The fish come up and try to utilize this surface film. The smaller the fish is, the smaller the mouth is. The smaller the mouth is, the more successful the fish is at utilizing this surface film, and the more likely it is to survive the episode.

Internally, the fish are also taking drastic, last ditch measures to try to stay alive. Among these are the clamping off of blood flow to the digestive tract and diverting it to the heart, brain, and gills in order to keep them functioning to the last. If this scenario continues long enough, the lining of the gut dies and sluffs off, leaving the fish open to invasion by bacteria. Disease usually begins killing the fish in 7 to 10 days.

In aquaculture, disaster is inevitable and is going to occur unless it is anticipated and prevented. Therefore, what are the most likely ones which will happen and what remedy is needed to head them off? The answer will vary somewhat by species, but for the most part, there are certain things that any facility ought to have before anything happens.

Save yourself a lot of "if onlys" and "gee, I wishes" and install electricity at each pond. Water is very valuable if you can afford it and have it available in time of need. Lacking that, you must have aeration devices. One of the best is the paddle wheel aerator, PTO driven by a tractor. It is a given however, that if you have 8 ponds and 3 paddle wheels and tractors, 6 of the ponds will be in trouble all in the same night. It helps therefore to have the electricity and at least a 1 horse electrical aeration device for each pond, to give the fish a refuge until you can get to that pond with the paddle wheel.

You may have noticed that so far, I have not said anything specifically about cage culture. That is because everything stated so far applies to all forms of aquaculture.

One of the things which differs about cage culture is feed. Be sure that the feed which you are using is formulated as a complete diet. One of the specific stresses on cage reared animals is that they are not able to supplement any dietary deficiencies by foraging on the natural foods produced in the pond.

We discussed the fact that there are stresses over which you have no control. One of these is what is done to the fish before you receive them, just before and during shipment. This is one of the few cases in which I agree with prophylactic treatments as a policy. When you receive your fish and place them in the cages, it is a wise policy to put your fish on Terramycin medicated feed at 3 grams of active drug per 100 lbs. of fish (yes, fish) per day for 7 to 10 days to protect them from the fish equivalent of shipping fever.
You may safely assume that the fish have been stressed and you are heading off problems which have a more than good chance of developing. It will serve another function at the same time, in that it will mark the bones of your fish with an oxytetracycline mark that will identify them as a farm reared product. This mark will be clearly visible to any properly equipped laboratory, but would not be visible to the naked eye.

Cage placement in the pond for maximum depth under the cage and maximum exposure to the fetch of the wind will minimize stress due to the accumulation of waste products and oxygen consumption within the cage. Cages should be plastic or plastic coated wire mesh with a minimum size of 0.5" bar (0.75" diagonal measure). Any smaller mesh tends to fill up with filamentous algae, block the flow of water, and cause stress due to environmental deterioration.

Serious producers will eventually come to the realization that any other fish in the pond outside the cages should either be producing profits (fathead minnows?), or should not be taking up the space for waste products. Loading in the cages is not really a function of cage size, but of pond size. In order to produce enough to be profitable, except for a pilot project, loading should be 2500 lbs/acre and up. Unfortunately, this is also about the level of loading where you will begin to run into environmental stresses of phytoplankton collapse due to cloudy weather, low D.O., ammonia, nitrite, and so on, which will begin to threaten production due to disease and/or direct suffocation.

Research by the Mississippi catfish growers has demonstrated that they are money ahead if they do not wait for oxygen problems to develop. Early in the cycle, they run their electric paddle wheel-type aerators every night, whether they anticipate problems or not. They find that it pays off in extra profits due to better feed conversion, increased and faster weight gain due to the prevention of marginal environmental conditions (stress management), and less disease.

Eventually, after a year or two, when you feel that you've got this thing whipped, the fish will start dying. Sometimes, even though you have tried your best to minimize stress in the fish, you fail. From time to time, the most difficult thing of all is to identify just what it is that is stressing them. At this time, you should head for the nearest diagnostic lab with 6 or so sick and dying (not dead ones) fish place on ice. Don't freeze them, it causes so much damage, it makes it difficult to tell what is going one.

Let me say that in 13 years of diagnosing fish diseases I have learned that no one can look at a fish and diagnose what is wrong with it. Each time I get cocky and try it, I then march into the laboratory and invariably prove myself wrong. There is no substitute for microscopic examination, bacterial cultures, and the other procedures available to a diagnostic lab. So save yourself time and money and get it diagnosed! A wrong guess as to what the problem is leads to the choice of incorrect therapy, which doesn't work, costs money in chemicals/antibiotics, mortalities, lost weight gain....

If the problem happens to be a parasitic protozoan, or an external bacterial infection, this presents special problems to the cage culturist. It does not make sense to stress the fish further by chasing them around in the cage with a dip net until they are exhausted and can be caught and placed in a treatment tank. This sort of action is worse than simply letting the disease run its course.
The treatment chemicals/antibiotics used against external disease problems are used at rates that are only slightly less toxic to the fish than they are to the disease organisms. These chemicals are not only prohibitively expensive to use in the amounts required to reach treatment level for the entire pond, but also, following the treatment, there is no way to remove the chemical, which would then go on to kill all the fish as well. Therefore, a bath treatment is used, of short duration, such as an hour.

The problem is how does one do that with a cage full of fish? Two methods come to mind, one for the small producer and the other for the larger investor. The first problem of such a treatment is to maintain the oxygen level of the treatment water at least 5 ppm for the duration of the treatment. The second is containing the treatment to the boundaries of the cage. The third is getting rid of the treatment chemicals after the treatment is over.

For the small producer, it is best to rig the cage with the ability to create a containment bag out of black plastic, fastened with Velcro fasteners to isolate the cage from the pond during the treatment. Remember, you must keep the oxygen level in the cage from falling during treatment.

IF YOU USE COMPRESSED OXYGEN IN A CYLINDER AND AN OXYGEN STONE, NEVER REPEAT NEVER GREASE OR OIL THE FITTINGS OR USE A COMPRESSED AIR STONE ON AN OXYGEN SYSTEM. A COMPRESSED AIR STONE IS CONTAMINATED WITH OIL FROM THE COMPRESSOR PISTON. ANY CONTAMINATION OF GREASE OR OIL IN AN OXYGEN SYSTEM WILL REPEAT WILL SPONTANEOUSLY EXPLODE EVEN UNDER WATER! THE RESULTING SHRAPNEL HAS BEEN KNOWN TO TRAVEL FROM THREE FEET UNDER WATER THROUGH THE AIR SOME 80 FEET!

Following the treatment, remove the containment bag and allow the treatment to dissipate into the pond. Don’t swim! Remember the treatment! In many cases, until it dissipates, it is strong enough to burn your eyes if you are in the water.

