WATER HARVESTING AND AQUACULTURE
FOR RURAL DEVELOPMENT

INTRODUCTION TO INTENSIVE CAGE CULTURE OF WARMWATER FISH

INTERNATIONAL CENTER FOR AQUACULTURE
AND AQUATIC ENVIRONMENTS
AUBURN UNIVERSITY

INTRODUCTION

Cage culture of fish is a method of raising fish in containers enclosed on all sides and bottom by materials that hold the fish inside while permitting water exchange and waste removal into the surrounding water. Cages are constructed in a variety of shapes using materials such as bamboo or wooden slats and wire, nylon and other synthetic meshes. Support structures can hold cages on the water surface or suspended above the bottom of a body of water (Figure 1).

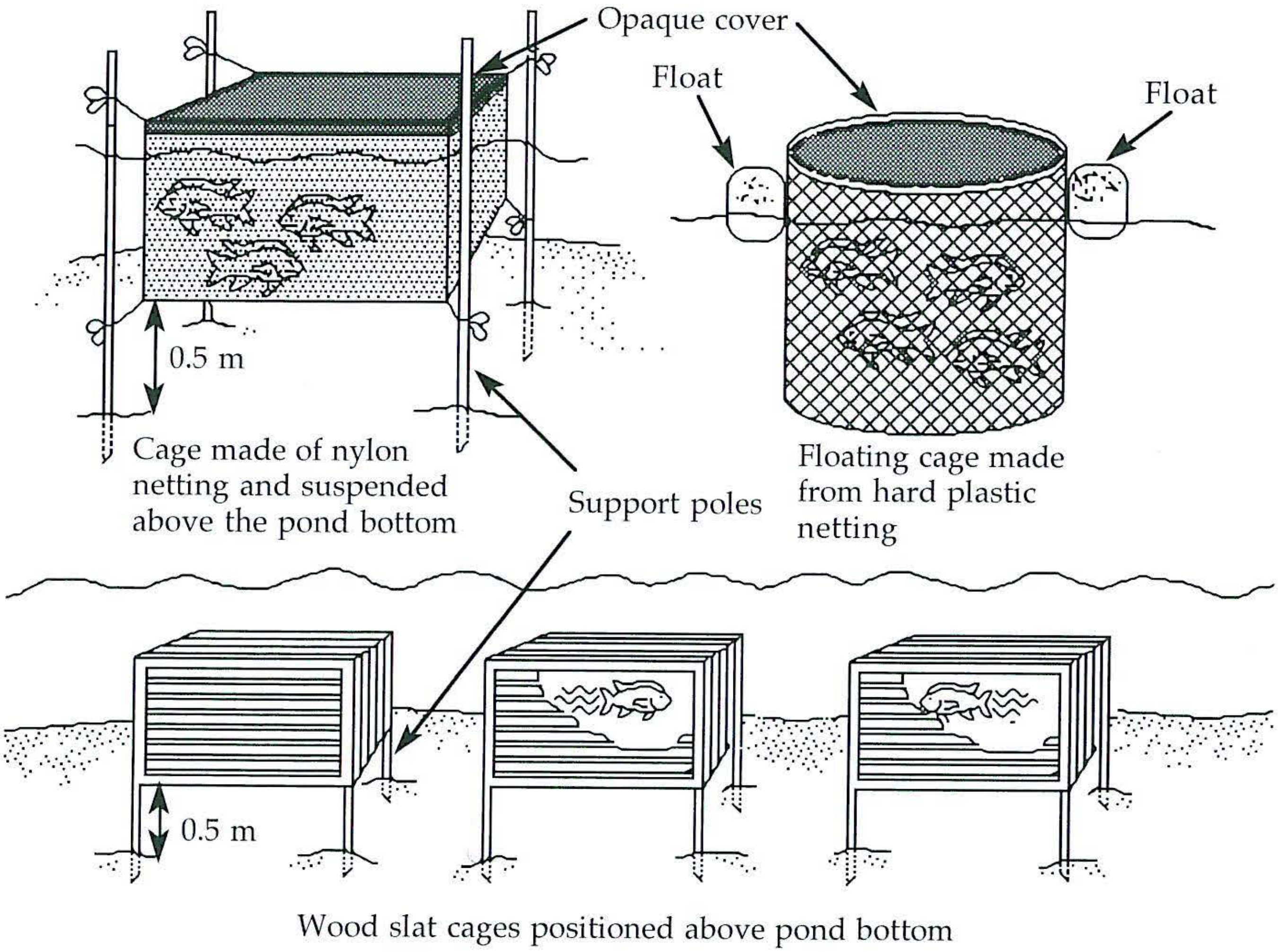

Figure 1: Examples of cages constructed from various materials and positioned above or on the bottom of the water body.

Cage culture was started by Southeast Asian fishermen to hold their fish catches alive for short periods of time. The intentional confinement of fish in cages to increase their size is a technology dating back to the early 1900s. Today cage culture is practiced in many regions of the world, and is a thriving industry in some areas. A detailed description of the culture methods used for each fish species cultured in cages is beyond the scope of this manual. However, the major considerations and guidelines for cage fish culture in ponds, lakes, and reservoirs will be addressed.

CAGE CONSTRUCTION AND POSITIONING

Cages range in size from 1-m^3 to several hundred m^3 and can be any shape, but rectangular, square or cylindrical shapes are typical. Small cages are more easily managed than large cages, and usually provide a higher economic return per unit volume. The following general guidelines may be helpful when considering cage culture:

1. Materials used for cage construction should:

   - be durable and strong, but lightweight
   - allow complete exchange of water volume every 30 to 60 seconds by using a minimum of 13-mm square mesh size
   - allow free passage of fish wastes
   - not stress or injure fish
   - be resistant to fouling
   - be inexpensive and readily available

2. Auxiliary cage equipment:

   - a completely or partially removable opaque cover to prevent fish from jumping out or predatory birds from getting in
   - floating feed box or ring cylinder with wire mesh cover extending 40 cm below and 20 cm above the water surface to retain floating feeds, or solid or fine mesh tray (covering 20 % of the cage bottom) with 5 to 15 cm raised sides if sinking feeds are used
