



Cage culture in reservoirs

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History of Cage culture

- Earliest record – late 1800s – S.E. Asia – in the lakes and rivers of Kampuchea.
- ~1950s – Marine cages introduced by Kinki University in Japan for *Seriola quinqueradiata*.
- 1970s – Thailand – cage culture for sea bream (*Pagrus major*), grouper (*Epinephelus spp.*)
- 1980s – Malaysia – large scale grouper farming.
- Started in late 1970s – end of 1980s – Korea – olive flounder (*Paralichthys olivacens*) and black rockfish (*Sebastes schlegeli*).
- 1980s – Phillipines – groupers and milkfish in 1990s.

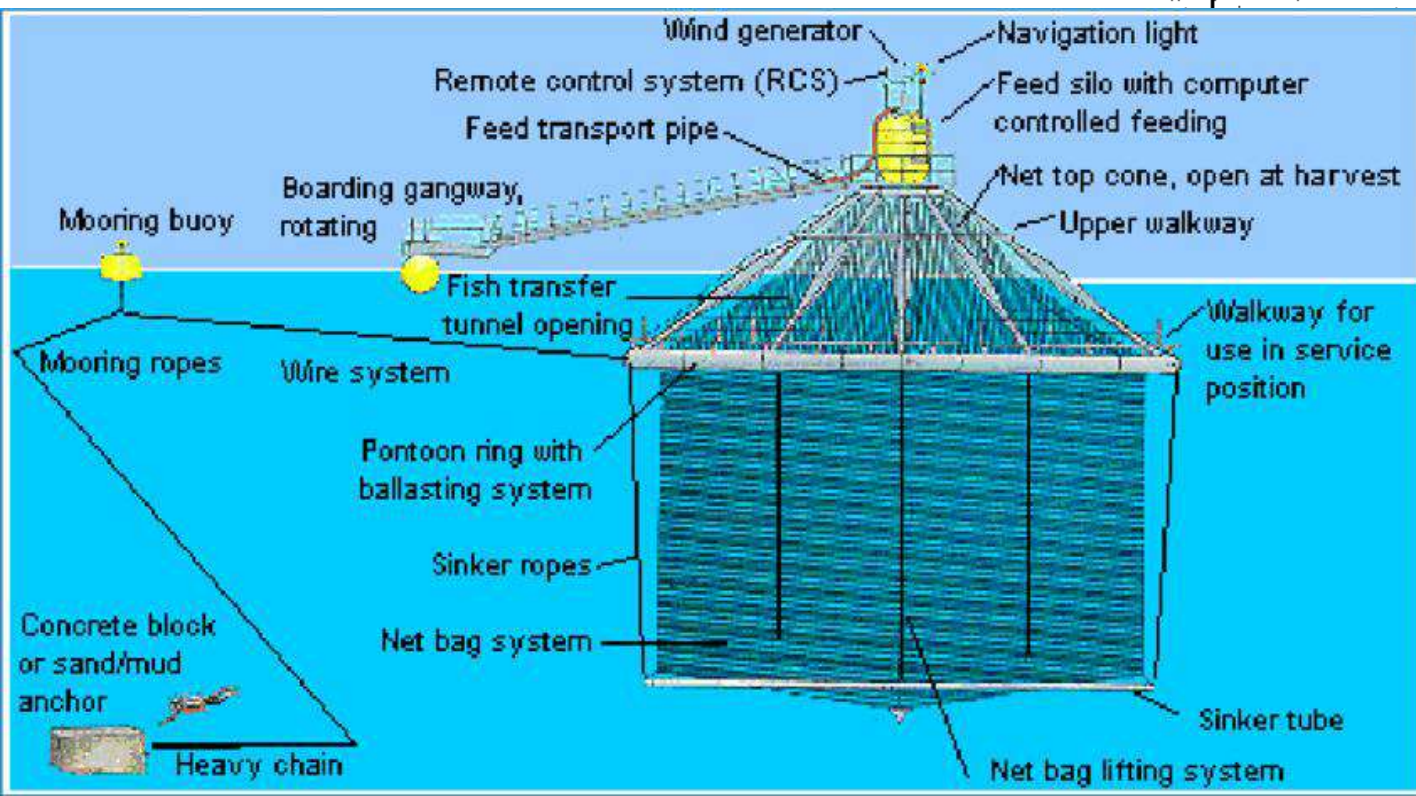
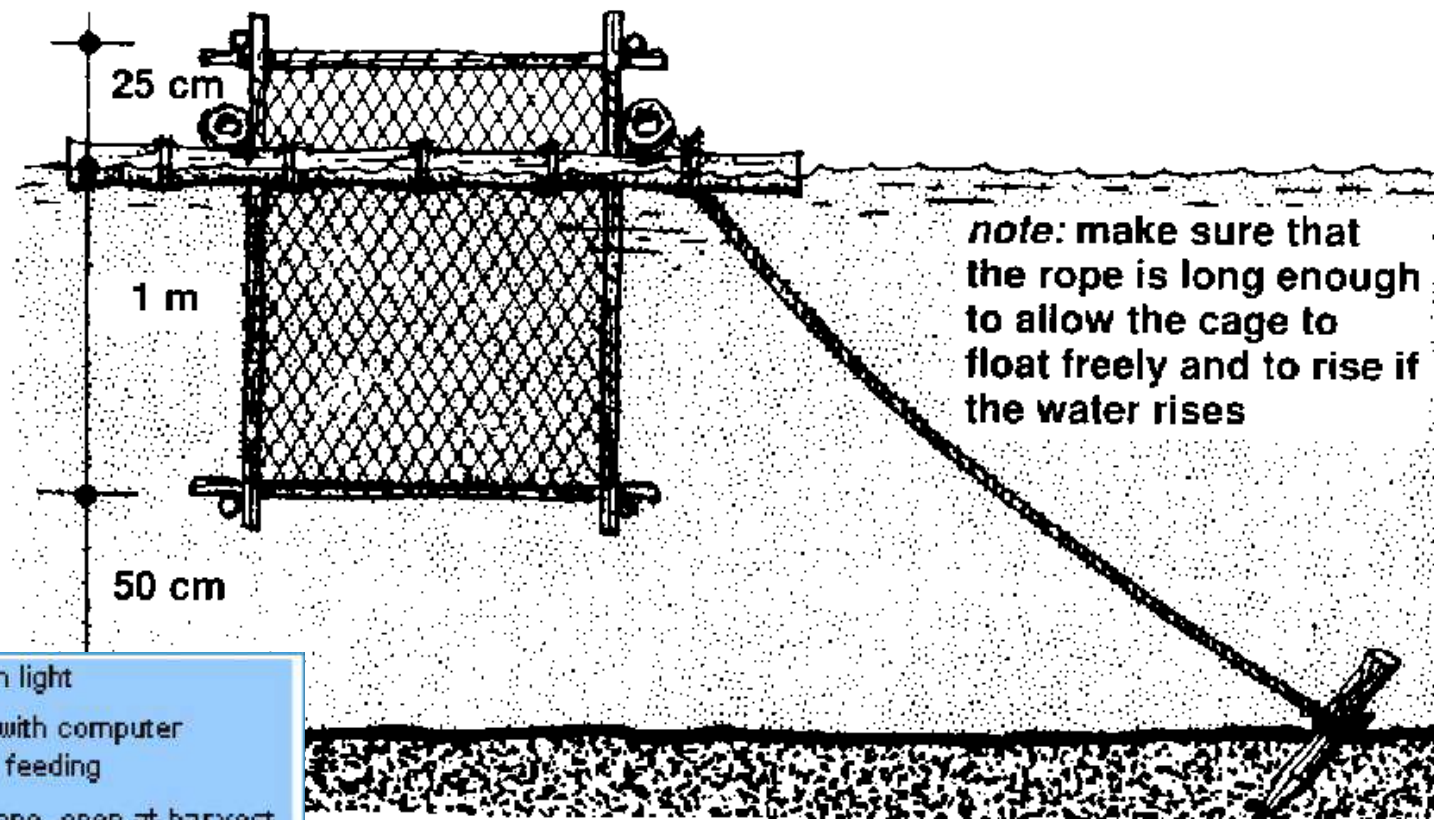
- Late 1950s – Norway – rainbow trout in freshwater system.
- Currently > 40% of Atlantic salmon of Norway is from cages.
- 1964 – USA.

