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Guidelines for Cage Culture in Inland Open Water Bodies of India

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1. Background

Cage aquaculture, though relatively new to the inland aquaculture scenario of the country, brings in new opportunities for optimizing fish production from the reservoirs and lakes, and also developing new skills among fishers and entrepreneurs to enhance their earnings. However, unplanned expansion of any activity can lead to adverse impacts in terms of environmental integrity and social equity. Recognizing this, a 'National Level Committee to Develop Guidelines for Cage Culture in Inland Open Waters' (NCGCC) was constituted on 25 April 2016 with a mandate *(a) to assess the potential of this culture system to contribute to increased production, employment, income generation and other benefits, (b) to assess the possible environmental and socio-economic impact, (c) to suggest precautions to be taken, and (d) to suggest the modes of propagating and scaling up of this technology to optimize benefits on a sustainable manner*.

The Committee in its first meeting held at Hyderabad on 14 June 2016, noted a glaring lack of data required for developing such guidelines, especially with regard to the environmental and social impact of cage culture activities. Nevertheless, it has resolved to formulate guidelines by making use of the available information at Institutes and also utilizing the secondary information sourced from the public domain. Although some research projects have been initiated to assess the environmental impact of cage culture, it would take some time before these efforts yield any meaningful results. Therefore, the Committee decided to develop advice on environmental impacts through an intensive effort to gather and process the information through a brainstorming by all known experts on the subject and to finalize the guidelines in six months. In the meantime, a need was felt to develop an interim set of advice making use of the available knowledge on the subject. Responding to this need, the Committee met on 30 July 2016 at the ICAR-Central Inland Fisheries Research Institute, the Institute where most of the research on cage culture has taken place. This report is the outcome of the deliberations made by the experts on the subject and the members of the National Level Committee to bring out an interim set of guidelines.

2. Objectives

The main objective of this document is to inform the national efforts being made to promote cage culture in the inland open water bodies like reservoirs and floodplain wetlands in the country, which inter alia advises how to leverage cage culture:

1) to augment fish production from lakes and reservoirs in a responsible manner, without affecting the livelihood of the traditional/local fishing communities;
2) toincrease per capita fish protein availability in the country;
3) to enhance the income and livelihood security of the fishers depending on inland fisheries resources; and
4) to ensure that the growth of aquaculture is:
    a) inclusive and sustainable,
    b) in harmony with principles of ecological integrity and natural resource conservation, and
    c) not in conflict with the genuine interests of other users of the water and land resources.

3. Purpose, Scope and Coverage

The guidelines contained in this document are addressed to all stakeholders including, Farmers, SHGs, Cooperative Societies, Other community organizations, Business Process Development Facilitators (BDFs), Farmer Producer Organizations (FPOs), Fisheries Departments of the States, Department of Animal Husbandry Dairying and Fisheries, Government of India and its Institutes, Research Organizations, Environmentalists.

At present, India does not have an umbrella agency that oversees/regulates freshwater aquaculture activities or implements Guidelines/ Best Management Practices (BMPs). Equally glaring is the lack of a uniform policy across the country that governs freshwater aquaculture. Thus, there is no scope for these guidelines to be readily implemented at this stage. However, efforts are on to put in place some policy and a regulatory framework. For instance, a draft 'Policy Framework for Aquaculture Development in India' was submitted by the Central Marine Fisheries Research Institute to the Department of Animal Husbandry Dairying and Fisheriesin 2014. This draft policy paper, though focussed heavily on mariculture, lays down the basic structure for a national level policy on aquaculture and proposes a 'District Level Task Force' to implement Guidelines and BMPs. Thus, despite the absence of any scope for direct application, these guidelines can be useful to those who will formulate aquaculture policies in future. In any case, the present guidelines can (a) guide the Departments/Agencies of the State and Central Governments in formulating development plans based on cage culture, (b) inform policies to be framed in future, and (c) guide farmers and entrepreneurs for practicing responsible cage culture in the country and (d) advise the District Level Task Force (as proposed in the draft policy).

Aspects covered under this document are: (1) Relevance and scope for cage culture in inland open waters, (2) Definition of cage and cage culture, (3) Cage size, shape and materials, (4) Site selection, (5) Cage maintenance, (6) Species selection, (7) Stocking density, (8) Feed and Feeding and FCR, (9) Fish health monitoring, (10) Safety measures, (11) Market, Post-harvest facilities and infrastructure, (12) Environmental precautions and impact assessment, (13) Carrying capacity, (14) Ownership, (15) Beneficiaries, (16) Governance, (17) and (18) Social relevance.