   - steel rebar, PVC pipe or other rigid materials if a rigid frame is used to support the cage walls
   - floats
   - anchors
   - platforms/walkways

3. Cage positioning:

   - in open areas with good water circulation, but protected from strong currents and high waves
   - away from still or stagnant water where poor water quality may stress or kill fish.
   - with rows of cages spaced at least 2 m apart
   - in water deep enough that the cage bottom is at least 0.2 m (0.5 m preferred) above the bottom sediments
   - in easily accessible areas to facilitate routine maintenance and feeding

4. Security considerations:

   - place cages where they can be easily monitored
   - guards may be required if poaching is a serious consideration.

FISH STOCKING

The minimum recommended stocking density for common carp, tilapia, and catfish is 80 fish/m^3. A recommended maximum stock density for beginning farmers is the number of fish that will collectively weigh 150 kg/m^3 when the fish reach a predetermined harvest size (Schmittou, 1991). The smallest recommended fingerling size for stocking is 15 g. A 15-g fish will be retained by a 13-mm bar mesh net. Larger fish can also be stocked into cages. Survival rates in well-placed and well-managed cages are typically 98 to 100 %. Unless greater mortality is expected, no adjustment is needed to calculate stocking density.

An example of how to calculate the number of fish to stock per cage follows:

Assume that a farmer wants harvest fish weighing 500 g from a 1-m^3 cage.

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

For a farmer wishing to harvest fish averaging 200 g, the number of fish to stock would be:

$$\text{Number to stock} = \frac{150\ \text{kg/m}^3}{0.2\ \text{kg}} = 750\ \text{fish/m}^3$$

The carrying capacity of a body of water limits the weight of fish that can be cultured. Stocking so many fish that the carrying capacity is reached will result in increased stress, disease, and mortality, and reduced feed conversion efficiency, growth rate, and profit. Generally, 1,000-m^2 of water surface area is needed to support 400 kg of fish. A calculation can be used to determine the maximum number of fish which can be stocked into a cage(s) to assure that the weight does not reach the carrying capacity of the water body during culture.