Species predominance:

- Tilapia and Carp in Asia
- Salmonids in Europe and the Americas.

Types of cages

- Floating
- Submersible



Site selection

- Due to ecological reasons, cage culture in rivers is discouraged world over.
- Large, deep reservoirs and lakes need to be chosen for cage culture, leaving aside small and shallow water bodies for the following reasons:
 1. Small and shallow water bodies are very productive and usually suited for free-ranching as there is no constraint in harvesting the fishes.
 2. Predators are not a big problem in small and shallow water bodies.
 3. Such water bodies are suitable for practicing culture-based capture fisheries, managed on the basis of annual stocking and harvesting.
 4. Small and shallow waters are generally rich in nutrients and the sunlight penetrates down to the bottom resulting in high rate of primary production. Cage culture involves high input of nutrients in the form of feed. This coupled with the high rate of deposition of fish excretory matters result in high rate of nutrient input to the system causes eutrophication. This will lead to the disruption of natural ecosystem processes and causing irreparable damage to the system.
 5. Small reservoirs do not have sufficient depths for the cages to remain afloat during the lean season. If water level recedes and goes beneath the critical level, the crop will be destroyed.

Site selection

- Cage culture shall be allowed in water bodies having a surface area 1,000 ha or more at FRL [full reservoir level]. (Exception to this can be made only in case of 'very deep abandoned mines', which are less than 1000 ha in area, but too deep for practicing culture-based fisheries).
- Cage culture shall be allowed in reservoirs with an average depth of 10 m (Average depth is calculated as: Area in hectares divided by water holding capacity in m³).
- The cage site at the reservoir should have at least 10 m depth round the year.

Site selection – Depth and water quality guidelines

- The reservoir should have at least 10 metres of mean depth and the cage site needs a water depth of at least 10 metres round the year.
- A clearance of 6 metres will be always needed from the cage bottom to the floor of the water body.
- As the cage culture operations will tend to increase nutrient load, BOD and COD in the water bodies, care must be taken to pre-assess the water quality of the location.
- It needs to be ensured that the water body is either oligotrophic (low nutrient content) or mesotrophic (moderate nutrient content) before starting the cage culture.
- Indian reservoirs in general – oligo or mesotrophic.
- EIA is necessary in eutrophic waters.
- Cage culture should not be attempted in any water body having total phosphorous and total nitrogen concentration in the water in excess of 0.02 mg/L and 1.2 mg/L, respectively

Site selection

Sites to be avoided:

- 1) Places with turbulence or excessive wave/wind action
- 2) Bad water quality
- 3) Water bodies with obstruction and heavy weed infestation
- 4) Low depth
- 5) Difficult access from site and logistic considerations
- 6) Nearness to dense human habitation, dams, tourist spots, industries and polluting industries.
- 7) Natural fish breeding nurseries
- 8) Protected sites – reserves, holy sites etc.
- 9) Navigable areas

Site selection

- Potential sites: lakes, reservoirs, ponds, quarries, rivers and streams.
- Laws of the land for the use of 'public waters' must be considered.
- The surface area should be at least one half acre and preferably an acre or larger (but should not include weed infested areas of the pond).
- Water should be at least 6 feet deep over a sizable area, and most of the area should be more than 3 feet deep.
- The water body must have good water quality and should be located where prevailing winds blow across it.
- The water body should not have direct access by livestock or large numbers of livestock in the watershed.
- The water body should not have a highly erodible watershed or one that allows the accumulation of large amounts of organic debris.
- The water level of the water body should not fluctuate greatly (2 to 3 feet) during the summer.
- The pond should not have chronic problems with aquatic weeds, surface scums, overpopulations of wild fish, or oxygen depletion problems
- The waterbody should have an all-weather access road.

