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CAGE CULTURE: MARICULTURE TECHNOLOGY OF THE MILLENNIUM IN INDIA

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Fisheries sector in India has emerged as an important industry during the last six decades. Fish is an important source of cheap protein to the people of India, and also a potential employ ment and income generating sector, besides earning substantial foreign exchange through seafood exports. Fisheries contributed about 5% of India's agricultural GDP and about one per cent of the total GDP during 2008-09. The sector supports livelihood options for about 40 million people in India.

The marine fishery resources of the country include a coastline of 8129 km with numerous creeks and saline water areas, an Exclusive Economic Zone (EEZ) of 2.02 million km^2, which are suitable for capture as well as culture fisheries. The annual harvestable marine fishery resources in the Indian EEZ have been estimated at about 3.93 million tonnes constituting more than 50 % demersal, 43% pelagic and 6% oceanic groups. The Indian fish production is contributed both by marine and inland sectors.

While, the share of marine fish production in the total fish production declined gradually from 71% in 1950-51 to 38.16% in 2008-09, and that of the inland sector increased from 29% to 68.14% during the same period. The marine fish production in India during 2009 was estimated at about 3.16 million tonnes, which is more than 70% of the harvestable potential.

With the marine capture fisheries reaching a stagnation phase with limited scope for further expansion, the alternative is to look for augmenting the fishery resources of the sea. Since the existing capture methods have exploited the resources indiscriminately mainly due to socio-economic pressure, there has been a necessity to exploit the resources in a sustainable way. Under such circumstances, mariculture or cage farming has been identified as one of the methods for augmenting the fish catch from the sea.

Aquaculture has been the world's fastest growing food production system with production steadily increasing at about 10% per year since 1984, compared with 3% for livestock meat and 1,6% for capture fisheries. Of the 300 species being cultured, 22 account for 80% of the production. The majority are filter feeders, herbivores or omnivores, and one species (Atlantic salmon) is carnivorous. In the finfish group Cyprinids dominate the production with 10.3 million meter.

Cage farming

Cage culture has been originated in Southeast Asian countries and now it is a major culture activity all over the world. Mariculture in cages began in Japan in the 1950s but developed largely as a result of the salmon farming industry in northern Europe and North America during the past two decades. Cages account for about 60% of coastal fish culture, and if considering Medite rranean aquaculture, it account above 90% of all seabass and sea bream production. The main advantages of cages when compared to conventional land-based systems include low capital costs and simple management.

Cage farming in India

As an R & D activity, the first open sea cage was launched in Bay of Bengal off Visakhapatnam coast during May 2007. Due to the rough sea conditions, the first version of the cage had lasted only for 45 days in the sea. With further modifications, the second version of marine cage was fabricated involving marine engineering and naval diving experts and was launched in December 2007. With a low stocking density, the trial was successfully completed in April 2008. The recovery percentage was 75% and the weight ranged from 300-1200g. The third version of the cage was also tried and found to be seaworthy at any extreme sea conditions. The first to third versions were 15 m dia HDPE cages. For easy manoeuvring and cost effectiveness in terms of reduced labour, the size of the HDPE cages have been modified to 6 m in the fourth version. In a demonstration trial, these types of cages have been found to be successful in many maritime states along the Indian coast. Latest version of open sea cage is a cost effective GI cage designed for low investment farming operations.

Open sea cage technology developed by CMFRI

Different criteria must be addressed before site selection for cage culture The first is primarily concerned with the physico-chemical conditions like temperature, salinity, oxygen, currents, pollution, algal blooms, water exchange *etc.* that determine whether a species can thrive in an environment. Other criteria that must be considered for site selection are weather conditions, shelter, depth, substrate *etc.* Finally legal aspects, access, proximity to hatcheries or fishing harbor, security, economic, social and market considerations *etc.* are to be taken care.

Size

It is a fact that costs per unit volume decrease with increasing cage size, within the limits of the materials and construction methods used. However, very large cages may limit stocking, grading and harvesting options, and maintenance aspects like net changing and disease treatment also become increasingly difficult as size of cages increase. CMFRI has developed open sea cages of 6 m dia and 15 m dia for grow out fish culture and 2 m dia HDPE cages for seed rearing. Ideal size for grow out cage is 6 m due to its easy manoeuvring and reduced labour. For fingerling 2 m cages can be used.

Cage frames and nets

Culture experiments and demonstrations using different cage materials have been carried out by CMFRI. Business entrepre neurs with high capital investments long lasting and expensive High Density Poly Ethylene (HDPE) frames can be used. Small groups and fishermen can opt for cost effective epoxy coated Galvanized Iron (GI) frames. GI frames have less life span com pared to HDPE frames.