$$\text{Maximum volume of cages (m}^3) = 2.6a^*$$

Where:

a = total surface area of water body (1,000s of m^2)

* The constant 2.6 is derived below

$$\frac{\dfrac{400\ \text{kg}}{1{,}000\ \text{m}^2\ \text{pond}}}{\dfrac{150\ \text{kg}}{\text{m}^3\ \text{cage}}}$$

Fingerling survival depends on many factors. Fish should not be stressed during the handling, transport and stocking to assure that they remain healthy. Water temperature affects fish mortality after stocking. Survival of catfish and carps is best when they are stocked at a water temperature of 15 °C or less. Tilapia survival is best when they are stocked at 20 to 22° C.

FEEDING FISH IN CAGES

Fish must be fed daily. Adequate supplies of good quality feed must be available. Nonfilter feeding fish confined in cages have limited access to natural pond foods and need a nutritionally complete diet. Simple feeding equipment may be manufactured to make feeding cages easier. Floating rings are used to retain floating feeds inside cages (Figure 2). Feeding trays may be built inside cages or placed on the cage floor to retain sinking pellets. Table 1 lists important considerations for feeding fish in cages.

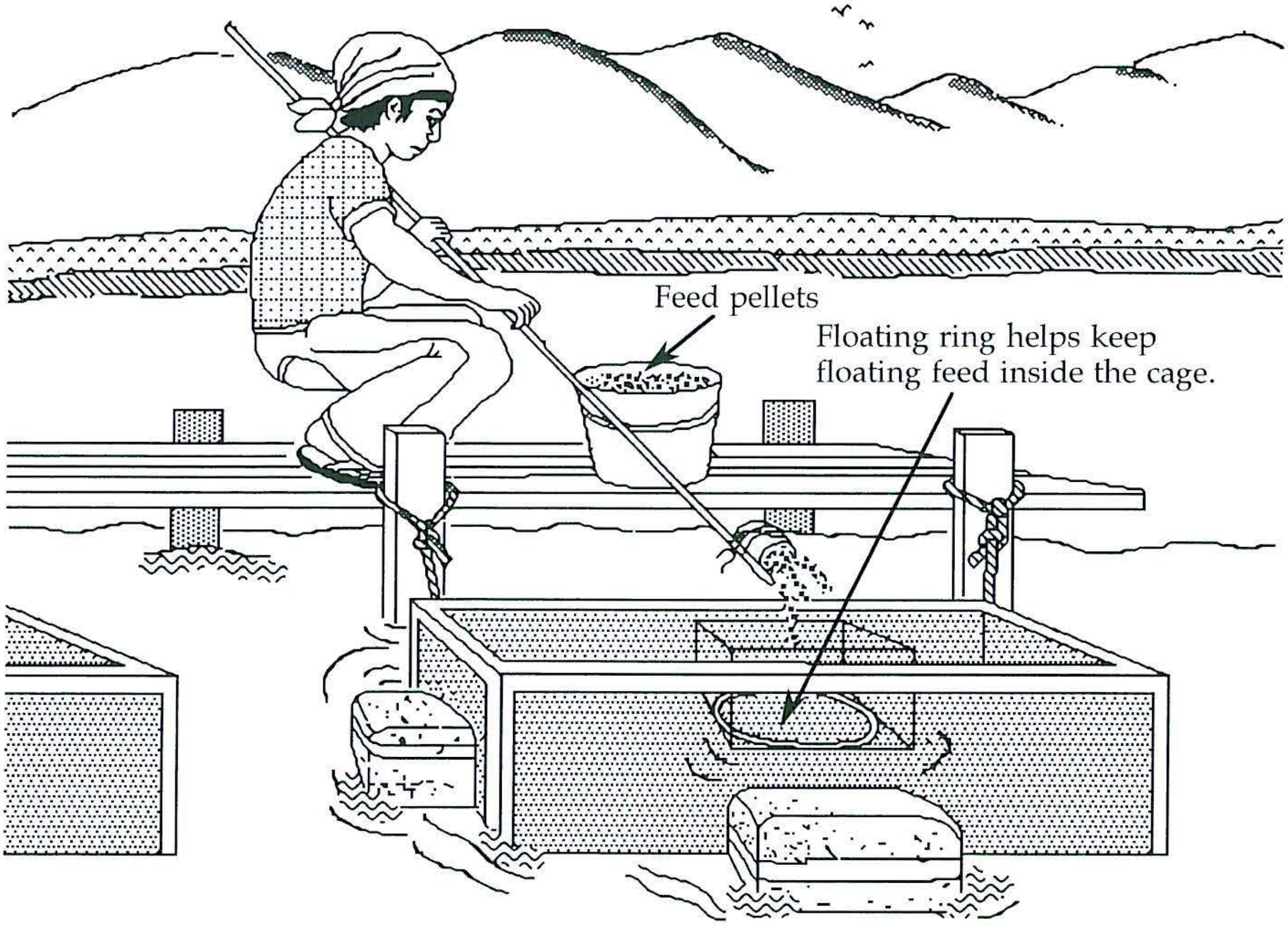

Figure 2: Feeding floating pellets with homemade equipment.

Feed should be used within 4 to 6 weeks of its manufacture date. It is best to purchase feed from reputable and established commercial feed manufacturers. Feeds may be produced by farmers using agricultural by-products. See *Feeding Your Fish,* in this series, for more information on formulating feeds.

Table 1: Considerations and recommendations for feeding fish in cages.

Consideration	Recommendation
1. daily feeding rate	- 3 % of fish body weight, readjusted weekly based on fish growth
2. feeding behavior	- feed should be consumed within 15 minutes
3. preferred feeding time	- 8:00 AM to 4:00 PM
4. feedings per day	- two, 6 to 8 hours apart
5. % crude protein in feed:	
catfishes	- 32 to 36 % with 7% from animal sources (typically fish meal)