Material selection for cages

- Durable
- Flexible
- Non-corrosive
- Non-toxic
- Rustproof



- Wood
- Plastic
- Fibre
- Knotless Nylon mesh
- Polystyrene
- Mild Steel
- Galvanized Iron (GI)
- Poly vinyl chloride (PVC)
- HDPE

Design of cages

- Circular
- Rectangular
- Polygonal

Circular cages

- Makes the most efficient use of materials and thus lowest cost per unit volume.
- Most favourable surface/volume ratio = less material use = light weight = simplified mooring and floating system.
- Based on swimming behavior of fish, circular shapes are found to be better in terms of utilization of space.
- More resistant to dynamic stress which makes them better suited to less sheltered sites.
- It is best to use round frame because the forces are equal all around the circumference: polygonal or square frameworks will have large forces in the corners and eventually breakage in the construction will occur.

Polygonal or square cages

- Polygonal collars are better than square collar because there are more corners to share the total forces and the force in each corner is therefore reduced.
- square and rectangular cages have certain advantages that make them preferable in sheltered areas such as: Ease of construction. Possibility of producing large modular structures.

Relationship between characteristics of a site and the most suitable cage model

Characteristics of site	Cage model		
	Shape	Size	Volume
Sheltered	Square/rectangular	Large Modular structures possible	Large
Exposed	Circular/hexagonal	Small	Small
Good quality (high level O ₂)	All type suitable	Large	Large
Lower quality (low level O ₂)	Square/rectangular	Small Modular structures possible	Small

(Piccolotti and Lovatelli, 2013)

Size of Cages

- The resistance of a cage to dynamic stress caused by swell and currents is also determined by its dimension.
- The most of suitable size (just as that of volume) depends on the characteristic of the site.
- In sheltered sites, the cage size can be increased, while in exposed sites, small cages are more suitable.
- The cost per cubic meter of cage volume is reduced as the size increases. Thus, a cage of 100m^3 is less expensive than two cages of 50m^3 , while achieving the same production – saving on material used.
- However, with large cages the losses are greater if the net is torn accidentally. In addition, routine maintenance and certain management activities such as, net exchange or fish sorting can become more complicated.

Volume of the Cage

- The volume is determined by the dimension of the net which demarked the space in which the fish lives.
- The water exchange inside the cage is inversely proportional to the volume of the net and depends on the speed of the current and the distance between the opposite walls.
- The level of dissolved oxygen is strictly related to the water change by the current (the movement of the fish also have the influence on the flow of the water inside the cage).
- Therefore, all condition being equal, small cages make it possible to increase the stocking density considerably (e.g. 200 Kg/m³ of fish can be obtained in cage of 1m³ , but only 25 Kg/m³ in a cage of 100m³).
- On the other hand, small volume cages often induce a loss of feed, which is carried outside the cage by the current before the fish is able to consume to consume it and hence the feed conversion ratio is adversely affected.

Cage culture operation - stocking

- Operation involves – stocking, feeding and farm management
- STOCKING: depends on the carrying capacity of the cages and feeding habits of the cultured species.
- For species which are low in the food chain, stocking will also depend on primary and secondary productivity of the sites.
- Optimal stocking density – ensures optimum yield and low disease prevalence.

Cage culture operation - feeding

- Many biological, climatic, environmental and economic factors affect feeding of fish in the cages.
- Growth rate is affected by feeding intensity and feeding time.
- Each species varies in maximum food intake, feeding frequency, digestibility and conversion efficiency. These in turn affect the net yield, survival rates, size of fish and overall production from the cage.
- Trash fish is the main feed for yellowtail, grouper, bream, snapper and other carnivorous fish species cultured in marine cages.
- The shortage of trash fish is a major problem in many countries with large scale cage farming.