For the larger producer, the simplest expedient is to have a work boat large enough to have a treatment tank on board. Design the cages to be capable of being lifted from their floating rack and swung inboard, to be placed, cage and all into the treatment tank. The same system will simplify harvest as well. Even for the small producer, a boat, or a dock extending out into the deep water will be necessary to keep the cage clean, feed the fish and so on.

Remember that no one will ever be able to write the book that will cover everything that will happen with your pond, and your fish, in your hands. The water, fertility, configuration and location of your pond, the style and timing of stocking, feeding, genetics of the stocked fish, and a whole host of other factors combine to make any fish culture operation unique. You will have to pick and choose what fits for you in your situation. Unfortunately, you will have to learn what those things are in the college of hard knocks. It is a difficult school, but the only one available in which to learn your business. Good luck.
CAGE CULTURE ECONOMICS

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Introduction

Cage culture offers farmers with one or more ponds on their land an opportunity to put this idle resource to productive use. Before attempting to begin a cage culture enterprise, however, the economic feasibility of such an attempt should be assessed. The purpose of this paper is to help current and potential aquaculturists to think about and examine their own marketing opportunities and production costs associated with cage fish culture.

Marketing Opportunities

Market Identification

Market identification is a critical aspect of any successful aquaculture venture. Because there is no established marketing system for cultured fish in most states, cage culturists will need to expend considerable time and effort in developing markets for the fish they produce. Perhaps the most important point to remember is that a marketing plan should be developed before production is even begun.

Some of the questions that need to be answered in market identification include:

- What specific market will I sell to?
- What species are acceptable in this market?
- Can I raise the desired species using cage culture?
- What selling price can I obtain in this market?
- What are the form, size, volume, and frequency requirements for this market?
- Can I meet these requirements?

The more detail with which these questions are answered prior to the actual time to market the fish, the less chance of an unexpected, major, marketing problem.

Possible Markets

Producing a small number of fish limits the range of possible outlets, but prospects for obtaining a selling price that is high enough to cover production costs and still yield a profit are quite good. The following is a discussion of possible markets for cultured fish. Use it to stimulate your own ideas on how you might search for potential markets in your location.

Live haulers. Live haulers don’t take title to your fish, but for some fee or a percentage of the selling price, they will transport your live fish to a market. This selling method requires no transportation or processing on your part, but payment may be more
difficult and delivery will be totally out of your control. Contact the aquaculture
specialist or aquaculture industry association in your state to find out if they have a list of
live haulers. Call the haulers to find out what species and markets they serve.

Processors. If you live in an area where one or more fish processors are located, you
may be able to sell to them. Processors typically operate in established markets where
prices to producers just barely cover production costs. In order to make a profit selling
to one of these processors, your production costs must be competitive with the larger
producers who supply the majority of the processor’s fish. This outlet for your fish
eliminates your responsibility for processing but typically does not provide for much
profit potential.

Distributors. Most distributors want sizable volume with frequent delivery, but
some, like the Chicago Fish House, are willing to take smaller lots in order for them to
fully supply their customers. The Chicago Fish House will buy live fish on ice, which you
must transport. They are interested in several different species including hybrid striped
bass. Other distributors may want processed fish.

Grocery stores and restaurants. Local, independent, retail establishments often are
willing to buy locally produced foods, including fish. They may be interested in live or
fresh fish harvested once a year out of your cages, or in frozen fish stored in your freezer
and delivered over time. Any fresh or frozen fish sold to these outlets likely will have to
be processed. Contact stores in your area to explore how it might be possible for the two
of you to come to an agreement.

Specialty stores. Perhaps there is an ethnic grocery store or health food store in
your area. These stores may be interested in buying fish from you that would appeal to
their distinctive customers. This type of “niche” market can be quite profitable. Like
other small outlet operations they may want weekly deliveries, however, they may be more
interested in unusual species and be willing to pay well for them or they may pay a good
premium for your higher quality or organically-produced fish.

Direct to consumer. This may be the most lucrative market for producers of small
quantities of fish harvested once a year. Advertising, whether in the local newspaper, on
a company bulletin board, by word of mouth, or by some other method, will likely be
important in selling your entire lot of fish. Roadside stands or farmers’ markets may also
be viable options in your area. Direct sales of live fish, while potentially the most
profitable marketing option available, may take some time to develop. For this market
you may want to produce a species which is a popular sport fish or has a familiar name.

Fee-fishing operations. Many fee-fishing operations buy live fish every year to re-
stock their lakes. They may not want to buy live fish in the fall, however. Fee-fishing
operations are relatively common in the Midwest and buy a variety of species.

In general, keep in mind that established markets tend to offer slim profit
opportunities and require you to be very cost-competitive. This means that if you want
to cage culture and sell catfish profitably, you will probably have to sell direct to
consumers or develop some other niche market. This should not be difficult. No matter
what species you want to raise, you will have to develop your own market for your fish.
Determine ahead of time which species offer adequate profit opportunities.
When pitching your fish to potential buyers, be sure to stress your product's quality. If you are selling catfish or other bottom dwellers, be sure to indicate that the fish were raised completely away from mud. In all cases, point out that your fish were grain-fed, and cage-raised in a pollution-free environment.

Processing

Fish sold fresh usually must be processed (dressed). If this is the case for you, arrangements must be made for the fish to be processed, either by you or someone else. Processing fish yourself will entail acquiring the appropriate equipment and labor, along with complying with any health regulations. Some aquaculturists have found it more cost-effective to hire out the processing, while others do it themselves. Health regulations are likely to become more stringent as Congress is being pressured to mandate federal inspection of fish and seafood. Legislation in this area is expected within the next couple years. State and local regulations will probably become more strict as well.

Financial Analysis

Enterprise Budgeting

Enterprise budgets provide a simple method of organizing and analyzing production costs and returns. Potential cage culturists need to invest some time and effort in determining as accurately as possible their costs and returns. Analysis of the estimated figures will give a reasonable prediction of whether the venture into cage fish culture will be a profitable one. Once the venture is underway, actual figures can replace the estimated once to reveal the true economic picture. Cost and return figures should be updated whenever new information is available to keep abreast of the financial situation.

Tables 1 and 2 are examples of enterprise budgets for the cage culture of two species, catfish and hybrid striped bass. The numbers contained in the tables are estimates of what the costs and returns would be for cage culturing fish in a five acre pond. Several assumptions (death loss, production time, feed conversion, etc.) have a significant impact on profitability. Actual costs, returns, and productivity factors will be different for every operation and probably for each year. Accurate record keeping will help the producer to determine the actual figures. The following is a discussion of the data and calculations contained in the example enterprise budgets.

Production factors. This is the group of numbers or assumptions upon which the budget is based. In order to analyze financial profitability, producers need to determine such things as how many fish can be grown in their pond, how fast the fish will grow, and how many pounds of feed each fish will eat. Most of these production factors are placed up front in the budget tables, while others (death loss, feed conversion) are contained in the calculations. A few assumptions are indirectly given such as: 1) the fish will all be grown in one batch and harvested at the same time, 2) the fish will be sold live, and 3) death loss will occur after the fish have been fed out to market weight. The production factors often will be the most difficult for the producer to determine accurately, but are very important in analyzing profitability.

