

VIII. GUIDELINES FOR CULTURING FISH AT HIGH DENSITIES IN LOW VOLUME CAGES

INTRODUCTION

The guidelines for low volume high density cage fish culture (LVHD) presented here apply specifically to channel catfish, common carp and Nile tilapia and generally to all feed taking fish raised in cages smaller than 4 m³ in freshwater ponds, lakes and reservoirs. They are intended for use as a quick reference for persons planning or actually engaged in raising fish in low volume cages.

ENVIRONMENTAL CRITERIA FOR LVHD

Physical Pond

1. Pond water area should be 2,000 m² or greater.
2. Water level (volume) should stay constant without significant water loss.
3. The pond should not be located in a deep, narrow valley or protected from gentle breezes by trees.
4. Ponds with continuous water flow are acceptable.
5. Water should be plankton green (transparency ≥ 40 cm) and not predominantly muddy or swamp brown. Watershed must be protected from erosion.
6. Pond bottom and water should not contain accumulated tree leaves, limbs, sticks and similar debris.
7. Pond open water should be free of "wild" and cultured fish, except in situations where grass carp, filter carp or other selected species are part of the management program.
8. There should be no conflicting use of the pond.
9. Pond should be accessible for routine management purposes and security.

Physical Lake and Reservoir

1. Pollution free, low fertility lakes and reservoirs are preferred. Water should be clear or mildly plankton green (transparency ≥ 80 cm) and not predominantly muddy or swamp brown.
2. Lakes and sections of lakes and reservoirs with more than 50% of the depth containing no dissolved oxygen should not be used for cage fish culture during periods of probable overturns unless the cage area is in shallow water with no or limited exposure to the overturn area.
3. Water level changes should be known and sites selected should have a minimum depth at least 50 cm deeper than cages.
4. Wind patterns and water currents should be understood and considered when selecting cage sites.
5. Cage sites should be free of aquatic weeds.
6. Cage sites should be within constant sight of the farmer for management and security purposes.

Pre-Culture Preparation

1. Prior to stocking fish into cages, prepare pier or other access from bank to cage locations. A fixed pier works well in ponds and is best constructed with the pond level drawn down. A floating pier-raft or boat access may be best in lakes and reservoirs.
2. Undesirable fish should be eradicated from ponds, preferably by complete draining followed by poisoning (degradable toxins only) of residual waters.
3. Lime (agricultural grade limestone), if needed in a pond, should be distributed evenly over the dry pond bottom or evenly over the water surface after the pond is refilled.
4. Before obtaining stock, check out all facilities and equipment needed for transporting, handling and stocking of fish. Assure feed supply and markets.

CAGE CRITERIA

Introduction

1. The basic principle of cage culture requires that a cage be made of material that is strong and durable enough to hold the collective weight of fish and yet allow relatively unrestricted exchange of water, hold feed within the cage until consumed by the fish, allow all fish wastes (respiratory, excretory and metabolic) to exit the cage without accumulation, be non-abrasive and otherwise non-injurious or stressing to the fish.

2. Cage size is measured by volume and should be no smaller than 1 m³ and no larger than 4 m³ based on individual preference; depth should be 1.0 to 1.5 m.
3. Cage shape is not critical, but cubical or rectangular is preferred.
4. Acceptable materials for constructing cages are numerous. Soft and flexible enclosing materials (e.g. knotted or knotless nylon) are preferred, except in unusual cases where metal mesh is necessary. An ideal cage material would be strong, durable, non-restrictive to water exchange, non-corrosive, fouling resistant, light, non-injurious to fish and inexpensive.
5. Mesh size may be critical; 13-mm square mesh might be considered a minimum mesh size for production, because that size is small enough to easily hold ≥ 20 -g fingerlings and yet large enough for adequate water exchange.