Cage culture operation - management

- For optimization of production at minimum cost.
- Efficient management depends on competence and efficiency of the farm operator.
- Includes feeding, stocking, minimizing loss due to diseases and predators, monitoring env parameters, and maintaining efficiency in technical facilities.
- Maintenance activities:
 - a) anti-corrosive paint to applied on GI/MS cages – prevents rusting.
 - b) Clean cages in 15-days interval – prevent clogging.
 - c) After emptying cage – sun dry, clean with jet-wash.
 - d) In-situ jet washing – dislodges pathogens – infects fish.
 - e) Have additional happas ready for emergencies
 - f) Record physico-chemical parameters regularly

Species cultured in Indian context

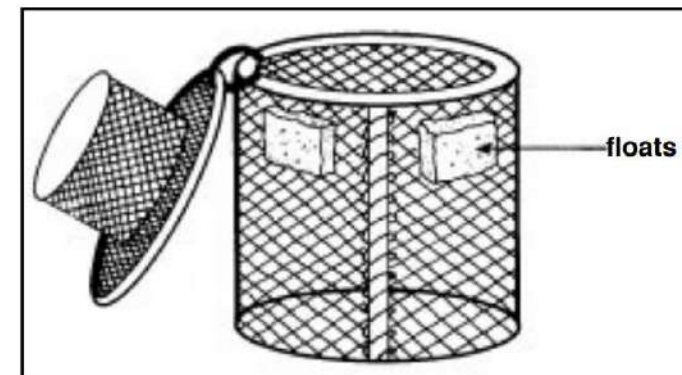
- Viable operation achieved with exotic pangasius (Sutchi Catfish), *Pangasianodon hypophthalmus*.
- Culture of GIFT tilapia, has been allowed subject to certain conditions such as: only all-male seed, sourced from authorized agencies.
- Tilapia culture has not picked up much.
- Adoption technology not available for indigenous species – sometimes advanced fingerlings of rohu (>10 cm) are stocked in the outer nets of cages @10-15 no/cage – browses and cleans the net.
- the following indigenous species need to be inducted into the cage culture domain: *Labeo bata*, *L. rohita* (Jayanti rohu), *Osteobrama belangeri* (pengba), *Ompok bimaculatus* (pabda), *Anabas testudineus* (koi), *Pangasius pangasius*, *Puntius sarana*, *Lates calcarifer* (bhetki), *Chanos chanos* (milk fish), *Etroplus suratensis*, *Chitala chitala* (featherback), Murrels (*Channa striata*, *C. marulius*), *Wallago attu* and shellfish *Macrobrachium rosenbergii*.

Reservoir stocking (not related to cage culture)

- Core species – Catla, Rohu, Mrigal (not for reservoir but for ranching)
- Other species that can be considered: *L. bata*, *L. calbasu*, *C. Idella*.
- Standard stock density for ranching – 1000 fingerlings/ ha
- Recommended size of fingerlings > 100 mm
- Stock density should not fall < 500/ ha in case of medium and large reservoirs, and above 2000/ ha for small reservoirs.
- Restrict stock density to 250 fingerlings/ ha in reservoirs where catfish is the major species.

Fabrication of cages

- The simplest cage design to construct is a cylindrical cage fashioned from 1/2-inch plastic mesh (Figure 2).
- The cylinder with netting is formed around two metal, PVC, polypropylene, or fiberglass hoops at the top and bottom of the cage. A third hoop is used to form the lid.
- Cages can be laced together with 18-gauge bell wire (plastic coated solid copper wire), stainless steel wire, hog rings, or black plastic cable ties (white cable ties should not be used as they deteriorate in sunlight).