Nets of varying dimensions and materials were tested for cage culture in India. CMFRI has used braided and twisted HDPE nets for grow out purpose. It can last for two or more seasons. Nylon net can be used economically, but since it is light weight, to hold the shape intact more weight has to be loaded in the ballast pipe. Sapphire is also good because of its high breaking strength compared to HDPE and nylon. Cost factor has to be taken care while using sapphire or dyneema materials for net cage. The depth of net ranging from 2 to 4 m for fingerlings and 5 to 6 m for grow out cages are ideal. For open sea cage culture, predator net to prevent attack by predatory organisms is essential.

Potential species and criteria for selection of species for cage culture

The selection of species for cage culture should be based on a number of biological criteria like omnivore or carnivore, hardiness, fast growing, efficient food conversion ability, availability of eggs and juveniles, and disease resistance. Economic marketability and demand are also taken into consideration.

Mariculture is a relative latecomer in the food production industry in the world. Following positive experiences in production of salmonids in floating cages at high densities in European countries, marine finfish farming in cages was successfully initiated in coastal waters of Mediterranean countries as well.

In India, marine fish present problems for the fish culturists since fry supply still remains as a bottle-neck in expanding of industrial mariculture. Marine fish eggs and small size larvae at first feeding make it too complicated a matter to rear them throughout their life cycles. Culture of marine fish has taken up only due to the promotion of cage culture of sea bass by CMFRI and to the improvement of the hatchery techniques by RGCA (MPEDA) which has enabled the fry production under a controlled price. Asian seabass *L. calcarifer* has been proven as a fine species for cage culture due to the availability of hatchery produced seed, market demand and fast growth. Another species which has great potential is cobia *Rachycentron canadum*, for which hatchery technology has been initiated by CMFRI. Once the technology is commercialized, cobia will snatch the scene of mariculture in India due to its fast growth and excellent market value.

Among crustaceans, lobster rearing in open sea cages has been proved highly lucrative. CMFRI has demonstrated lobster rearing in cages at Vizhinjam, Kanyakumari, Mandapam and Veraval. Within a short span of 3 months fishermen were able to raise more than four times revenue by lobster rearing. Otherwise, juveniles of lobsters are sold for meagre amount in the local market. This practice also leads to reduction in loss of natural stock due to juvenile capture which is not uncommon in Indian waters.

Stocking

Although stocking densities should be determined by species requirements and operational considerations, the influence of stocking densities on growth and production has been determined empirically. The stocking density depends also on the carrying capacity of the cages and the feeding habits of the cultured species. Optimal stocking density varies with species and size of fish. For producing 5 tonnes of 500-600 g seabass from a 6 m dia. HDPE cage, 30-50 individuals (100 g) per cubic meter can be stocked.

Feeds and feed management

Fresh or frozen trash fish, moist pellet (MP) and floating dry pellets are the common feed for growing fish in cages. Feeding in cages is quite easy compared to that in ponds. The ration can be divided into equal portions and supplied at regular intervals. Feeding can be done either by broadcasting or using feeding trays.

Harvest

Harvest of fish or lobster in cages is made very easy compared to that in ponds. Cages can be towed to a convenient place and harvest can be carried out. Also based on demand, partial or full harvest can be done.

Cage management

Cage culture management must result in optimizing production at minimum cost. The management should be so efficient that the cultured fish should grow at the expected rate with respect to feeding rate and stocking density, minimize losses due to disease and predators, monitor environmental parameters and maintain efficiency of the technical facilities (Chua, 1982). Physical maintenance of cage structures is also of vital importance. The raft and net-cages must be routinely inspected. Necessary repairs and adjustments to anchor ropes and net-cages should be carried out without any delay. Monthly exchange of net should also be considered, as this ensures a good water exchange in the net, thereby washing away feces, uneaten food and to a certain extent reduce the impact of fouling.

Fouling of cage net

Fouling of cage nets and other structures has been observed at many instances of cage farming. Nets get covered with bio-foulers. Fouling by molluscs, especially edible oysters and barnacles have to be checked before its growth advancement. Algal mats and other periphytons can be removed by introduction of omnivorous grazers in cages. A fouled net will be heavier, thereby increasing drag, and this result in loss of nets and fish.

To avoid/ reduce fouling, net should be changed as and when required, which may vary from 2 to 4 weeks depending on the intensity of fouling. During oyster fouling, net exchange has to be done immediately after the seasonal spat fall.

Herbivorous fish such as rabbit fish (*Siganus* spp.), pearl spots (*Etroplus* spp.) and scat (*Scatophagus* sp.) can be used to control biofoulers (Beveridge, 1987), but their application on a large scale needs to be assessed.

Disease monitoring

Monitoring of fish stock health is essential and early indi cations can often be observed from changes in behavior, especially during feeding.