Variable costs. If the quantity used of a resource is varied during the production period based on the quantity produced or if a resource is purchased and used only when
production occurs, the cost of this resource is classified as a variable cost. In the example budgets, items such as fingerlings and feed are considered variable.

**Fixed costs.** Fixed costs are costs that are independent of the level of production, and have to be paid whether or not production occurs in a particular year. An expenditure on a resource whose quantity is not varied during the production period is a fixed cost. Examples include cages, aerators, and hauling tanks. Generally, fixed costs are spread out over the expected life of the production input involved. This allows the producer to take into account the long-term view of profitability.

**Returns.** Three different returns are calculated in the budgets. Each provides different, useful information to the producer. Gross returns indicate how much cash will be generated as a result of fish sales. Gross returns less variable costs reveals how much money will be left over after paying the variable costs. This money is then available to pay for fixed production costs and a return to the producer’s labor and management. If this figure is negative, production should not be undertaken. In the short run (one or two years), production should occur if all variable costs are covered. However, for long-term success, fixed costs as well as variable costs must be covered. Net return is the amount available after all expenses are paid, and is compensation for the producer’s labor and management input. If the producer must hire someone else to perform these functions or if he or she is unwilling to undertake a venture without assurance of a satisfactory return for these functions, then a cost for labor should be included; in variable costs for hired labor or in fixed costs for owner labor.

**Break-even price.** The break-even price is the figure to look at when deciding whether or not to undertake the cage culture venture. If the expected market price is equal to or above the break-even price, then the producer will break even or make a profit on the venture.

**First year investment plus variable costs.** This figure is the dollar amount the producer must come up with before the first year of production to buy all necessary equipment and pay the first year’s operating expenses.

**Record Keeping**

Consistent, accurate record keeping is indispensable to determine the productivity and profitability of the cage fish culture operation. Good record keeping habits will help the producer be involved or acquainted with not only costs of production and market prices and their patterns, but also with fish behavior, growth, and fish interactions with the environment. Fish are sensitive to their environment, so fatal conditions can occur abruptly and spread rapidly. Good record keeping will help the producer be a good manager on a daily basis, and so be able to anticipate and quickly detect any problems. Table 3 is a sample record keeping sheet, containing spaces for the producer to keep track of both important economic and environmental data. Each producer should have a record keeping sheet appropriate for the operation.
Table 1. Enterprise Budget for the Cage Culture of Catfish.

Pond size: 5 acres.
Production: 7,500 lbs. (1500 lbs. per acre).
Stocking rate: 343 fish per cage.
Production time: 5 months.
Fish harvest size: 1.25 lbs.
Cage size: 3-1/2' x 4', cylindrical.
Cage number: 7500 lbs. + 1.25 lbs. = 6000 fish + 240 (4% death loss) = 6240 fish
6240 fish + 343 = 18.2 cages + 1 (emergencies) = 19 cages.

Variable Costs

Fingerlings: 6240, 6-8", @ $0.30 $1872
Feed: 7500 lbs. fish + 300 (death loss) = 7800 lbs. fish 3120
7800 x 2.0 feed conversion = 15,600 lbs feed @ $0.20 95
Chemicals: $5/cage x 19 cages = $95 254
Interest on operating capital: $5087 for 5 months @ 12% annual rate 5341

Total Variable Costs $5341

Fixed Costs

Cages: 19 cages, frame/flotation $20/cage, wire $5/cage, netting $25/cage, total materials $50/cage, $50 x 19 cages = $950 over 10 years $95
Boat: used or floating platform, $300 over 10 years 30
Aerator: 2 @ $75 = $150 over 5 years 30
Oxygen meter: $300 over 5 years 60
Licenses, permits: annual expense 10
Hauling tank: $500 over 7 years 71
Misc.: scales, dipnets, rope, buckets, annually 45
Interest on equipment: $2255 @ 12% annual rate, 1 year 271

Total Yearly Fixed Costs $612

Total Yearly Fixed and Variable Costs $5953

Gross Return: 7500 lbs. @ $1.30 $9750

Gross Return Less Variable Costs $4409

Net Return (Gross return less total costs) $3797

First Year Investment plus Variable Costs $7867

Break-Even Price: Total Costs + Production $5953 + 7500 lbs. = $0.79 per lb.
Table 2. Enterprise Budget for the Cage Culture of Hybrid Striped Bass

Pond size: 5 acres.
Production: 7,500 lbs. (1500 lbs. per acre).
Stocking rate: 343 fish per cage.
Production time: 6 months.
Fish harvest size: 1.50 lbs.
Cage size: 3-1/2' x 4', cylindrical
Cage number: 7500 lbs. + 1.50 lbs. = 5000 fish + 350 (7% death loss) = 5350 fish
5350 fish + 343 = 15.6 cages, 15 +omergencies = 16 cages

Variable Costs

Fingerlings: 5350, 4-6", @ $0.75  $4,012
Feed: 7500 lbs. fish + 525 (death loss) = 8025 lbs. fish
8025 x 3.0 feed conversion = 24,075 lbs feed @ $0.26  6,260
Chemicals: $5/cage x 16 cages = $80  80
Interest on operating capital: $10,352 for 6 months, @ 12% annual rate  621
Total Variable Costs  $10,973

Fixed Costs

Cages: 16 cages, frame/floatation $20/cage, wire $5/cage,
netting $25/cage, total materials $50/cage,
$50 x 16 cages = $800 over 10 years  $80
Boat: used or floating platform, $300 over 10 years  30
Aerator: 2 @ $75 = $150 over 5 years  30
Oxygen meter: $300 over 5 years  60
Licenses, permits: annual expense  10
Hauling tank: $500 over 7 years  71
Misc.: scales, dipnets, rope, buckets, annually  45
Interest on equipment: $2105 @ 12% annual rate, 1 year  243

Total Yearly Fixed Costs  $579

Total Yearly Fixed and Variable Costs  $11,552

Gross Return: 7500 lbs. @ $2.50  $18,750

Gross Return Less Variable Costs  $7,777

Net Return (Gross return less total costs)  $7,198

First Year Investment Plus Variable Costs  $13,331

Break-Even Price: Total Costs + Production
$11,552 + 7500 lbs. = $1.54 per lb.
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33
CAGE CULTURE AS AN EXTENSIONIST'S TOOL FOR THE DEVELOPMENT OF A REGIONAL AQUACULTURE INDUSTRY

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Cage Culture as an Entrance into Aquaculture

Cage culture is frequently the most rapid and economical means of entering into aquaculture practice. In many areas, multi-purpose farm ponds which commonly serve for irrigation, livestock watering, and/or recreational fishing are readily available and, in general, are underutilized in terms of fish production potential per unit of surface area. The relative investment required to begin cage production is a small fraction of the costs entailed by the creation of specialized pond systems which may cost in excess of $2000.000/surface acre for construction costs alone. Many state extension services and universities have sponsored assistance programs in past years to introduce landowners to cage culture in areas where farm ponds are common. Growing crops of fish within existing farm ponds, allows farmers to gain first-hand fish culture experience while risking very little and help make the decision as to whether or not this endeavor is the right one before putting great amounts of capital into fish farming. In this manner, cage culture can be used as a "stepping stone" to increased levels of involvement in aquaculture. To illustrate this point, and to help identify the advantages and disadvantages to this approach, a description of a state-sponsored cage culture program, The Tilapia Extension Cage Culture Project presently being implemented by the University of South Carolina is provided below.