Feed Containers for Cages

1. Feed for caged fish should be in pelleted form, manufactured to either float or sink. The cage farmer wants 100% of the feed to be retained in the cage until consumed by the fish; therefore, feed enclosures are necessary.
2. Floating feed may be held in the cage within a box that has no top or bottom and extends at least 40 cm below and 20 cm above the water surface. Water surface area inside the box should be approximately 25% of the total top surface area of the cage. Wire mesh may be used to cover the feed enclosure to prevent access by ducks and other animals but allow feed to be poured into the enclosure.
3. Sinking feed is applied through a tube to a bottom feed holding structure. The entire cage bottom and lower 20 cm of all sides are lined with fine mesh to hold the feed. A 10-cm diameter PVC pipe is permanently fixed in the cage to serve as a conduit of the feed from the surface to 15 cm above the center of the cage floor.

Cage Cover

A complete, removable opaque cage cover is recommended, primarily to protect fish from the effects of long term exposure to direct sunlight and from predaceous birds and other animals. Opaque covers over cages have resulted in 10% higher production performance and 30% higher profits compared to production in cages with transparent or no covers. However, the farmer needs to be able to observe the water surface and be able to remove dead fish if they appear. Dead fish will usually float.

Cage Placement and Positioning

1. Placement and positioning of cages are primarily dictated by access to the cages for management purposes and water quality maintenance within the cages.

2. Routine access to cages for feeding and other management activities is essential. However, efforts to facilitate access must not adversely affect water quality in the cage. Cages may be placed and positioned in several ways, including individual cages suspended at random or in lines in the open water accessible by boat or raft, or attached to floating or fixed piers or rafts accessible by boat or a walkway to shore.
3. The entire volume of water in the cage should ideally be exchanged at least once per minute. Less frequent water exchange may cause physiological stress because of low water quality. More frequent water exchange may cause physical stress because of water force or turbulence. Water current rates from 1 to 10 m/min are acceptable, and a current of about 5 m/min is ideal.
4. Cages should be placed in open areas away from both stagnant waters of narrow coves and areas subject to strong currents and wind induced, white capped waves.
5. Cages should be suspended from the water surface, and spaced at least 2 cage widths apart in lines and never in "chess-board" grids. Water currents should not directly carry water from one cage into another. A space of at least 50 cm should separate the cage bottom from the pond or lake bottom.

FISH STOCK CRITERIA

Fingerling Quality

1. Fingerlings for stocking in cages should be of relatively uniform size and large enough not to escape through the cage mesh.
2. Fingerlings must be disease free. Inspection by a certified fish disease specialist is recommended. Some key indicators of good health are uniformity of skin color among the group, absence of spots and frayed fins on individuals, and vigorous capture avoidance by all of the fish.

Number of Fingerlings to Stock

1. Do not exceed suggested maximum numbers of stock per volume of cage and cage area of total water environment. Numbers to stock are dependent upon total and average individual weights expected at harvest and anticipated optimum carrying capacity of the cage.
2. Suggested maximum weight per cage volume decreases with increasing cage volume. In ponds the decrease would be from about 160 kg in a 1-m³ cage to 130 kg/m³ in a 10-m³ cage.
3. Suggested maximum weights of caged carp and catfish per pond area are 2,250 kg/ha without emergency aeration and 4,200 kg/ha with emergency aeration. Expect approximately 20% higher rates for tilapia.

4. Suggested maximum optimum standing crops for open lakes and reservoirs are 200 kg fish/m³ of cage, 320 kg/ha of total water area, 20 mt in a 1-ha designated cage culture area and 60 mt (6 mt/ha) in a 10-ha designated cage culture area.
5. Understocking may be as common as overstocking fish in cages. A minimum stock density of 100 fish/m³ of cage is recommended. Maximum stock density will vary with environmental quality, but a recommended maximum stock density for a first-time cage farmer is the number of fish that will collectively weigh 150 kg/m³ of cage at harvest. For example, if a farmer wants to harvest fish averaging 500 g and the expected collective weight per m³ at harvest is 150 kg, then:

$$\text{Number to stock} = \frac{150 \text{ kg/m}^3 \text{ (total fish weight at harvest)}}{0.5 \text{ kg (desired avg. fish weight at harvest)}} = 300 \text{ fish/m}^3$$

6. It is common for 1 or 2% of fish to die during the first 7 to 10 days after stocking. However, if the fish being stocked are healthy and are handled properly, 100% survival can be expected.