TechnicaL issues in developing open sea cage farms in Indian waters

- Lack of sea farming policy is a major issue which has to be taken care by the concerned states in the country before taking up commercial cage farming.
- Modification of the cage design to withstand strong sea currents/ tidal flow and retain their effective volume; developing cages that are better suited to the sea conditions in different regions and to different species.
- Developing stronger cage-nets that can withstand varying sea conditions and fouling.
- Producing associated facilities and equipment, including that for safety and security of the structure and stock, feeding,

grading, net-cleaning, monitoring, harvesting *etc*.

- Developing cost-effective and nutritionally complete formulated feed to replace the trash fish that is used at present. Formulated feed has been used in aquaculture for more than 30 years, but is not widely used in marine cage culture.

Capture based aquaculture

Capture based aquaculture (CBA) is a good concept for species for which hatchery technology has not been developed. Southern blue fin tuna (*Thunnus* spp) is cultured in Australia using wild-caught juveniles, which has great demand in global market. In India also many species can be cultured in a similar way. The juveniles of high valued species caught in different gears if brought alive can be effectively used for CBA in cages. Juveniles of koth, ghol, pomfret, pompano, snappers *etc.* can be used for CBA. The only precaution to be taken is that CBA should not target to any single species, which might lead to vulnerability to endangering/ extinction in future. CBA enhances marine fish production and reduce the wastage of resource as low value by catch and regular supply of high quality seafood items.

Constraints that may occur in open sea cage culture

- Biological, mainly disease problems, and biodiversity concerns due to the introduction of new species in the region.
- Market constrains, such as fluctuation of prices based on supply, quality control problems, demand for aquaculture products, *etc*.
- Zoo-technical constraints, such as seasonality of production
- Environmental concerns, linked to the location of farms and the impact of their effluents on the surrounding environment (in commercial ventures only)
- Scarcity of potential sites for new aquaculture projects, and competition with other coastal users (urbanization, tourism, navigation, wildlife park projects, harbours, maritime traffic, *etc*.) and

- Scarce administrative organization with regards to the integra tion of aquaculture activities in coastal areas.

Economic analysis

The success of the adoption of any innovation or new technology lies in its economic performance. The rate of return per rupee invested is the economic indicator that guides the investor to choose a particular enterprise or practice. Besides, the analysis of the economic performance serves as an indicator for the investor to allocate his resources in the enterprises. This becomes very much essential, since the resources are scarce and the investor is interested to invest his scarce capital resource in that enterprise that gives the maximum return for his investment.

The economic performance of the cage culture experiment had been worked out by calculating the annual fixed costs, variable costs and the annual total costs from the cost side. From the returns point of view, the harvest from the cage, the gross revenue from the sales of the product had been worked out. Using the cost and returns figures, the economic indicators are estimated to test the economic viability and financial feasibility of any enterprise. This would serve as guidelines to the institutional agencies that are extending the financial support to the enterprise.

Case studies

Demonstration of open sea cage culture for finfish and shellfish was carried out by CMFRI in Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh and Orissa. Lobster culture was successful at Kanyakumari, Vizhinjam and Mandapam. Asian seabass culture was highly encouraging at Karwar, Balasore and Chennai. Mullets, seabass and pearl spot were also successfully harvested from backwater cages at Cochin. Based on the success CMFRI has developed an open sea cage farm at Karwar bay. The detailed economic analysis of the experimental cage culture demonstrated in Visakhapatnam (Andhra Pradesh) and Balasore (Orissa) is given in Tables 1-5 to indicate how the economic analysis of the enterprise is done.

Visakhapatnam

Table 1- Initial investment of the cage culture farm of 1061 m^3

Sl. No.	Items	Investment (in Rs.)	% to total	Economic life(in yrs)
1	HDPE Cage frame	4,00,000	27.12	10
2	HDPE nets	3,00,000	20.34	10
3	Galvanized Iron Chains	80,000	5.42	10
4	Mooring equipments	60,000	4.07	10
5	Stone Anchors	1,50,000	10.17	50
6	Floats	1,50,000	10.17	10
7	Shock absorbers	25,000	1.69	10
8	Ballast	35,000	2.37	10
9	Ropes-HDPE	35,000	2.37	10
10	One time launching charges	2,40,000	16.27	
	Total Initial Investment	14,75,000	100.00	

Table 2. Details of annual fixed cost

Sl.No.	Details	Amount (in Rs.)
1	Depreciation	1,16,000
2	Insurance premium (5% of investment)	73,750
3	Interest on fixed capital	1,77,000
4	Administrative expenses (2%)	29,500
	Total fixed cost	**3,96,250**

Table 3. Details of annual variable cost of cage culture (crop duration: 7 months)