4. Relevance and Scope for Cage Culture in Inland Open Waters

During the last five decades, contribution of marine fish in the total production of the country has decreased from 71% in 1950s to 35% during 2014-15 (www.dahd.nic.in) with a corresponding increase in inland fish production. This shift in catch structure in favour of the inland segment is attributable to the growth of inland aquaculture, as opposed to the sole dependence of capture fisheries in the marine counterpart. In view of the dwindling production from natural waters, both inland and marine, any substantial increase in production has to come either from inland aquaculture or mariculture. Inland aquaculture presently contributes 4.4 million tonnes (in 2014) of fish annually (FAO-SOFIA, 2016); with the three Indian major carps *viz.,* catla (*Catla catla)*, rohu (*Labeo rohita)* and mrigal (*Cirrhinus mrigala)* constituting 87% of the production. Several variants of carp culture such as wastewater-recycled culture, integrated agriculture aquaculture (IAA) and many short-term culture practices are also available. However, freshwater aquaculture in India by and large still centres on pond-based systems.

Considering the ever-increasing and often conflicting cross-sectoral demands for water and land, there are limitations for growth in pond-based aquaculture. In this context, culture of fish in enclosures such as cages and pens installed in open water bodies offer scope for increasing production obviating the need for more land-based fish farms. Considering India's rich and varied open water resources like reservoirs, lakes and floodplain wetlands, enormous scope exists to increase production through enclosure aquaculture. Utilizing a modest fraction of their surface area, large and medium reservoirs can contribute a substantial quantity of fish to the total inland fish production basket. Although cage culture has not yet reached the desired commercial proportions capable of making any impact on the production figures, it is growing at a very fast pace giving hopes and also causing some concern.

India has 3.15 million ha of reservoirs and more than 5.0 lakh ha of floodplain wetlands (*beels, jheels, mauns, pats, etc*.) spread across the numerous river basins in the country. The present fish yield from reservoirs is low, to the tune of about 82 kg/ha (Jha, *et al.,* 2013), in spite of their high production potential (500 kg/ha, 250 kg/ha and 100 kg/ha in small, medium and large reservoirs, respectively). Similar is the case with floodplain wetlands, where the present yield has been estimated at 400-800 kg/ha, against the production potential of 1500-2500 kg/ha (Sugunan and Sinha, 2001). Harvesting is a major problem in most of the reservoirs and lakes in the country as most of them are either weed-choked or having obstructions in the form of boulders or tree stumps limiting operation of many a fishing gear. Presence of predators often results in high natural mortality of stocked fishes causing low productivity (Sugunan, 2000). This, coupled with poor utilization of all food niches available in these ecosystems in the absence of efficient fish grazers, is mainly responsible for low fish yield from these ecosystems. It is prudent, therefore, to explore alternate production tools to augment fish yield. Thus, enclosure culture systems have a definite role to play in augmenting fish production from inland open waters in India especially the reservoirs and floodplain lakes. These can overcome many production constraints in lakes and reservoirs by maintaining a captive stock, growing it on artificial feeds, protecting it from predators and enabling harvesting at will.

It has now been established beyond doubt that a major reason for the low productivity of Indian reservoirs is poor stocking compliance. Small and shallow reservoirs and lakes are managed on the principle of culture-based fisheries and therefore need to be stocked with advance fingerlings in appropriate numbers in order to get the desired production level. According to one estimate, >3000 million fingerlings of size 80-100 mm are required annually to stock reservoirs alone in India (Jha, *et al*., 2013). But, due to non-availability of advanced fingerlings, vast majority of Indian reservoirs remain understocked. Available land-based nurseries are inadequate to meet the huge demand that emanates from the culture-based fisheries of reservoirs. Pens and cages erected in reservoirs can be effectively used as nurseries to raise stocking material to obviate the necessity of constructing land-based nurseries which are cost-intensive. Studies conducted in many States across the country have shown that *in situ* production of fingerlings has resulted in better stocking compliance and resultant high yields (Sugunan and Katiha, 2004).

Advantages of enclosed culture systems in inland fisheries can be summarised as:

- Augmenting fish yield by optimizing the use of all available water area
- Raising fingerlings in large numbers for stocking in a cost effective way

- Optimization of trophic structure and functions to the advantage of fish production
- Effective utilization of weed-choked water bodies and those with obstructions like tree stumps and boulders, where harvesting of wild fish is difficult
- Reducing pressure on land for farms and nurseries
- Scope to keep a captive stock within the open water bodies allowing rapid, sure, complete and easy harvesting
- Direct and easy observation of stock for feeding, growth and general health
- Considerable indirect employment opportunities.