Stocking Conditions

1. Fingerlings may be stocked any time of year, but the process of stocking stresses fish and may adversely affect fish health. Stocking fish during the warmest part of the day is especially stressing. The warmer the water, the greater the stress.
2. Stocking is preferred during the non-growing season when water temperatures are $\leq 16^{\circ}\text{C}$ for catfish and carp and $18\text{-}20^{\circ}\text{C}$ for tilapia.
3. Best times to stock during the culture season are during early morning hours and on cloudy and rainy days when water temperatures are at their lowest.

Instructions for Handling Fish

1. The fundamental objective of every activity where fish are handled is to effectively and efficiently accomplish the activity with minimum stress to the fish. The component parts of the objective, i.e. effectiveness, efficiency and minimum stress, are interrelated. For example, techniques that improve efficiency will likely result in improved effectiveness and reduced stress to the fish.
2. Techniques and procedures for achieving specific fish handling objectives related to transporting, stocking, sampling and harvesting are subject to the same four-stage process:
 - a) Plan the materials and methods of the procedure based on specific objectives;

- b) Prepare the materials and methods, including all personnel, before beginning the activity;
- c) Implement the procedure specifically following the plan;
- d) Evaluate the results of the technique relative to achieving both the fundamental and specific objectives and the efficiency and effectiveness of the process.

FEED CRITERIA

Feed Quality

1. Quality feed is absolutely critical for feeding caged fish. The feed used must be nutritionally complete. Be suspicious of a bargain feed from an unestablished feed company.
2. Feed protein levels should generally be 32 to 36%. Higher protein feed is more expensive but usually worth the extra cost, especially until the fish average 150 g or greater.
3. It is essential that the feed contain complete vitamin and mineral premixes with supplemented vitamin C and phosphorus.

Feeding Caged Fish

1. The amount of feed caged fish will consume is primarily related to water temperature and average weight of the fish.
2. Feeding practices may vary greatly but the following are basic recommendations:
 - a) Begin feeding (first few days) at a 3% rate (3 kg feed/100 kg of fish); after fish are actively eating, feed all they will consume within 2 to 5 minutes;
 - b) Some fishes, especially catfishes, normally feed at night. However, they should be trained to feed during the day. The preferred feeding time(s) is between 8:00 a.m. and 4:00 p.m.
 - c) Feeding twice or more per day is not necessary. However, feeding 2 or 3 times/day 6 to 8 hr apart will result in somewhat faster growth and better feed efficiency, especially for smaller fish and for tilapia and carp;
 - d) Overfeeding, which is indicated by feed left uneaten 10 minutes or longer after feeding, should be strictly avoided. This becomes increasingly more important as standing crops approach carrying capacity, both for cages and for open water in which the cages are placed;
 - e) Where cages are used in ponds, do not feed catfishes and carps more than 30 kg of feed/ha/day and tilapias more than 40 kg of feed/ha/day without emergency aeration capability. Do not feed catfishes and carps in ponds more than 60 kg and tilapias more than 85 kg of feed/ha/day with aeration. This rule does not generally apply to feeding fish in cages in lakes and reservoirs.

Feed Purchase and Storage

1. Purchase only the amount of feed that will be used within 4 to 6 weeks.
2. Store feed in a dry, ventilated, shaded and cool location protected from animals and insects.