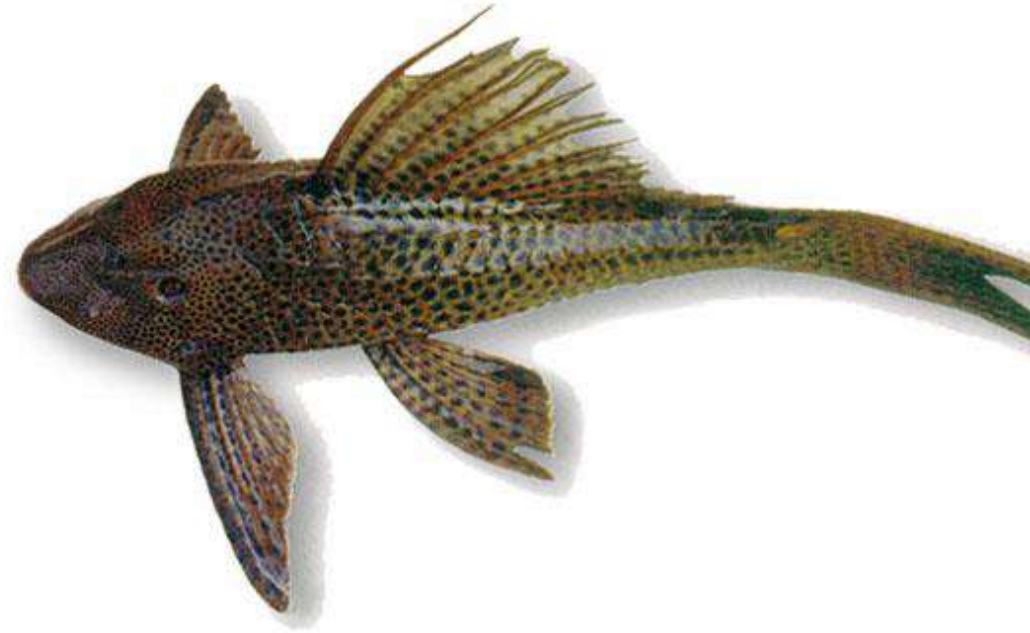


Fabrication of cages

- All cages need feeding rings to keep floating feed inside the cage.
- Feeding rings prevent floating feed from falling out of the cage.
- Feeding rings should be about 15 inches in width and should be attached to the cage so as to extend 3 inches above the water level with 12 inches extending into the water.
- Feeding rings can be attached to the cage or suspended from the lid.
- The feeding ring is prone to fouling because of its smaller mesh size.

Cage culture operation

- Cage culture can be extensive, semi-intensive, intensive.
- Intensity of operation depends on economics – availability of fingerlings, feed and market demand for the fish.
- Cage can be used as – hatcheries, nurseries, grow-out.
- Janitor fish species – *Hypostomus plecostomus* or *Pterygoplichthys spp.* – stocked at low densities to prevent algae from clogging nets.



Hatchery and nursery system

- These cages are similar to hapa
- Common carp breeding, using water hyacinth, has been achieved in Indian reservoirs.
- However, the hatching success and survival from larval stage to 40-50 g size still remains an outstanding issues – non availability of suitable zooplankton.
- Floating hatcheries and nurseries for tilapia as well developed and has high acceptance rate in tropical countries.

Single cage system

- These cages comprise of net bags suspended from a raft of bamboo or oil drums – can be connected to obtain a battery of cages
- Size can vary but most common size used is 6x4x4 m.
- Stocking density:

Pangasius (fry to fingerling)	500 – 700 nos./m ³
Pangasius grow-out	60-100 nos/m ³
IMC (50 mm suitable size)	Stock. Density not standardized
GIFT Tilapia	40.m ³ (nursery not permitted in reservoir)

Biculture cage system

- Two different species can be cultured simultaneously
- Common carp is raised in small-mesh cage floated above or placed within larger cages used for rearing tilapia.
- Low FCR obtained because – Tilapia browsed on fouling organisms and algae – kept nets clean – better water exchange and food availability for common carp.
- Practiced in Saguling reservoir, Indonesia
- Inner cage = 7x7x3m with 1.5 cm mesh
- Outer mesh = 7x7x3.5-4.0m (50-100 cm headspace for tilapia)

Advantages of Cage Culture:

Following are the advantages of cage culture when compared to other methods of fish culture:

- (1) It requires less investment.
- (2) Its installation is easy.
- (3) Since it covers only a fraction of the pond, the remaining part can be used in the normal way.
- (4) It provides opportunity for controlled culture of choice.
- (5) Inspection of fishes and their feeding is much easier.
- (6) Treatment of disease is much simple than that of pond culture.
- (7) In emergencies it can be removed from one place to another.
- (8) Since the cage is meshed, the fishes inside have less chances of being attacked by predators.
- (9) Harvesting is very simple.
- (10) The number of fish required at a particular time can be harvested and in this way it helps to maintain the non-seasonal supply of the fish.
- (11) It is economical as compared to other methods of fish culture except fish-culture in running water.
- (12) Fish tastes much better than the fish reared in ponds. Condition factor is also better.

Disadvantages:

- (1) Pond fish can make use of naturally occurring food, while cage grown fish only have a limited access natural food since they cannot forage on their own. Cage grown fish therefore needs to be fed by the farmer to a much higher extent. The food that is given to the cage grown fish also has to be nutritionally complete, e.g. contain proper amounts of all necessary vitamins and minerals.
- (2) During feeding a good amount of food passes out through the mesh, hence there occurs enough loss of food. Moreover the fishes are to be fed many times a day.
- (3) In certain seasons, especially summer the oxygen concentration decreases. The fishes which are free in ponds come to the surface layer of water, as the surface water always remains saturated with oxygen. But the caged fish do not have enough water surfaces available to them hence the chance of caged fish suffering mortality due to suffocation is more.
- (4) Predators can be attracted to the cages and for that additional protection has to be provided such as predator nets
- (5) Poaching is easier
- (6) Marine cages face problems like fouling and is more expensive
- (7) Storms can damage the cages.
- (8) When cages are installed indiscriminately, its impact on environment and biodiversity is adverse and it will have influence on current flow and increase local sedimentation
- (9) Since cages occupy open water sources, it may affect navigation in the area, or reduce landscape value of that area and are vulnerable to pollution from any source.

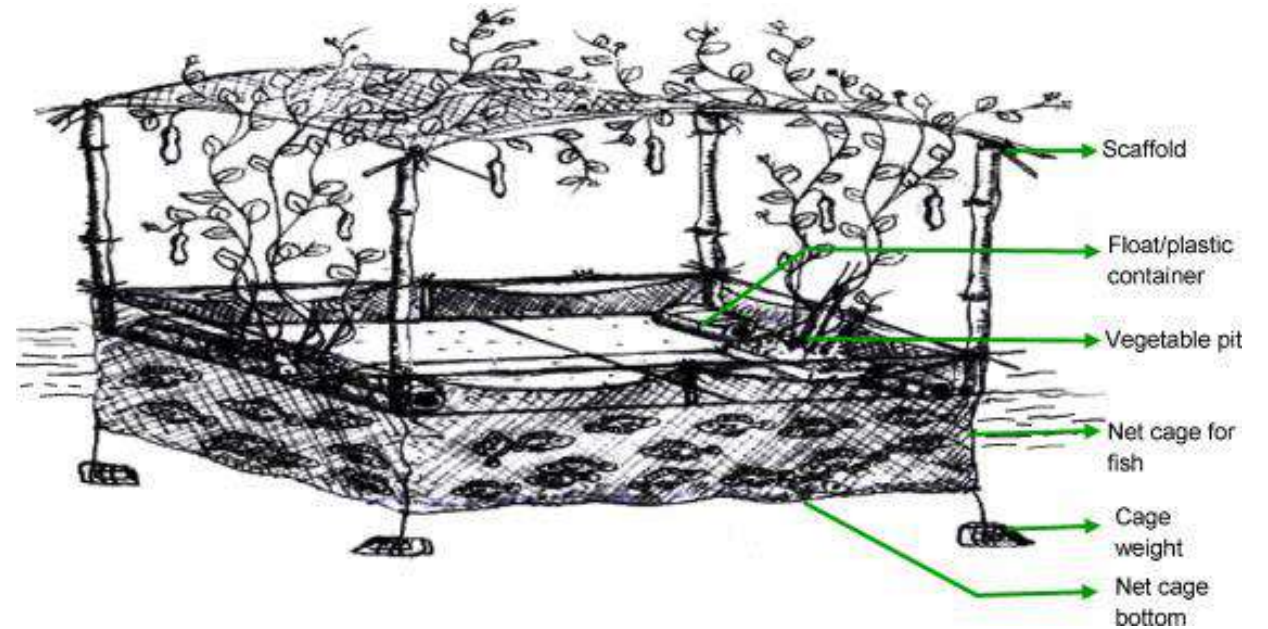
Integration of Cage culture with other systems