5. Cage Culture - Definitions

Cage is an enclosed space to rear organisms in water that maintains free exchange of water with the surrounding water body. 'Pens' are essentially portions of a water body cordoned off by erecting a fence like structure. Usually pens are enclosed portions of the lake margin, with fencing on three sides; the free fourth side being contiguous with the land. But, pen can also be away from the shore with fencing on all the four sides. The main difference between a pen and a cage is: pen bottom is never covered so that the soil water interface of the water body is not compromised. Enclosure aquaculture in the context of inland fisheries in India refers to both 'cage culture' and 'pen culture'. *This document deals exclusively with cage culture.*

6. Shape of Cages and Cage Materials to be Used

The cages are generally enclosed on all sides, except for leaving an opening at the top for feeding and handling the stock. They can be positioned at the bottom, middle or surface of the water column, but floating cages are very popular and easy to manage. Cages are of many shapes (round, square or rectangular). While round cages with a cylindrical net, supported by circle-shaped support frames, are extensively used for sea cage culture in India, cube-shaped, rectangular/square cages are used in reservoirs. Both round and rectangular cages are equally good from production point of view and their choice is mainly based on other considerations such as endurance (against turbulence), life, cost, availability of materials, convenience in assembling and transporting the components. However, it must be kept in mind that it is not easy to mobilize floating cranes and other logistic support for moving and installing huge structures in inland water bodies. Round cages are considered more suitable for choppy waters with wave- and wind-driven turbulence.

Size of a cage for fish culture in reservoirs can vary, but often multiple units are installed as a battery of cages with catwalks for easy access to the fish stock and floating huts. However, from operational and planning purposes, a cage with the dimensions: 6m (length) x 4m (width) x 4m (height) is considered as a standard unit and a battery comprises 6, 12 or 24 such cages, as per requirement. The cages in a battery are arranged in caterpillar design for better exchange of water thereby facilitating relatively high dissolved oxygen.

Durable and stable cage materials are essential for achieving better results. A cage comprises hard frames as support and nylon nettings as cage body. It is desirable to have environment-friendly, HACCP (Hazard Analysis and Critical Control Points) protocol compliant, rust-free materials for cage fabrication. Commonly used materials for cage frames are bamboos, mild steel (MS), galvanized iron (GI), poly-vinyl chloride (PVC) and virgin-grade HDPE (High Density

Polyethylene) (for runner-based & pontoon-based frames). The bamboo based frames are not recommended for commercial cage fish farming due to their poor longevity and strength to withstand turbulence

Knotless nylon nets are recommended for cage fabrication. The net mesh size recommended for rearing fry of *Pangasianodon hypophthalmus* is 10 to 12 mm and that for fingerling to marketable size is 20 to 30 mm. (In case of IMC, the mesh size should be 5 mm for fry and 10 mm for fingerling). Protective net may be put above the cage to avoid crop loss due to predation by birds (Table 1).

Table I. Recommended Cage Net specifications for culture of *Pangasianodon hypophthalmus*

Type of Nets	Specification (Ply)	*Mesh Size (mm)
Fingerling Growing Nets (knotless)	10-12	10-15
Grow-out Nets (knotless)	20-30	30-40
Predator or Outer Nets	25-30	35-40
Bird Protection Nets	18-20	60-80

*Mesh Bar (knot to knot) is half the length of mesh size (stretched mesh)

Separate cages are needed for nursery rearing and grow-outs. Normally, 30% of the cages in a battery are earmarked for *in situ* rearing of fingerlings (stocking materials); the rest being grow-out cages. Special care is needed on mooring/anchoring of the cage structure to avoid displacement or damage to the structure. Anchoring needs to be done diagonally opposite at the four corners of the cage structure by providing heavy sinkers such as anchors or black stones having a dimension of 0.5 m x 1.0 m (not less than 40 kg in weight) tied with strong nylon rope.

7. Site Selection

7.1 Selection of Water Body

Due to ecological reasons, cage culture in rivers is discouraged world over. In India, the riverine ecosystems are already under severe stress resulting in habitat loss/degradation due to a number of reasons such as dams, water abstraction, low flows, river training and pollution from industrial, domestic and agricultural runoff. Cage culture in a water-starved stream will add further stress to the ecosystem and therefore cage culture is not recommended in rivers. Subject to other conditions, it can be practiced in estuaries, lagoons, lakes, and large/medium reservoirs. 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.
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.