One Example of Cage Culture Extension: Current Status and Progress Summary of the University of South Carolina Tilapia Extension Project

The Tilapia Extension Cage Culture Project was designed to find appropriate methods for producing seasonal food fish crops of blue tilapia in farm ponds in the coastal region of South Carolina as well as to examine the economic feasibility of various means of marketing farm-raised tilapia both within and outside of the targeted area. Landowners from Georgetown and Horry Counties were selected to participate in the project with the help of Clemson Extension Service personnel based in each county. The landowners participating in the project had little or no fish culture experience prior to the onset of this study. Although all of the farm ponds contain other warmwater fish species, management is on an extensive level with harvests made only as a product of recreational fishing activity.

Both counties have an active involvement in agriculture but presently very few operating aquaculture operations. The large number of farm ponds within this area provides an important resource for aquaculture development. The majority of these are groundwater ponds, built by removing earth (often taken for use as fill in highway or building construction) from a site to a depth below the natural water table (in the South Carolina Low Country, water table level is often less than 10 feet below the natural ground level). Watershed ponds, created by damming a natural stream bed are also common. Growing fish in cages enables the farmer to use a pond or other body of water that would otherwise be difficult or impossible to manage. This includes extremely large ponds, ponds that can not be drained, and ponds which can not be easily seined due to
irregular shape, depth or the presence of obstructions such as stumps and logs. At the present time, the abundance of these ponds constitutes the greatest readily available resource for freshwater aquaculture in the two county region.

Rural landowners in Georgetown and Horry counties of South Carolina raised young-of-year and overwintered blue tilapia fingerlings during 1988 and 1989 respectively in floating cages. Young-of-year tilapia which were spawned in freshwater earthen ponds in May 1988 grew to an average size of 136g before harvest in late October with no significant difference in size between male and female fish. Overwintered fingerlings stocked in May 1989 attained an average weight of 232g by harvest in early October however, males outgrew females by an average ratio of 1.63 to 1. Males and females were not observed on any of the sample dates during the 1988 or 1989 growing season, although swollen female genital papillae were observed during the 1989 season indicating the possibility of spawning activity.

A marketing study conducted in the course of the two-year study indicated that a minimum average weight of 350g was required for tilapia to be sold to high-paying specialty markets. Smaller tilapia are not acceptable to these markets but can be sold elsewhere at a much lower price per pound. Farmers participating in this project were able to sell tilapia of 350g average weight to a specialty market in New York through a livehauler for $1.00/pound on a live weight cash-and-carry basis. Some blue tilapia of the same size range were sold locally in small amounts for prices up to $1.25/pound. Area wholesale markets paid a maximum price of $0.60/pound.

Study results demonstrated that blue tilapia of three-quarter pound average size and above are the most marketable. Overwintered male fingerlings grew significantly better than overwintered females in mixed-sex cage culture, suggesting that all-male populations might yield higher productions and more uniform size fish at harvest. Outside specialty markets currently offer the most attractive price when minimum size requirements are met or exceeded and appear to be the most profitable outlet for farm-raised blue tilapia at this time.

Farmers are presently raising all-male tilapia crops obtained by hand-sexing mixed-sex fingerlings and will harvest and market these fish in fall 1990. The project will provide workshops for project participants during the remainder of 1990 and 1991 addressing the topics of hormone sex-reversal procedures for the production of all-male fingerlings and the design, building and operation of appropriate overwintering facilities.

**Cage Culture as a Means of Developing Aquaculture Industry Infrastructure**

It is important to realize that aquaculture is not simply a form of farming, it is an industry. The development of an industry is largely dependent on the creation of many affiliated manufacturers, distributors, and other types of businesses. In regions in which aquaculture is still at an early stage of development there are usually few management inputs available to the fish farmer. Cage culture requires many of the same materials, supplies, equipment and services that are needed on large-scale fish farms and which must be readily available before larger enterprises can be successfully established. In itself, cage culture can not bring in all of the support that will ever be needed by full-time aquaculture enterprises but it can be helpful by laying the essential groundwork.
Aspects of Aquaculture Initially Impacted by Cage Culture

One of the foremost management inputs required for aquaculture on any scale is feed. Although most feed and seed stores in an agricultural county will carry catfish feed, the majority of this may be sold to landowners which feed their farm ponds on an occasional or supplemental basis and generally buy no more than a few bags at a time. This is presently the case in the coastal counties of South Carolina where food prices can be as high as $14.00/50-pound bag for 32% protein floating catfish feed when purchased in small quantities. This is the equivalent of $560.00/ton at a time when bagged feed can be purchased for $300.00/ton or less on orders of one ton or more. In areas with large fish farming industries small quantities can often be purchased at near bulk bagged prices. For the average farm pond owner the actual price may not be an important consideration if the pond(s) are primarily used only for recreational fishing and the fish used for family consumption. However, in commercial fish farming, feed cost is the greatest single line item among operating costs and can make the difference between making a profit and taking a loss. The first stage of development of commercial aquaculture in many areas involves introducing farmers to the basic idea that fish, like poultry and hogs, can be raised as a profitable, mainstay crop, instead of a merely a novelty or a sideline.

When commercial cage culture or other small-scale commercial aquaculture begins to develop in a region of low previous aquaculture activity, an increased demand for feed at discount prices also develops. Wholesale feed distributors and feed and seed retail stores can move greater volumes of feed and subsequently purchase larger quantities from their suppliers at increased savings. With greater market demand for feed (or any other required product or service), the end result is, eventually, an increased availability at a lower price. In coastal South Carolina, at this time, farmers practicing cage culture on a small scale buy collectively in order to attain discount prices on feed since prices are high for quantities less than one ton. However, an increasing level of fish farming has brought down per bag prices at some of the larger farmers cooperative supply companies in the region. Since transport cost from outside feed mills are considerable, the most substantial reductions in feed cost come only once local feed mills begin producing aquaculture feeds in large quantities.