Feed Conversion Ratio (FCR)

1. FCR is a measure of nutrient efficiency of producing fish from feed and is influenced by several factors, including feed quality, feed quantity, fish species, fish size and water quality.
2. FCRs for a high quality pelleted feed for Nile tilapia, channel catfish and common carp raised from 15 g to 500 g should be about 1.2 to 1.7 kg feed per 1.0 kg of fish weight gain.

Other Considerations

1. Nutrition (feed) has long been considered a major factor in fish management. Feed quality cannot be taken for granted. Exercise caution in purchasing and handling feed, because feed and feeding are the highest single management cost.
2. Fish feeding behavior is the best index to fish health. If fish feed actively, conditions are good and vice versa.
3. Automatic and demand feeders are not recommended because of the added equipment cost, usually higher feed conversion, and the need for the farmer to observe fish condition, fish feeding behavior and general water environment at least once every day. Mechanical feeders do have potential for future use.
4. Feed weights should be measured and recorded each time the fish are fed. If weighing each day's ration is not practical, then a volume-weight method to measure feed weight may be used. However, volume-weight measurements must be determined every time feed brands or types are changed.
5. Sinking feed is less expensive than floating feed and may be used in cages if care is taken to make sure the feed does not pass through the cage. Floating feed is preferred in cages, because it is more economical and allows direct observation of the fish.
6. Feed costs to raise a crop of caged fish may be greater for a lower priced feed than a higher priced feed if the difference in price is directly related to feed quality. Judge a feed for its economic efficiency rather than only its price.

WATER QUALITY CRITERIA

Oxygen and Low Dissolved Oxygen Syndrome (LODOS)

1. Concentration of dissolved oxygen and availability of oxygen are critical factors to caged fish. These factors belong to a complex syndrome of numerous chemical, physical and biological factors.
2. Water quality, specifically LODOS (low dissolved oxygen syndrome), is the most important factor in caged fish management and it is the most difficult to understand, predict and manage. Most fish kills, disease outbreaks, poor growth, poor feed efficiency and similar management problems are directly related to poor water quality, especially LODOS.
3. Normally in fish ponds and nutrient-rich lakes, oxygen is plentiful in mid-afternoon and limited in early morning. However, there are deviations from the normal pattern. These deviations are "overturms," plankton "die-offs," and periods (2+ days) of reduced sunlight. Any of these deviations will cause lower than normal oxygen levels for one to several days. When these deviations occur in mid-summer, they usually cause partial or total fish kills or, at the least, disease problems unless timely, emergency aeration is used to maintain oxygen at above critical levels of ≤ 3 mg/l.
4. Oxygen concentrations may be measured by one of several devices that range in accuracy and price. Chemical analysis kits are sufficiently accurate and relatively inexpensive, especially when compared to electronic instruments. However, an electronic dissolved oxygen meter should be a priority whenever affordable.
5. Oxygen management in ponds is either biological or mechanical. Biological management is accomplished in ponds by maintaining a healthy phytoplankton population indicated by a depth visibility of ≥ 30 cm. Mechanical management is the employment of some form of aerator such as a paddle wheel.
6. The following are causes of LODOS, with indicators they have occurred, are occurring or may occur:
 - a) Cloudy weather: Sunshine and phytoplankton, through photosynthesis, are responsible for almost all of the oxygen dissolved in pond, lake and reservoir waters. Therefore, even a few consecutive days with little or no sunshine will restrict photosynthesis and result in LODOS conditions;
 - b) Thunderstorms: Winds and hard rains are notorious for creating "overturms" in ponds, lakes and reservoirs where LODOS conditions are formed by mixing "bad" quality bottom water with "good" quality top water. The net effect is "bad" LODOS quality water;
 - c) Exceptionally cool periods, such as those that sometimes occur during monsoon seasons, also cause "overturms";