carps and tilapias	- 28 to 30 % with 5% from animal sources (typically fish meal)
6. Feeding	

Maximum feed amount depends greatly on water quality. Without emergency aeration or water exchange, the feeding rate may range from 25 to 70 kg feed/day/hectare of water. With aeration and water exchange, the maximum range may be doubled or tripled. The following amounts are recommended as a rule-of-thumb.

maximum feed amount without emergency aeration to water body in which cages are located	
carps	- 27 kg feed/day/hectare of water
tilapias	- 37.5 kg feed/day/hectare of water
maximum feed amount with emergency aeration	
carps	- 60 kg feed/day/hectare of water
tilapias	- 80.5 kg feed/day/hectare of water
7 type of feed	- floating or sinking pellets

WATER QUALITY CONSIDERATIONS

Fish densely stocked into cages require feed in adequate quantity and quality to promote fish growth. When feed is provided, water exchange is needed to bring oxygen into the cage and to remove waste products generated by the fish as a result of feeding. Waste removal becomes more critical during times of the year when temperatures are high and water circulation from wind action is minimal. At such times, water in the area surrounding the cage can become depleted of oxygen. This typically results when uneaten feeds and fish wastes accumulate under cages; and oxygen consumption by bacterial decomposition of the wastes and the fish in the cages lower dissolved oxygen to critical levels.

Waste removal is aided by the following practices: 1) Use as large a mesh size as possible to facilitate water exchange. Place cages in areas where gentle breeze action can circulate water through the cage; 2) An exchange rate of 1 cage volume every 30 to 60 seconds is ideal. Place the broad side of a cage into the prevailing wind to aid water exchange; 3) Suspend cages so that the bottom rests at least 50 cm above the pond bottom; 4) Feed only as much as the fish will consume within 15 minutes. If fish do not consume the feed in 15 minutes or stop feeding, reduce or stop feeding until fish respond eagerly to the feed.