Creation of a Local Market for Fingerlings

In areas where aquaculture is just beginning, fingerling supplies are not available locally on a regular basis. Farm pond owners often acquire pond stocks of fish from outside area fish farm which are brought in by livehauling and sold on prescheduled dates and locations within the farming community. In South Carolina the cost per fingerling from these suppliers is often many times the price charged by large-scale fingerling producers. The increased fingerling market created by regional cage culture and small pond aquaculture can provide a niche for small-scale fingerling producers. As an example of this, in Orangeburg, SC, where cage culture of catfish has seen widespread activity in recent years, there are now a handful of local fish hatcheries which provide fingerlings of the commonly stocked farm pond species. Fingerling production, unlike food fish production, generally necessitates the use of ponds on commercial scale operations. Fingerling production farms have traditionally been the first "permanent" aquaculture installations to enter a specific area. In addition to gaining a more local supply of fingerlings the area gains a resident core of full-time fish farmers which can help support each other and help newcomers to the industry. Aquaculture development has demonstrated over the years that all of the extension efforts and outside support systems in the world can not replace the impact created by the local group of
entrepreneurs. Further development of the regional aquaculture industry from that point on can be largely dependent on the success of these first "full-time" fish farmers.

This illustration of the effect a growing aquaculture industry can have on local feed and fingerling supplies and prices is applicable to other essential needs as well. Often, retailers that are in business at the advent of fish farming in a given local will cater to its specific needs in order to better serve their time-honored customers. A current day review of the development history of the aquaculture industries in Arkansas, Mississippi, Alabama, and Louisiana would reveal that many materials, equipment and consulting services which were unavailable ten years ago are now easily attainable from many sources.

Cage Culture as a Marketing Tool

Although marketing is the last chore a fish producer performs it is far from the least. Marketing can make the difference between making an attractive profit and barely breaking even. One time, at a fish farmer meeting, when an experienced fish farmer was asked what advice he could give to someone just starting out, he replied, "Start selling fish before you ever raising them." While this may not always be possible for everyone, the farmer's statement certainly emphasized the importance of an area too often neglected. Cage culture can be used as a method for diversifying fish production in order to locate and test markets for various fish species before entering into production on a large-scale. Cages provided the flexibility to devote more or less production space and effort to any given fish species within a single pond. For example, farmers can experiment with a new species of fish without devoting an entire pond to its production. In addition, many small production units can be used to advantage when seeking high-paying "niche" markets, or, in other words, small, retail level, fish outlets, which can sometimes pay many times the price paid by wholesale distributors or processors for relatively small quantities of fish. Some of these include: restaurants, five-fish markets, farmers markets and other retail fresh fish markets. It is only common sense to try to market your fish where it is well-known and appreciated in order to get the highest return on your investment. In some instances this may mean dealing with distant markets via livehaulers or by the farmers providing their own means of transport. Many successful fish farming operations have been built by persons like the experienced fish farmer at the meeting who entered the industry as livehaulers and gradually moved into production. By selling fish grown by other producers in small lots they can locate the highest paying market outlets before going into production on their own.

Similarly, cage culture can allow a new producer to enter gradually into production of a certain fish species by adding cages while he builds his market and develops a marketing strategy. Within a single existing pond the novice fish farmer can change his marketing priorities as dictated by current market situation. In addition to permitting the culture of different species of fish within a single pond, cages, enable a farmer to separate fingerlings into different size lots for marketing over a longer period of the year. Staggered size lots of fingerlings can be grown out in separate cages so that some fish can be marketed ahead of the principal harvest season in the fall and help buffer the possible ill-effects of downside market fluctuation. This can be especially advantageous for farmers in South Carolina who raise tilapia in cages and outdoor ponds. Pre-autumn tilapia prices can be substantially higher than in October when the majority of pond-raised tilapia are harvested and brought to market.

While these avenues are open to all producers, they are most needed by small-scale farmers who do not enjoy the lower operating costs created by the economy of size on
large farms. In some areas regional farmers markets may allow live fish to be sold directly to the consumer. Small or large quantities of cage-raised fish can also be sold directly from the farm to the local population. When selling direct to the consumer, the farmer can sell at prices which provide the largest profit margin. Wholesale outlets and processors can provide an avenue for marketing very large volumes of fish, but the price paid to the producer is most always lower. At the risk of oversimplification, successful marketing means selling your product where you take home the highest net profit.

Creation of Fish Farmer Association

Extension agents have many methods of bringing farmers together and establishing cooperative ties between them. These are most successful when the links formed will result in farmers saving money and increasing their profit margin. In a developing cage culture program, in which most farmers are operating on a small scale of production, operating costs can be trimmed right from the onset by organizing feed purchases among local groups of farmers. Farmers buying collectively can purchase feed in lots of one ton or more and cut their individual costs considerably. Often, feed distributors will deliver free within a local area or for a small fee when minimum purchase requirements are met. Feed deliveries to a storage shed can also mean increased convenience for each farmer involved.

Fingerling purchases can also be made more easily and economically when they can be made in quantity. Many large-scale fingerling production farms will transport their own fingerlings to distant markets for the on-farm price plus the cost of transport for a specified minimum quantity. Fingerling prices from the large farms in the major fish farming states can be substantially lower than those of smaller farms elsewhere. Farmer groups can thereby enjoy greater savings and a lower cost of production.

These two examples are only the beginning of the types of cooperative efforts that can be developed between farmers during the implementation of a cage culture program. Farmers can be organized together at a later point in the season to arrange for marketing their fish. Cage harvests can be combined to meet the minimum requirements of various markets, fish brokers, and/or live haulers. As an alternative, farmers can schedule their final harvests in order to make the most profitable use of small area fish retail markets or to sell direct to the local public from roadside stands on their own farms.

The value created by an association of farmers, however, can be measured in much more than just dollars and cents. Farmer associations also serve as a self-support group for each individual member. Diversifying into a new sector of agriculture can be unsettling to a farmer and initially filled with doubts and worries about the risks involved. Sometimes newcomers to fish farming are met with enormous skepticism and even ridicule as expressed by peers and acquaintances within their communities. The ability to talk over difficulties encountered with others who are sharing the same experiences can provide a lot of moral support and peace of mind. A forum for idea exchange is also established through farmer association and this is probably the most effective form of education. There is no better source of information than that which is acquired through first-hand experience. The benefits mentioned in this paragraph are not always considered prior to the creation of a farmer association, but, in the long run, they are often the best reasons for keeping it together.
The Goal of Cage Culture: From an Extensionist's Viewpoint

In some locations, cage culture may be the only form of aquaculture feasible due to conditions which are poorly suited for the construction of manageable ponds. In these instances, cage culture may be the final solution for producing fish crops. The long-term success of commercial-scale cage culture in any area will likely depend on the regional aquaculture infrastructure which develops. Cage culture will always be dependent on a source of fingerlings which inevitably must come from established fish farms. The success of tilapia cage culture in South Carolina as begun in the USC Tilapia Extension Project will ultimately depend, to a large extent, on the steady availability of fingerlings from a local supplier or through the cooperative efforts of farmer groups. The present goals of the project are to concentrate work efforts with the most progressive farmers in order to increase their progress toward self-sufficiency of production. Normally, new farmers will buy fingerlings until their level of production reaches the point at which it becomes more profitable to invest in the facilities needed to produce their own stocks or when regional demand reaches a level at which fingerling production presents more attractive advantages than food fish production. From an extensionist's point of view, cage culture's real goal is met when it is used effectively to help farmers progress to such a stage at which they become permanently established, full-time fish farmers instead of seasonal cage culture producers.
CAGE CONSTRUCTION
"ROUND OR SQUARE?"