Therefore:

- *Cage culture shall be allowed in water bodies having a surface area 1,000 ha or more at FRL. (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, subject to all other conditions prescribed in this document).*
- *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 m^3).*
- *The cage site at the reservoir should have at least 10 m depth round the year.*

7.2 Site Selection

Criteria for site selection are based on safety of the location and smooth culture operations avoiding or minimising user conflicts. Thus, the sites to be avoided are: (1) places with turbulence and excessive wave/wind action, (2) bad water quality, (3) water bodies with obstructions and heavy weed infestation, (4) low depth, (5) difficult to access the site and logistic considerations and (6) nearness to dense human habitation, dams, tourist spots, industries and polluting industries. Areas of fish nursery and breeding grounds, sensitive areas like wildlife habitat including birds nesting, socio-culturally important areas like pilgrimage centres, water bodies for public use like drinking water, cleaning, navigation, etc, and protected aquatic reserves, sanctuaries, etc. are also to be avoided. The ideal locations for siting cages in large and medium reservoirs are the protected bays/coves to avoid damage due to strong wind action. However, some mild turbulence always helps exchange of metabolites and nutrients between the cage and outside environment.

By using these basic criteria, water bodies or specific locations within a water body can be chosen for cage culture. This information can be included in a map to be prepared at district and State level. The State Department of Fisheries should take initiatives of their own to select the suitable reservoirs and the sites therein for cage fish farming and draw-up maps in GIS platform to facilitate easy planning. However, if necessary they can take the advice of experts from the concerned ICAR and Central Institutes.

7.3 Depth and Water Quality

Depth is an important criterion for selecting the reservoir and also the cage site. 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. Excessive nutrient load from cage culture inputs, especially feeds can create eutrophic conditions with disastrous consequences to the ecosystem. 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. Although generally, Indian reservoirs are either mesotrophic or oligotrophic in nature, those water bodies receiving effluents or drained by rich catchments can show eutrophic tendencies. If cage culture is practiced in such eutrophic reservoirs, the leftover feed and the metabolic wastes from the stock can cause eutrophication. Therefore, it is necessary to conduct an Environment Impact Assessment (EIA) before cages are installed in reservoirs. The ICAR research Institutes have the capacity to make rapid EIAs. Estimation of chlorophyll, nutrients (nitrates and phosphates) and Secchi Disc transparency can give sufficient clue to the trophic status of a water body. *In any case, 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.*

8. Cage Maintenance

Anti-corrosive paint should be applied to GI/MS cages to prevent rusting and to increase the durability. Cage should be cleaned at 15-days interval to avoid net clogging. After shifting the stock to another cage, each cage is taken out, sun-dried and cleaned thoroughly by scrubbing/ water-jet wash to remove debris and fowling organisms. *In situ* cleaning using water jets is not advised as it will dislodge the pathogenic organisms throwing them into cages to infect the fish. Additional *hapa*s/nets may be maintained for this purpose or to meet other emergency situation. The physico-chemical parameters of water should be recorded regularly as a part of water quality monitoring.

9. Species

At the moment economically viable cage culture is practiced in inland water bodies of India by growing the exotic pangasius (Sutchi Catfish), *Pangasianodon hypophthalmus*. Culture of another exotic species *viz.,* GIFT tilapia, a genetically improved strain of *Oreochromis niloticus* has been allowed subject to certain conditions such as: only all-male seed, sourced from authorized agencies can be used. However, culture of tilapia has not picked up in any appreciable manner. In the absence of any adoptable technology to culture indigenous species, culture of exotic pangasius and GIFT tilapia certified/supplied by authorized agencies are allowed. However, cage culture of more species drawn from the indigenous species-pool needs to be encouraged at all levels. Depending on just one or two species will be unsustainable in the long run and the high density culture practice of exotic pangaisus can invite major disease issues in future. Considering the consistent demand for species of high economic and nutritive value, coupled with the regional preference (for some species), 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*. At the present level of technology, cage culture of the indigenous species mentioned above is not economically viable although they have good market and consumer preference. Sometimes, *Labeo rohita* is stocked in the outer nets of the cages @ 10-15 advanced fingerlings (> 100mm) per cage. By virtue of its browsing habit, rohu cleans the algal growth over the nets, besides giving some additional fish biomass.

Apart from Pangasianodon hypophthalmus and GIFT Tilapia, all other exotic species (including illegally introduced fishes) are strictly prohibited for cage culture.

10. Stock Management

10.1 Culture of *Pangasianodon hypophthalmus*

The fish seed for stocking should be sourced from authentic and reliable agencies, subject to government stipulations. Proper records on seed sourcing shall be maintained and the seed should be quarantined and acclimatized and bathed in 3 mg/L $KMnO_4$ (as prophylactic treatment on need basis) before stocking. The size at stocking and optimum stocking density vary according to requirements, depending on growth and survival. However, stocking density for *P. hypophthalmus* range from 500 to 700 nos./m^3 of 20 mm size fry for rearing to fingerlings. For grow-out, the stocking density is in the range of 60 to 100 nos./m^3 of fingerlings (50-60 mm size). The stocking material is better transported to the cage site in water loaded open tank with frequent stirring. Stock maintenance involves periodic sampling to assess the growth and general health condition. The culture period of *P. hypophthalmus* is generally 7-8 months.