Biofouling of cage material can occur (Figure 3). Cage fouling is more of a problem in salt water, and less so ion brackish and fresh water. Biofouling is caused by organisms that attach themselves to the cage and restrict water exchange. Marine biofouling organisms include algae, oysters, clams, and barnacles. Special antifouling agents can be purchased and applied to cage surfaces prior to submersion in the water. These agents may be expensive and unavailable. In fresh water, some biological control may be effected by stocking 1 to 3 common carp or tilapia/m^3 of cage volume. These fish graze the cage mesh and can remove biofouling organisms inside the cage. Mechanical control may be effected by exchanging cages every 2-weeks, and drying the fouled cages in the sun. Cages made of flexible material facilitate this. The exterior of a cage may also be scraped manually every few days.

Figure 3: Biofouling organisms (*Bryozoan* colony) attached to cage.

FISH PRODUCTION IN CAGES

The weight of fish produced in cages depends on many factors including the fish species, stocking density, fish size at stocking, culture period, cage size, water quality, and feeds used. Reported yields can be misleading unless production details are provided. Numerous studies have been done with cages, and some yields and conditions are presented below.

Table 2: Fish production from 1-m3 cages in Indonesia.[a]

<u>Oligotrophic freshwater lake</u>[b]

Species	Stocking Density/m^3	Mean Stocking Size (g)	Culture Period (Days)	Yield (Kg)	Mean Harvest Size (g)
CC	140	450	40	88	628
CC	280	450	40	176	630
CC	560	450	40	337	602
CC	400	76	97	167	417
CC	400	55	160	204	514
CC	600	55	160	289	489
CC	400	25	183	149	396
CC	600	25	183	215	381

<u>Mesotrophic freshwater reservoir</u>[c]

Species	Stocking Density/m^3	Mean Stocking Size (g)	Culture Period (Days)	Yield (Kg)	Mean Harvest Size (g)
CC	200	102	100	99	495
CC	300	104	100	140	466
CC	400	105	100	180	451
RT	250	20	100	97	389
RT	375	22	100	134	357
RT	500	32	100	176	352

<u>Saltwater bay</u>[d]

Species	Stocking Density/m^3	Mean Stocking Size (g)	Culture Period (Days)	Yield (Kg)	Mean Harvest Size (g)
RT	250	15	90	50	221
RT	500	18	90	85	202
RT	750	14	90	101	165

<u>Brackishwater pond</u>[e]

Species	Stocking Density/m^3	Mean Stocking Size (g)	Culture Period (Days)	Yield (Kg)	Mean Harvest Size (g)
MF	75	33	75	11	191
MF	125	33	75	11	173
MF	175	33	75	17	167

<u>Legend of fish species</u>

CC = Common carp (<u>Cyprinus carpio</u>)
RT = Red tilapia
MF = Milkfish (<u>Chanos chanos</u>)

<u>Notes</u>

a Reproduced from Schmittou, 1991
b-d sinking pelleted feed of 28-30 % crude protein content
e no feeding

GLOSSARY OF TERMS

cage - a container enclosed on all sides and bottom by mesh materials that permit free exchange with the surrounding water.

carrying capacity - the total weight of fish that a body of water with defined conditions will support.

complete feed - a feed which satisfies all nutrient requirements of fish.

intensive culture - culture of fish stocked at a high density and fed agricultural by-products or pelleted feeds.

mesotrophic - having a moderate amount of dissolved nutrients.

oligotrophic - Deficient in nutrients, unstratified, and free of pollutants.

supplemental feed - a feed that does not completely satisfy nutritional requirements of fish, but which supplements naturally available food.

REFERENCES

Beveridge, M. 1987. Cage aquaculture. Fishing News Books Ltd. Farnham, Surrey, England.

Schmittou, H. 1991. Guidelines for Raising Principally Omnivorous Carps, Catfishes and Tilapias in Cages Suspended in Freshwater Ponds, Lakes and Reservoirs. In: Proceedings of the People's Republic of China Aquaculture and Feed Workshop. Akiyama, D., Editor. 1989. American Soybean Association, Singapore. P 24 - 42.

Funding for this series was provided by the United States Agency for International Development. Communication regarding this and other technical manuals on water harvesting and aquaculture should be addressed to:

Alex Bocek, Editor
International Center for Aquaculture
Swingle Hall
Auburn University, Alabama 36849-5419 USA

Suzanne Gray, Illustrator