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Illinois-Indiana Sea Grant
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Purdue University

Introduction

I am sure that at this point in our workshop everyone is eager to obtain the last piece of the puzzle which will allow you to get started on your way to becoming a new or better fish farmer. I hope that you understand by now too, that constructing your cages is really the simplest part of cage fish farming. Nevertheless, after determining if you have a market for you fish and whether your pond or ponds are suitable for cage culture, cage construction is still one of the first things you will have to do. You may also think that between now (late summer) and next spring there is really nothing that you can do in preparation for next year. On the contrary, constructing cages this winter will give you a head start next spring.

For those of you that prefer, cages may be purchased from many companies handling aquaculture products. Many of these companies advertise in popular aquaculture magazines such as *Aquaculture* and *Water Farming Journal*. Other local companies also construct cages. But, like most of us who are "handy" will a few simple tools and are always looking for a way to save money, constructing your cages probably is the answer.

Every good fish cage built was constructed only after considering several factors. Three of these are:

1. Cages should be made of sturdy materials. Small cages will cost at least $50, therefore a cage fish farmer wants his cage to last several years. I think it is correct to say, that with proper care and maintenance, a ten year life expectancy is possible from a cage.

2. The netting selected is very important. The netting mesh size should be as large as possible and still prevent your fingerlings from escaping. A pretty good rule of thumb for catfish is to allow one fourth inch mesh size for every two inches of fingerling length. For example, 6-8 inch fingerlings will require 3/4 inch mesh. Other species that have different body girths should be tested prior to stocking. Selecting the largest mesh possible that will still retain your fish is critical to the health of your fish by allowing good water circulation. Since your fish will be confined to a small volume of water, a good exchange of water in the cage will carry out fish wastes while bringing in fresh oxygenated water.

3. The design should be as economical as possible while keeping in mind the first two factors.
During the next few minutes I would like to discuss:

1. The parts of a cage
2. Cage Design and construction
3. Placement of the cage in the pond
4. Stocking the cage

**Parts of a Cage**

A cage consists of a frame, netting, feeding ring, floatation and a lid. The frame of the cage can be constructed from wood, iron, steel, aluminum, fiberglass polyethylene or PVC. Frames of wood or steel must be coated with a non-toxic yet water-resistant substance to prevent rot or rust. The frame serves as a place to attach the netting and in some instances (polyethylene or PVC) serves as floatation.

The netting material can be galvanized wire, plastic coated welded wire, solid plastic mesh or nylon netting. Nylon netting is the least desirable of these since the accumulation of uneaten food will attract turtles which may chew through the cage bottom. Mesh size will vary according to the size of fingerlings selected, but for food fish production it is recommended to use at least 1/2 inch mesh.

As a result of wind and the feeding activity of the fish a feeding ring is used to prevent floating fish food from passing through the cage. It can also be constructed of netting if the mesh is small enough to retain the feed. Plastic netting constructed of 1/8 or 3/16 inch mesh and extends six inches below the water surface is a good choice for a feeding ring.

The floatation is necessary to maintain the top of the cage just above the water surface. Flotation can be provided by Styrofoam, waterproofed foam rubber or sturdy plastic jugs such as antifreeze jugs. Milk jugs are not good floatation devices since they break down after exposure to sunlight. In certain instances, the frame when constructed of polyethylene or PVC pipe will provide adequate floatation.

The lid for the cage can be constructed from the same type netting as the rest of the cage or from plywood, masonite, or light gauge aluminum. One advantage to constructing the lid from netting is that feeding is made easier by throwing feed directly through the lid rather than removing it each time you feed.

**Cage Design and Construction**

There are probably as many different cage designs in use as there are materials used to construct them; each has its advantages and disadvantages. I will not go into these numerous designs except to give you an idea of their dimensions. The three most common types used on smaller farms are the round, square and rectangular cages. Where large quantities of water are available, such as along the coast and large privately owned lakes, cages containing several thousand cubic feet of rearing area are in use.

I will give the design and construction procedures for a round and a rectangular cage having volumes of 37 and 160 cubic feet respectively. After gaining experience or when larger lakes are available, larger cages should be considered.
Round Cage Design and Construction

The round cage has one advantages over a square cage. For pelagic species which constantly swim, such as hybrid striped bass, round cages have no corners that these species can bump into. Constructing round cages of this size will allow two complete cages and the wall of a third cage to be constructed from one 50 feet roll of netting. The completed cage will have a volume of 37 cubic feet.

Materials Needed for One Round Cage:

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<tr>
<td>1. 3/4 in. plastic mesh netting</td>
<td>18 ft. 6 in. X 4 ft.</td>
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<td>2. 1/8 in. plastic mesh netting</td>
<td>11 ft. X 12 in.</td>
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<tr>
<td>3. 1/4 in. galvanized steel</td>
<td>11 ft.</td>
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<td>4. 1/4 in. galvanized steel couplers</td>
<td>1</td>
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<tr>
<td>5. 1 1/2 in. polyethylene pipe</td>
<td>11 ft.</td>
</tr>
<tr>
<td>6. 1 1/2 in. plastic coupler</td>
<td>1</td>
</tr>
<tr>
<td>7. 1 1/2 in. hose clamps</td>
<td>2</td>
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<tr>
<td>8. 1 in. polyethylene pipe</td>
<td>23 ft. 7 in.</td>
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<tr>
<td>9. 1 in. plastic coupler</td>
<td>2</td>
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<tr>
<td>10. 1 in. hose clamps</td>
<td>4</td>
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<tr>
<td>11. 18 gauge plastic coated wire</td>
<td>100 ft.</td>
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Procedure:

1. From the 18 ft. and 6 in. piece of 3/4 in. plastic netting cut a piece 11 ft. and 2 in. length. This will be the cage wall (Fig. 1).

2. Roll the cage wall into a tube that is 3 1/2 feet in. diameter. Using a few short pieces of wire, temporarily tie the edges together allowing a 2 in. overlap.

3. Using 18 gauge wire lace the wall together. Be sure to allow two inches of overlap and go through every mesh when lacing.

4. Using the 1/4 in. galvanized steel, cut a 11 ft. piece. Form a hoop 3 1/2 ft. in. diameter connecting with the galvanized coupling. This hoop will form the bottom of the cage.