- d) Plankton die-offs: Dense phytoplankton populations will sometimes die all at once. The causes of these plankton die-offs are not fully understood, but severe LODOS conditions follow. Die-offs are not predictable, but they occur more often when algal scums have developed on the water surface, or when depth visibilities are limited to about 15 cm. An indication that die-off has recently occurred is the abrupt clearing of the water within hours. Visibility increases 2 to several times followed by changing of water color from green to a dilute coffee-brown color often streaked with black. This condition is usually accompanied by a distinct odor. By this time LODOS conditions are critical. Corrective measures in ponds are generally limited to supplemental aeration until the condition corrects itself, usually in 2 or 3 days.
7. No practical oxygen management techniques exist for large lakes and reservoirs. Cage culture should not be practiced in lake and reservoir environments unless minimum depth visibility is ≥ 80 cm and preferably ≥ 200 cm. Clear water is not desirable in ponds, but it is desirable in large lakes and reservoirs.

Temperature

1. Optimum water temperature for carp, catfish, and tilapia growth is from 26 to 28°C. Growth is poor at 16°C and no growth occurs below about 12°C (minimum tolerable temperature for tilapia). Growth and feed efficiency decline steeply above 30°C, and growth ceases at about 33°C, followed by disease and death.
2. No practical management techniques exist for controlling water temperature in and around cages. Shading may have other benefits, but it will not affect water temperature.

Nitrogenous Wastes

1. Ammonia and nitrite are forms of nitrogenous wastes resulting from protein digestion. These wastes may become problems in intensive fish production systems but should not be problems at the recommended stocking and production levels for caged fish.
2. No practical management techniques exist for controlling nitrogenous wastes except by limiting feed inputs through limited production intensity.

Visibility into Water

1. An index to healthy pond water is a distinctly green phytoplankton color, no surface scum and a depth visibility of ≥ 30 cm. Less visibility indicates potential trouble with LODOS. Visibility of ≤ 15 cm is critical.

2. Low visibility in ponds due to dense phytoplankton is associated with high feeding levels.
3. In large lakes and reservoirs visibilities of ≥ 200 cm are preferred.

Liming

1. Properly limed ponds have fewer LODOS and related problems and less extreme pH swings in a day-night cycle. Pond water pH is acidic at night, especially at dawn, and alkaline during daylight, especially at mid-afternoon. Ideal pH range would be from about pH 6.5 to pH 8.5.
2. Lime is needed when total alkalinity of pond water is ≤ 20 mg/l. When applying lime, spread it evenly over the dry pond bottom or apply it evenly over the water surface so it will fall evenly over the bottom muds.
3. Liming of large lakes and reservoirs is usually not practical.

FISH PRODUCTION

Yields and Carrying Capacities

1. There are always limits to weight yields of fish that can be produced per volume of cage and per area of water environment where the cages are placed. The maximum yield that can be produced is called carrying capacity. However, the maximum yield is usually not practical because stress factors begin to negatively affect production before maximum weight is achieved. The weight that is more technologically practical and economical to produce is the optimum carrying capacity or optimum yield.
2. Maximum and optimum yields vary greatly because of many factors, including species and their life stages cultured, quality and quantity of feed, and biological, chemical, and physical characteristics of the water environment. Therefore, there are no standard maximum or optimum yield numbers, only approximations.
3. Maximum yields of ≥ 600 kg/m³ and optimum yields of ≥ 300 kg/m³ have been achieved in large infertile lakes and reservoirs, but optimum yields are more likely to be about 160 kg/m³ in ponds and about 200 kg/m³ in lakes and reservoirs.
4. Silver carp, silver-bighead hybrid carp, and other plankton filtering fishes grow well in cages without feeds in plankton rich (visibility < 100 cm) waters. Optimum silver-bighead hybrid carp yields of 90 kg/m³ LVHD cage and 1,300 kg/ha have been obtained in ponds with moderate to high densities of plankton as the only food source.