Sl. No.	Details	Cost	% to total
1	Feeding	2,24,000	14.02
2	Seedling	1,50,000	9.39
3	Feed cost	9,00,000	56.32
4	Net cleaning	75,000	4.69
5	Underwater inspection	50,000	3.13
6	Net mending and Maintenance	25,000	1.56
7	Post crop overhauling	20,000	1.25
8	Security	1,00,000	6.26
9	Interest on working capital @6% for one crop duration	54,040	3.38
	Total	**15,98,040**	100.00

Table 4. Economic indicators of the cage culture of *Lates calcarifer*

Sl. No.	Details	Amount (in Rs.)
1	Annual fixed cost	3,96,250
2	Annual Variable cost	15,98,040
3	Annual total cost	19,94,290
4	Gross revenue (after harvesting from 5th to 7th month)	37,50,000
5	Net operating income	21,51,960
6	Net income (profit)	17.55,710
7	Capital Productivity (Operating Ratio)	0.43
8	Annual Rate of return to capital	119%

Balasore

At Balasore, the initial investment for a 6m diameter cage worked out to Rs.3,00,000. The fixed costs for the culture period of six months was calculated at Rs.54,000. The variable costs of the culture operation worked out to Rs.2,31,750. Thus the total cost of production to the participants worked out to Rs.2,85,750 (Table 5).

Table 5. Economic analysis of the experimental cage culture demonstration at Balasore

Sl. No.	Details of cost and returns	Amount (in Rs.)
1	Initial investment for a 6m diameter cage	3,00,000
2	Fixed cost (For crop duration of six months)	
	a) Depreciation	30,000
	b) Insurance (2% on investment)	3,000
	c) Interest on Fixed capital (12%)	18,000
	d) Administrative expenses	3,000
3	Total Fixed cost (A)	54,000
4	Operating costs	
	a) Cost of seedlings	5,0000
	b) Cost of feeding and other labour chages	1,75,000
	c) Interest on working capital (6%)	6,750
	Total Operating cost (B)	2,31,750
6	Total cost of production (Six months)	2,85,750
7	Yield of sea bass (in kg)	3,032
8	Gross revenue from 3032 kg	5,75,760
9	Net income (8)-(5)	2,90,010
10	Net operating income (Income over operating cost)	3,44,010
11	Cost of production (Rs./kg) (6)/(7)	94.24
12	Price realized (Rs./kg) (8)/(7)	189.89
13	Capital Productivity (Operating ratio) (5)/(8)	0.50

The culture of sea bass yielded 3.03 tonnes at the end of six months, thus earning a gross revenue of Rs.5,75,760 to the participants. The culture has earned a net operating income of

Rs.3,44,010 at the end of six months and a net profit of Rs.2,90,010 at the end of the same period. The cost of production per kg of sea bass worked out to Rs.94.24 against the value realization of Rs.189.89 per kg. The capital productivity measured through operating ratio was worked out to 0.50. These economic parameters indicate that this open sea cage farming of sea bass is economically viable.

Factors to be considered before the establishment of open sea cage farms

- Identification of scientifically suited, resource specific and location specific sites for the establishment of open sea cage farms.
- Appropriate leasing policies conferring the rights/ or legally valid authorization to the fishermen groups, SHGs or fishermen cooperatives to undertake open sea cage farming.
- Introduction of a socio-economically conducive mechanism under participatory mode to share the cost and economic benefits so that social conflicts are avoided.
- Ensuring adequate and regular supply of seed of the selected species from hatcheries, providing technical support and arranging for suitable financial assistance with the help of organizations like the State Fisheries Departments and development organizations like National Fisheries Development Board (NFDB).

Conclusion

Responding to the challenge of filling the gap between growing demand and capture fisheries supply, mariculture production has to satisfy the optimistic expectations. Significant progress is being made by CMFRI in this area through cage culture as evidenced by both the scientific achievement and the production trends. The economic analysis of the cage culture has also been worked out with higher net operating income and net income in a crop period of seven to nine months. It is to be noted that once the practice is further expanded to many areas and farms, the cost will decline due to the economies of scale of operation. Open sea cage farming is a viable alternative and economically and financially feasible mariculture operation for the stake holders to make use of. Open sea cage culture develop ment must be sustained in future by research and development in genetics, nutrition, health management, production economy, product handling *et*c. Technological advances aiming to reduce capital and operating costs are particularly needed as to counteract the tendency for prices to fall as mariculture production increases. Future project assessments should involve not only technological and socio-economic considerations, but also its environmental efficiency. Co-operation between government, investors and financial institutions is a prerequisite into achieving a new era of mariculture development in India. The State Fisheries Departments and the organizations like NFDB can promote the concept of cage culture on a large scale with their institutional and financial support, availing the technical expertise of CMFRI.

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