5. Using the steel hoop for a template, cut a piece of 3/4 in. mesh plastic netting for the bottom (Fig. 1).

6. Temporarily tie the bottom netting to the hoop with a few short pieces of wire.

7. Lace the bottom of the cage to the wall (Fig. 2). Again be sure to go through each mesh.
8. Slip two 1 and 1/2 in. hose clamps onto the 10 ft. section of 1 and 1/2 in. polyethylene pipe then insert the 1 and 1/2 in. plastic coupling into one end of the pipe. Tighten one of the clamps securely over the joint. Carefully form a hoop by joining the other end of the pipe to the coupling. Tighten the second clamp securely to this joint. This hoop should be 3 ft. in. diameter and will form the top of the cage.

9. Attach the top of the cage to the wall using wire (Fig. 3). Be sure to go through every mesh.

10. Form a hoop 3 ft. 6 in. in diameter as in step 8 using a 11 ft. piece of 1 in. polyethylene pipe, 1 in. coupling and 1 hose clamps. This hoop will provide additional support and flotation to the cage wall.

11. Attach the hoop mid-way down the cage wall on the outside using wire.

12. Using the 1/8 in. plastic netting form a feeding ring on the inside of the cage by attaching the netting to the top of the cage wall. The feeding ring should extend six inches above and below the water surface.

13. Form another hoop 4 ft. in diameter as in step 12 using the 1 in. polyethylene pipe, 1 in. coupling and 1 in. hose clamps. This will form the lid of the cage.

14. Using this hoop as a template cut from the remainder of the 1 plastic netting a piece for the lid (Fig. 1).

15. Lace the plastic netting to the 1 in. pipe with wire.

Rectangular Pen Design and Construction

Larger cages have two advantages over smaller cages. They are usually cheaper to construct on a per cubic foot basis and total labor required to feed is less than smaller cages. There are, however, disadvantages to larger cages. Larger cages are harder to maneuver around than smaller cages and will require more labor to harvest. Outbreaks of diseases can cause higher mortality because of larger numbers of fish per cage. With these advantages and disadvantages in mind, the design and construction procedures for a pen, 4 ft. x 4 ft. x 10 ft. are given. The completed cage will have a volume of 160 cubic feet.
Figure 1. Diagram of dimensions needed for plastic netting to construct cage wall, bottom and top for a 3 1/2 ft. x 4 ft. round cage.

Figure 2. Photo illustrating cage bottom being attached to cage wall.
Figure 3. Photo illustrating cage top being added to cage wall.

Figure 4. Dimensions for the top frame and flotation of a 10 ft. x 4 ft. cage.
Materials:

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<tr>
<td>1. 4 in. diameter PVC pipe</td>
<td>30 ft.</td>
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<td>2. 4 in. diameter PVC elbows</td>
<td>4</td>
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<tr>
<td>3. PVC primer</td>
<td>8 oz</td>
</tr>
<tr>
<td>4. PVC cement</td>
<td>8 oz</td>
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<tr>
<td>5. 3/4 in. mesh plastic coated welded wire</td>
<td>38 ft. 3 in.</td>
</tr>
<tr>
<td>6. 1 in. PVC pipe</td>
<td>37 ft.</td>
</tr>
<tr>
<td>7. 1 in. PVC elbows</td>
<td>4</td>
</tr>
<tr>
<td>8. 1 in. PVC tee</td>
<td>2</td>
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<tr>
<td>9. 1/2 mesh netting</td>
<td>5 ft. X 11 ft.</td>
</tr>
<tr>
<td>10. 18 gauge bell wire</td>
<td>200 ft.</td>
</tr>
<tr>
<td>11. 1/8 in. plastic netting</td>
<td>28 ft. 3 in. by 1 ft.</td>
</tr>
<tr>
<td>12. 1/4 in. nylon mesh netting</td>
<td>12 ft. X 6 ft.</td>
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Procedure:

1. Cut two pieces of the 4 in. diameter PVC pipe that are 9 ft. 8 in. long.

2. Cut two other pieces of 4 in. diameter PVC pipe 3 ft. 8 in. long.

3. Using the 4 in. PVC elbows, sections of pipe, PVC primer and cement construct a rectangular frame that has inside dimensions of 10 ft. X 4 ft. (Fig. 4). The plastic coated wire box will be attached to this frame.

4. Cut a section of the 3/4 in. plastic coated wire 28 ft. 3 in. Bend the netting in four places to create a rectangular box 10 ft. X 4 ft. (Fig. 5). The excess 3 in. will be the overlap used when lacing walls together.

5. Lace the wall together at the overlap using the 18 gauge plastic coated wire. Be sure to go through every mesh.

6. Form a bottom by lacing the remaining 10 ft. section of netting to the walls (Fig. 6)

7. Attach the frame to the cage walls using the 18 gauge wire. Be sure that there is no space (which could allow fish to escape) between frame and top of netting.

8. Using the 1/8 in. plastic netting form a feeding ring on the inside of the cage by attaching the netting to the top of the cage wall. The feeding ring should extend six inches below the water surface.

9. Cut 4 pieces of 1 in. PVC pipe 5 ft. 5 in. long and 3 pieces that are 5 ft. long. These will be used to make the lid.

10. Using the pre-cut sections of 1 in. PVC pipe, 1 in. tee’s and the 1 in. elbows construct a rectangular frame that is 11 ft. by 5 ft. Sew the 1/4 in. nylon netting to the frame using the 18 gauge wire.

11. Place the lid on the cage, and make a hinge using two pieces of wire. Use another piece of wire for the latch.
Figure 5. Diagram of wall formation for a plastic coated wire mesh cage 10 ft. x 4 ft.

Figure 6. Diagram of constructed cage wall and cage bottom.
Placement of Cages in Ponds

Placing a cage into the pond means more than just throwing it into the water. First you need to find a good location in the pond. Then, you must make sure the cage is floating properly. Finally, you should anchor the cage so it will not drift away.

Location

Location of the cage is critical since water must circulate through the cages to ensure adequate waste removal and high levels of dissolved oxygen. In addition, the farmer must go to the fish when feeding and for observing, instead of the fish coming to the farmer. Therefore, prior planning is essential before placing the cages so the farmer can minimize his efforts for day-to-day activities. Piers, either floating or permanent, are a convenient way of taking care of your fish by attaching cages to them. However, they require time to construct and are somewhat expensive.

A good location for cages is just as important as other aspects of cage culture. It is important that there be at least two feet of clearance between the bottom of the cage and the pond bottom (Figure 7). There should also be at least two cage widths between each cage to provide better water circulation. Cages placed too close together will increase the chances of low dissolved oxygen levels. Placing cages too close together will reduce circulation and is a sure way to kill your fish.

The best location for cages is one which receives lots of wind action. Shallow areas and areas with aquatic vegetation should be avoided. Consideration should also be given in regard to disturbances from people and other animals which can increase the chances of stress and resulting disease outbreaks.

Floatation and Anchoring

Adequate flotation should be provided by the polyethylene or PVC pipe used. If addition flotation is required it can be provided by securely attaching Styrofoam or jugs to the frame.