PROBLEM INDICATORS

Bio-Fouling

1. Water exchange between the cage and open water may be restricted by attachment and growth on the cage of a mass of living, bio-fouling organisms. The reduced water exchange is caused by reduction in the size of the size of mesh opening of the cage material.
2. Bio-fouling is a common problem in marine and some brackish waters but is not common in freshwater. Bio-fouling organisms must not be allowed to grow on cages. Algal growth can usually be controlled with shading by an opaque cage cover. In freshwater, common carp and most tilapias will feed on bio-fouling organisms as they develop. Tilapia may be stocked at 5-6/m³ in catfish cages to control bio-fouling. Barnacles and bivalves are especially difficult problems in marine environments. Bio-fouling may be brushed off cages, but this is difficult and stresses the fish. Chemical controls are not recommended.

Fish Health

1. Healthy fish, especially catfish, will seldom come near the water surface during daylight. However, they will surface and actively, even aggressively, take floating feed when trained on a routine feeding schedule. Unhealthy fish are more likely to be observed near the surface during daylight and are unlikely to take feed.
2. A few dead fish (2-3%) observed from 2 to 6 days after stocking or other handling are not unusual, and that is not an indication of disease. However, if the number is significantly greater or if dead fish continue to appear after 6 to 7 days, then disease is probable.
3. Caged fish on a routine feeding schedule will actively take feed at the time of feeding. If the proper amount of feed is being fed it will all be consumed within 2 to 5 min after feeding. When feeding actively declines and all feed is not consumed, disease and stress should be assumed.
4. Other indicators of disease are dead fish (usually floating), fish lazily swimming or "hanging" at the surface, "saddles" or bands around the middle of the body, light blotches or small white spots on the skin, sores, frayed fins, sunken or swollen eyes, and emaciated (skinny) bodies.
5. The incidence of disease is rare where healthy, disease-free fingerlings are stocked and good feeding and water quality management are practiced. However, some disease problems should be expected following periods of stress caused by handling and poor water quality.

LODOS

1. LODOS affects fish directly by suffocation and indirectly by causing stress that affects production performance. LODOS may cause disease and death.

2. LODOS conditions are caused by insufficient photosynthesis, plankton die-offs and overturns.
3. Aeration and flushing are management options for pond cage farmers. Lake and reservoir cage farmers may practically use mechanical means to push a current of open water through the cages, but this is a low probability, desperation solution.

Physical Loss of Fish

1. Predation and escapes are examples of physical losses of fish from cages. Mammals, birds and reptiles have been known to take living or dead fish from cages. Some minor observed losses have been to snakes and herons. Major losses have occurred through holes made by basking turtles to get dead fish, and by otters preying on live fish. Rodents are known to have cut through net cages above the waterline, probably to get feed. Fish losses to predation and escapes are usually simply controlled by covering the cages or other common sense methods.
2. Greatest potential for physical loss of fish from cages is to humans (poachers and vandals) who may, within a minute, cause the loss of an entire cage of fish.

SOME WORDS OF WISDOM

1. Marketing is perhaps the first thing a cage fish producer should think about and plan for when beginning cage fish culture. Usually cage fish producers have more market opportunities than non-cage producers.
2. Keep complete records of everything (numbers, dates, weights, costs, etc.) and make notes of important observations. Do not depend on memory for records and observations.
3. Make at least one visit every day to observe the fish, their feeding behavior, the color and general appearance of the water, etc. Get to know the total cage and water environment to know what is and what is not normal.
4. Fish farming is "crisis management." Plan ahead and know what to do in case of emergency, such as if:
 - a) The fish stop eating?
 - b) The fish show disease symptoms?
 - c) Bio-fouling organisms start growing on the cage?
 - d) The fish are "gasping" at the water surface?
 - e) A heavy thunderstorm occurs with strong wind and hard rain (conditions for "overturn")?
5. In lakes and reservoirs be especially mindful of water level fluctuations and draw-downs.