Integrated Floating Cage Aquageoponics System (IFCAS) :

- an aquaculture-horticulture based on the concept of integrated farming system approach firstly in Bangladesh in 2013 to produce fish and vegetables in floating condition where waste materials (fish feces and unused feed) from fish culture dissolved in the pond water and settled on the bottom mud are used for vegetables production.
- Soil is used as a medium instead of conventional media such as hydroton, pebbles, and sponges.
- The concept of IFCAS was developed by Dr. M. Mahfujul Haque (Ripon), Professor, Department of Aquaculture, BAU.

Integrated Floating Cage Aquageoponics System (IFCAS) :

- A 9 m² rectangular iron-bar made structure is constructed, having four concave grooves in its four corners for holding floats of plastic drums.
- The whole bottom of the structure is surrounded by a rectangular nylon net cage with the dimensions of length-3.66 m × width-2.44 m × depth-1.25 m.
- Under the four corners and middle points of the net, half-brick weights are hung to ensure that the net retained a rectangular structure under the water.
- In the middle of both widths of IFCAS, two pits filled with dried pond mud of the same pond are used as medium for vegetable plantation.
- On the top of the structure, a scaffold was made using split bamboo and net for vegetables to climb on.



Integrated Floating Cage Aquageoponics System (IFCAS) :

- Monosex Tilapia of 100 fry per cubic meter.
- For vegetables, cucumber, bean, bitter melon, Asian spinach etc. are recommended.
- Tilapia production of 31 kg and 52 kg per 9 m² were found within 120 days of period in the IFCAS placed heavily shaded and moderately-shaded ponds, respectively.

IFACS production

Growth and production	Initial weight (g) of fish	Final weight (g) of fish		T-test <i>p</i> - value	Culture period (no. of months)
		HSP (<i>n</i> = 5)	MSP (<i>n</i> = 4)		
Individual growth (mean ± SE)					
Tilapia in IFCAS (g)	0.73	76.2 ± 8.3	112.3 ± 37.9	0.002*	4
Catla in pond (g)	3.36	373.4 ± 122.23	409.6 ± 121.9	0.151	5
Rohu in pond (g)	2.37	188.1 ± 22.9	235.1 ± 41.2	0.030*	5
Mrigal in pond (g)	2.54	175.0 ± 26.8	220.1 ± 75.8	0.010*	5
Common carp in pond (g)	3.00	470.0 ± 3.2	390.4 ± 80.2	0.021*	5
Stinging catfish in pond (g)	0.60	75.5 ± 6.3	–	–	5
Total production of fish					
Tilapia in IFCAS (kg 9 m ⁻² 4 months ⁻¹)		31.2 ± 4.4	52.2 ± 25.9	0.003*	4
Carp in pond (kg ha ⁻¹ 5 months ⁻¹)		2,470.8 ± 325.9	2,957.2 ± 754.2	0.045*	5
Stinging catfish in pond (kg ha ⁻¹ 5 months ⁻¹)		64.8 ± 12.5	–		5
Vegetable production in IFCAS					
Vegetable production (kg 9 m ⁻² 4 months ⁻¹)		13.1 ± 2.4	16.8 ± 3.5	0.201	5