(For raising fingerlings of Indian major carps, fry measuring above 25 mm length are suitable for rearing in cages. The size at stocking and stocking density of Indian major carps and other indigenous species shall be need-based as these have not been standardized yet. To raise finferlings for culture of Indian major carps, it is always better to stock 50 mm fry as these will grow faster and survival rate would be higher. Harvesting can be done after rearing for 60 days. However, this depends on natural productivity and supplementary feeding. It is helpful if land-based nurseries are available near a reservoir or a cluster of them for rearing fry to fingerlings. Pen culture is ideal for raising stocking material of IMC, but all reservoirs do not have the ideal conditions for taking up pen culture.)

The cage fish farming being purely based on supplementary feeding, selection of good/best fish feed and its application in right quantity is important to achieve desirable results. It is advised that only quality floating feed is selected. Sinking feed is totally unsuitable for cage fish farming as it accumulates at the base and fouls the cage/reservoir environment. The rate of feeding for *Pangasianodon hypophthalmus* is given in Table II.

Table II. Feed requirement of *Pangasianodon hypophthalus* in Cage Culture

Stage	Feed	Protein Requirement	Feeding Rate (% of Fish Body Weight)
Fry to Fingerling	Crumble Floating Feed (0.5 -1.0 mm)	30 to 35%	Less than 10% body wt., 4-5 times a day
Fingerling to Table Fish	Pellet Floating Feed (Above 1.0 mm)	25 to 30%	First 2 months 5% body wt., twice a day. From 3rd to 5th month 3% body wt., twice a day or as required. From 6th month onward 2% body wt., twice a day or as required.

10.2 Culture of GIFT Tilapia

Rajiv Gandhi Centre of Aquaculture (RGCA) has developed culture technologies for GIFT Tilapia (*Oreochromis niloticus*) and Sea Bass (*Lates calcarifer*). Details of cage specifications and feeding for GIFT Tilapia are given below (Table III to V).

Table III. Specifications of Net Cage for Tilapia Culture

Net Cage Specifications	Fish Weight
Fish net cage without top cover made of HDPE 0.75/16mm mesh size webbings with rope (Cage size : 5m x 5m x 5m)	50 - 150 grams
Fish net cage without top cover made of HDPE 1.25/20mm mesh size webbing with rope (Cage size : 5m x 5m x 5m)	150 – 250 grams
Fish net cage without top cover made of HDPE 1.25/24mm mesh size webbing with rope (Cage size : 5m x 5m x 5m)	250 – 500 grams, till harvest

Table IV. Stock Management of Tilapia

Items	Details
Cage Size	5m x 5m x 4m
*Mesh Sizes	16 mm, 20 mm, 24 mm
Body weight, Feed Pellet Size & Protein Content	50-150 grams – 2 mm (28% protein) 150-500 grams – 3 mm (28% protein) 500-600 grams – 4 mm (25% protein) 600 grams and above – 5 mm (22% protein)
Stocking Density	40/m^3
Cage Changing	Fortnightly
Nursery	Not permitted in Reservoirs; minimum stockable size is 50 grams

*Mesh Bar (knot to knot) is half the length of mesh size (stretched mesh size)

Table V. Feeding Chart for Tilapia

S. No.	ABW (g)	Feeding rate (% of Body Weight)	Culture Phase
1	1-5	8%	Nursery Rearing
2	6-10	6%	
3	10-15	5.5%	
4	15-20	4%	
5	20-50	4.0 - 2.5%	
6	50-100	2.5 -1.7%	Growout Rearing
7	100-200	1.7 - 1.3%	
8	200-300	1.3 - 1.0%	
9	300-500	1.0 - 0.9%	
10	500-700	0.9 - 0.8%	
11	>700	1.8 - 0.6%	

10.3 Culture of Sea Bass *Lates clacarifer*

Recommended cage materials, mesh size, maintenance of biomass and feeding of Sea Bass in Cage Culture in Inland Waters (Reservoirs & Dams) are given in Table VI, VII and VIII).

11. Fish Health Monitoring

As fish health monitoring involves maintaining hygienic and healthy culture environments, it is important to source seed and feed from authorized and genuine agencies that follow high standards. Usage of suitable quality feed, maintenance of optimum stocking densities, adoption of preventive measures such as prophylactic treatment before stocking, regular monitoring of stock and periodic cleaning of cages will avoid outbreak of diseases and stock loss.