Cages need to be anchored to the bottom of the pond, a pier or a cable so they do not drift about freely in the pond. When anchoring be sure to allow enough slack line to prevent high water levels from covering the top of the cage which will allow the fish to escape.

Overwintering

Cages containing fish have been overwintered. Generally, it is best to reduce densities in cages and try to maintain ice free areas around the cages. These ice free areas can be made by aerating or manually breaking ice from around the cages.
Figure 7. Diagram of pond showing properly spaced cages.
Stocking of Cages

Contrary to popular belief, there is no single stocking rate that is perfect for every pond. Stocking rates are at best—guidelines that have been developed through research and experience. The maximum pounds of fish that can be harvested from a surface acre will depend on many different variables. The two single most important variables to consider are feed type and amount and dissolved oxygen levels. By now, it is understood that feeding is essential in cage culture. However, if permanently high oxygen levels were maintained, using for example mechanical aeration, then the maximum yield would also be increased. For the beginning cage fish farmer, who is feeding but not aerating, a maximum yield of 1,500 pounds per acre (lbs./a.) is a good estimate. Using aeration, the maximum yield can be increased to well over 2,500 lbs./a.

Assuming that 1,500 lbs./a. is your maximum yield, you will want to know how many fish to put in each cage and the number of cages needed per acre. **To determine the number of fish to stock, assume a stocking rate of 10 fish per cubic foot of cage.** Using the stocking rate of 10 fish per cubic ft. you could stock the round cage with 370 fish and rectangular cage with 1,600 fish.

To determine the number of cages needed for per acre it is necessary to know the market size of your fish in addition to the maximum yield of 1,500 lbs./a. Market size of four potential cage culture species are given:

- **Catfish = 1.5 lbs.**
- **Trout = 1.5 lbs.**
- **Hybrid striped bass = 1.5 lbs**
- **Bluegill = 0.5 -0.75 lbs.**

As an example for determining the cages required we will use the round cage design containing 37 ft.² and farm catfish, which have a market size of 1.5 lbs./fish.

First, divide maximum yield by market size.

\[
\frac{1,500 \text{ lbs}}{1.5 \text{ lbs}} = 1,000 \text{ fish per acre}
\]

Then, divide number of fish per acre by cage capacity

\[
\frac{1,000 \text{ fish}}{370 \text{ fish}} = 3 \text{ cages}
\]

From this example you will need 3 cages, each containing 370 fish to yield 1,500 lbs. of 1.5 lbs. fish. Two important factors not included in these determinations are stocking size and percent mortality. Stocking size is a function of the growing season in your area and the growth rate of the farmed species. For the Midwest, stocking 6-8 in. catfish fingerlings should be large enough for them to grow to marketable size within one growing season.

The mortality rate is another factor to consider when calculating the number of fish to stock in each cage. There will be fish lost during the course of the growing season. The number of which depend usually on water quality. for a farmer just starting out in fish farming expect to lose more than someone who has several years experience. If you want to compensate for expected mortality then add 5 percent to the stocking number.

As you gain experience, this figure can be adjusted for your operation.

The last point I want to discuss is handling fish during stocking and harvesting. The most important fact to remember is that fish live in water and anytime they are out, you increase the likelihood of death.
A few guidelines for handling during and after stocking are given:

1. Temper fish before stocking by gradually equalizing water temperature.

2. Always move fish in well aerated water and if possible use 0.5-1.0 percent salt solution.

3. After fish are first stocked feed medicated feed for the first ten days.

If these general guidelines for construction and stocking are followed then the chance of success for the beginner is greatly increased. Good luck in your endeavors and do not become discouraged.

Summary

Cage construction is not complicated if prior planning is used. Cages should be constructed of sturdy-rust proof materials. Plans are given for the construction of a 37 ft.² round cage and a 160 ft.² rectangular cage. Cages should be anchored securely in an area of the pond which receives adequate water circulation. There needs to be at least two feet of clearance between the bottom of the cage and bottom of the pond. Also allow two cage widths between each cage. Proper spacing and adequate depth will allow proper waste disposal and water circulation. Ponds with no other fish in them can yield up to 1,500 lb./a. with daily feeding, but no aeration. Stock no more than 10 fish per cubic foot of cage volume for food fish production.
CONCLUSION

Cage culture is a form of aquaculture that uses existing bodies of water that may be otherwise inappropriate for use as culture ponds (i.e., too deep, uneven bottom, not drainable, etc.). Cage culture provides first-hand experiences in raising fish, but without the large-scale economic investment associated with other forms of aquaculture—a good learning system. Because fish are dependent on water for their life support, small changes in water quality can kill numerous fish. In fact, one of the sayings you may hear is "You are not an aquaculturist until you have killed several thousand fish." With the cage culture approach, you are less likely to lose a great deal of money, and you will be gaining the necessary skills to expand and intensify your aquaculture business after you decide if this is an agricultural venture you want to pursue. You probably became aware during the course of this workshop that there is no cookbook method for raising fish, particularly most of the coolwater fish under consideration in the Midwest. The more you know about aquaculture in general and about your targeted species, the better chances you have of success.

We attempted to provide you with a broad introduction to aquaculture, covering many of the most important aspects. We encourage you to contact as many people as possible, learn as much as you can, and proceed slowly. The aquacultural infrastructure (Processing plants, feed mills, fingerling producers, and disease diagnostic capabilities) are not fully established in the Midwest, but things are changing and the opportunities are real. Consumption of fish is increasing, wild-caught supplies are diminishing, the world's waters are becoming increasingly polluted; thus, aquaculture has been projected to continue the dramatic production increases seen in the 1980's when it was the most rapidly growing segment of US agriculture. Twenty years ago, catfish production in the South was not much more than a dream—today it is the largest aquacultural industry in the US. We can learn a great deal from the existing, successful industries. Combine forces (buy feed and fingerlings together with your neighbor), ask for help from the research and extension communities at the universities represented here, and talk to the feed companies about your needs. The critical mass of individuals needed to answer these questions is being established in the region. Do not get discouraged if you lose fish—you will be very lucky if you never experience unexpected mortalities. Learn from your mistakes and when you have mastered the basics of fish husbandry, then look to expand. If we can produce and market 300 million pounds of catfish, how many pounds of hybrid striped bass, or yellow perch, or walleye, or sunfish, can we market?
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524 South Second Street
Springfield, IL 62706
217-782-2964

Indiana

Fisheries Staff Specialist
Indiana Department of Natural Resources
607 State Office Building
Indianapolis, IN 46204
317-232-4080
Indiana and Illinois Aquaculture Associations

Both Indiana and Illinois have a very active Aquaculture Association which organize many activities that can benefit Aquaculture directly or indirectly. Their addresses and membership fees are listed below.

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Lawrence, IN 46236

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I.A.I.A.
625 South Second Street
Springfield, IL 62704

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