Table VI. Type and Number of Net Cages required for Sea Bass Culture

Sl. No.	Particulars of Cage	No. of Cages Required (%)
1	500PE/8 ply/12 mm (knot to knot)	6
2	500PE/8 ply/16 mm (knot to knot)	8
3	500PE/8 ply/20 mm (knot to knot)	10
4	500PE/8 ply/24 mm (knot to knot)	12
5	500PE/8 ply/32 mm (knot to knot)	16
6	500PE/8 ply/38 mm (knot to knot)	23
7	500PE/8 ply/44 mm (knot to knot)	25

Additional 30% Cages of 38 mm and 44 mm mesh bar (knot to knot) are required as standby because 12 mm and 16 mm mesh bar size cages are not used when the fish attain harvestable size.

Note: Irrespective of the cage size the mesh sizes vary as given in Table

Table VII. Cage Mesh Size and Biomass Capacity for different sizes of Sea Bass

Size of Fish (cm)	Wt of Fish (g)	Cage Mesh* (mm)	Biomass (kg/cu. m)
10.0 - 12.0	13.0 – 23.0	12 0	2.5 – 3.0
12.0 – 14.0	23.0 – 53.5	12.0	3.0 – 3.5
14.0 – 16.0	53.5 – 76.0	16.0	3.5 – 4.0
16.0 – 18.0	76.0 – 105.0	16.0	4.0 – 4.5
18.0 – 20.0	105.0 – 140.0	20.0	4.5 – 5.0
20.0 – 22.0	140.0 – 180.0	24.0	5.0 – 5.5
22.0 – 24.0	180.0 – 230.0	24.0	5.5 – 6.0
24.0 – 26.0	230.0 -280.0	24.0	6.0 – 6.5
26.0 – 30.0	280.0 – 350.0	32.0	6.5 – 7.0
30.0 – 32.0	350.0 – 420.0	32.0	7.0 – 7.5
32.0 – 34.0	420.0 – 500.0	38.0	7.5 – 8.0
34.0 – 36.0	500.0 – 600.0	38.0	8.0 – 9.0
36.0 – 38.0	600.0 – 700.0	38.0	9.0 – 10.0
38.0 - 40.0	700.0 – 820.0	44.0	10.0 – 11.0
40.0 – 43.0	820.0 – 1000.0	44.0	11.0 – 12.0

*Mesh Bar (knot to knot) is half the length of mesh size (stretched mesh)

Table VIII Feeding of Sea Bass

Size of Fish (cm)	Av. Wt. (g)	Feed Type	Pellet Size (mm)	Feeding Rate (% Body Wt.)
9-10	9.7-13.0	Floating	2.0-2.2	5.0
10-12	16.0-23.0	Floating	3.0	4.8
12-16	23.0-53.5	Floating	4.0	4.6
16-18	53.5-76.0	Floating	4.0	4.4
18-20	76.0-105.0	Floating	6.0	4.2
20-22	105.0-140.0	Floating	6.0	3.8
22-24	140.0-180.0	Floating	8.0	3.6
24-26	180.0-230.0	Floating	8.0	3.2
26-28	230.0-280.0	Floating	10.0	3.0
28-30	280.0-350.0	Floating	10.0	2.8
30-32	350.0-420.0	Floating	10.0	2.6
32-34	420.0-500.0	Floating	12.0	2.4
34-36	510.0-600.0	Floating	12.0	2.2
36-38	600.0-700.0	Floating	12.0	2.0
38-40	700.0-820.0	Floating	14.0	1.8
40-43	820.0-1000	Floating	14.0	1.8

As far as possible, use of antibiotics and chemical should be avoided. However, in the event of it becoming necessary under exceptional circumstances, the use should be judicious and *it must be clearly understood that only approved drugs/chemicals, permitted by Government regulatory authorities (See Table IX) at standard doses shall be used.*

In case of severe infection, the fish should be removed from the cages and buried/incinerated/ bleached. Health of the fishes stocked in cages must be monitored at monthly interval and proper treatment measures must be adopted in case of disease outbreak, (if any). Standard doses of chemicals like $KMnO_4$ and formalin can be used for dip treatment. In case of bacterial disease, Oxytetracycline (OTC) and its derivatives can be administered through feed or other modes. These are the only antibiotics allowed for fish culture in cages. A record on incidence of fish disease and control measures adopted including medicines used should be maintained. In case of disease outbreak, the State Fisheries Department or National Institutes (one of the eight fisheries research Institutes under ICAR (other Central Government labs like NABL accredited aquaculture lab of RGCA) or any laboratory belonging to the State governments can be approached.

Table IX. Drugs and Chemicals allowed to be used in Cage Aquaculture

Drug/ Chemical	Recommended Dose	Indications	Adminis-tration
Chlor-amine-T	20 milligrams per litre static bath once per day for 60 minutes on consecutive or alternate days for 3 days	Columnaris disease associated with *Flavobacterium columnare*	Immer-sion
Formalin	External parasites 250µL/L for 1 hour	Control of external protozoa (*Chilodonella* spp., *Costia* spp., *Epistylis* spp., *Ichthyophthirius* spp. *Scyphidia* spp. and *Trichodina* spp.) and the monogenetic trematode parasites (*Cleidodiscus* spp., *Dactylogyrus* spp., and *Gyrodactylus* spp.) on all finfish	Immer-sion
Oxytetra-cycline dihydrate	Catfish – 2.5 to 3.75 g Oxytetr-acycline/50 kg of fish for 10 days through feed (Active ingredients: 200 g Oxytetracycline/ 0.5 kg)	Control of *Hemophilus piscium*, Furunculosis caused by *Aeromonas salmonicida*, Bacterial hemorrhagic septicemia caused by *Aeromonas liquefaciens*, and Pseudomonas disease	Medica-ted feeds
Florfenicol	10 mg Florfenicol/kg of fish/day for 10 consecutive days through feed (Active ingredients: 500 g of Florfenicol/kg)	Control of *Flavobacterium psychrophilum* and *Aeromonas salmonicida*, *Streptococcus iniae, Flavobacterium columnare*	Medica-ted feeds

12. Safety Measures

Cage culture involves working in a risky environment and therefore, all security measures should be taken to avoid injury and loss of life while installing cages and working in cages to manage the stock (rearing the fishes). Adequate number of lifebuoys/ other life-saving equipment should be provided at the cages and in vessels used for approaching (managing) the cages. Similarly, the workers should wear life-jackets all the time while working in water and cages. Emergency life-saving kits and first-aid boxes should be provided at the cages/boats/floating huts or field camps. The international conventions related to 'safety at sea' and procedures prescribed in the FAO-Code of Conduct for Responsible Fisheries (FAO-CCRF) will be the guiding principles for safety measures (http://www.fao.org/docrep /005/v9878e/v9878e00.HTM). The cage stock needs to be protected from poaching/ trespassing by keeping efficient watch and ward.

13. Market, Harvesting and Post-Harvest Management

The feeding should be stopped 2 days prior to harvesting. If antibiotics were used during the culture period, sufficient withdrawal period may be given before harvest. It is advisable that the harvesting of stock may be done in phased manner like larger fish first, especially to avoid glut in the market, to avoid low price for the harvested fish and get a better market price. Records of harvest should be maintained at the site. Cage culture is a high-intensive culture practice that could result in harvest of large quantities of fish at a time. Growth of this segment of fish production without a planned link to a whole value chain approach, could result in marketing problems and post-harvest losses. It is essential to have a post-harvest and marketing strategy before launching cage culture ventures on a large-scale. The large-scale cage production centres should either have their own facilities or have linkages for:

- Proper harvesting gadgets
- Fish holding and storage
- Live fish transport
- Post-harvest processing centres like fillet plants
- Market chain including E-markets.

In any case, it is advisable for all cage units (including small units) to have a small ice-making device at each cage site for preservation of the harvest before being transported for storage or to the market. There should be at least one insulated van at site for transportation of fish. Efforts may also be made to create live/preserved fish sale outlets at strategically important points in nearby cites for better return.

14. Environmental Precautions and Assessment

Cage culture is a relatively new area of fish production in India and its environmental impacts are not fully understood. There are models for assessing the environmental impact in terms of nutrient loading developed in other countries. But these models are not directly applicable in India due to the difference in environmental regimes under which these have been developed, especially the variations in temperature and trophic status. Efforts are on to develop such models in India, but the results will not be available in short time. Nevertheless, the cage culture activities are growing at a very fast rate causing concerns, especially when viewed in the light of our bad experience with coastal aquaculture in the 1980s and 1990's when unregulated growth without addressing environmental concerns have resulted in disastrous consequences to ecosystems.

Following the guidelines of the FAO-CCRF for dealing with data-deficient systems, our policy towards EIA of cage culture should be based on a precautionary approach and hence the limitations on phosphates and nitrates values as given in para 7.3 above. Accordingly, the following measures need to be adopted for cage culture projects:

1. Major environmental threats from cage aquaculture include the release of excessive nutrient that accumulate in water and sediments.
2. With the aim of protecting aquaculture operations from excessive nutrient loading in water and sediments and also to protect the environment from the harmful effects of cage culture (eutrophication and chemical/pharmaceutical inputs), Environmental Impact Assessment is necessary before clearing cage culture projects. This will be done/facilitated by competent authorities/organisations, following the standard procedure. States should exercise greater control over cage aquaculture operations through appropriate governing procedures.

3. The State governments should demarcate, list and notify water bodies that are suitable for cage culture on the basis of its trophic characteristics and other criteria of site selection (as given above at 7.1, 7.2, 7.3 above) and upload the list of water bodies and their suitability on GIS platform with the help of concerned institutions.
4. It will be mandatory for the cage culture operators to record the water quality parameters like Dissolved Oxygen, pH, CO_2 and Total Alkalinity, inside and outside the cages from the day-one of the operation, keeping in view the need for long-term environmental impact. Any increase in nutrients level away from the cage area should be taken as a warning.
5. It will be mandatory for the cage culture operators to collect data on the trophic status in and around the cages as well as the areas away from the cages, periodically and report to the authorities to assess the impacts in terms of nutrient loading. Studies on other chemical and physical quality parameters of water and sediments also shall be undertaken as per the risk perception.
6. NFDB and Central Organizations will build capacities of States to interpret such data and arrive at conclusion.

15. Carrying Capacity and Limit of Cage Numbers

Carrying capacity of a water body to hold cages is the most vital input for decision making in cage culture. But, unfortunately we are not in a position to arrive at carrying capacity levels with precision due to paucity of data. Therefore, our policy on carrying capacity has to be based on a precautionary approach. Provisions of FAO-Code of Conduct for Responsible Fisheries (http://www.fao.org/docrep/005/v9878e/v9878e00.HTM) clearly stipulates to follow the 'precautionary approach' while dealing with data deficient systems. Accordingly, taking into account, the general trend of nutrients in Indian reservoirs and possibility of nutrient loading from cage culture, the following carrying capacities have been developed on a precautionary approach basis (Table X):

Table X. Limits set for Cage Culture in Reservoirs

Reservoir Area (ha)	Maximum Number of Cages Allowed*
< 1000	Not allowed
1001 to 2000	500
2001 to 3000	1000
3001 to 4000	1500
4001 to 5000	1900
5001 to 10000	3000
>10000	5000

*As Stand-alone or in Batteries (of 6, 12 or 24 Cage Units), as required

*One Cage Unit is 6m x 4m x 4m

16. Ownership, Beneficiaries and Governance

Unlike the land-based aquaculture undertaken on private land, cage culture is practiced in common property resources. Therefore, the question – who owns the cages installed in reservoirs needs an important consideration. While answering the question, the following facts need to be considered:

(a) Almost all large and medium reservoirs in the country are owned by the government or government agencies and fishers fish these water bodies as common property resource with free or almost free access.

(b) Fish produced from the reservoirs is essentially a natural resource and the traditional and local fishers communities have the 'natural primary rights' to this resource.

(c) Livelihoods of many poor people depend on catching fish from reservoirs.

(d) Reservoir fishing is used sometimes as a means to rehabilitate the people ousted from the dam project sites.

Considering the above facts, it is essential to ensure that expansion of cage culture do not impair the livelihoods and income of the fishers. Cage culture can adversely impact the interests of local fishers by denying access to fishing grounds, obstructing their pathways, and decline in fish catch if cage culture affects the natural productivity of the water body. At the same time, it is equally important to utilize the additional fish production potential through cage culture. Considering the need to avoid conflicts, the best way to achieve the goal is to empower the fishers to take up this activity collectively without conflicts. Following a purely revenue approach by allowing individual investors and corporate houses to undertake cage culture will be against the spirit of inclusive growth and can create social tension. Thus, the community (or a group of members of the community) should own the cages as a common property and they should be the beneficiaries of this technology.

A strong governance platform based on co-management principles is essential for responsible cage culture operations to be undertaken by the community. But the existing Fishermen Cooperative Societies have poor track record of functioning as a responsible entity to work as a group. This throws a big challenge on the government to organize and empower the fisher communities and develop capacity among them to enable them to take up cage culture. SHGs, Cooperative Societies, FPOs or other such groups should be given licenses to undertake cage culture. *Under any special circumstances, if a private entrepreneur or investor is to be brought to the scene, government through strong policies, should protect the interest of the local fishers and fisher communities, who have the primary rights to the natural resource. A Conflict Management Cell should be established to address complaints.*

17. Social Relevance

Cage culture in inland open waters is a fast growing activity and it could have many environmental and social impacts, which may not be predictable. But adequate precautions need to be taken to ensure that it should not lead to any such issues in future. The ultimate goal should be increased fish production through environmentally sustainable and socially inclusive means. The additional income generated from the reservoirs through the growth of cage culture should be shared by the fisher community rather than an investor walking away with all the benefits and the fishers get only the wages. The social impact should be additional income and improved standard of living for one of the weakest sections of our society. This should be the ideal social impact of cage culture operations apart from the increased availability of fish.

***

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