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Foreword

The ICAR-Central Marine Fisheries Research Institute (CMFRI) is a premier research institute involved in marine fisheries and mariculture research in the past several decades. The institute has been instrumental in developing noteworthy technologies and policies aimed at augmenting fish production and livelihoods of coastal fisherfolk in the country. In view of the declining catches from the marine capture fisheries, the enormous potential of mariculture need to be tapped for achieving the blue revolution targets. CMFRI has made significant strides in developing and popularising mariculture technologies such as mussel and edible oyster farming, sea weed farming, seed production techniques for high value finfishes and marine ornamental fishes.

Cage fish farming is an emerging aquaculture technology in the country developed and popularised by the institute. Development of hatchery technologies of high value finfishes, standardisation of culture protocols as well as successful frontline demonstrations and participatory technology development programmes by the institute paved the way for popularisation of cage fish farming in all the maritime states of the country. Cage fish farming is low impact farming technology with high economic returns which has tremendous scope for employment and income generation for the coastal population in the country. There are at present 3000 cage farm units installed in the marine and coastal waters of the country under the direct technical supervision of CMFRI.

The economic viability indicators play a vital role in the effective adoption and upscaling of any farming technology. The micro level investment decisions as well as macro level policies by the government and financial institutions very much depend on the economic viability indicators. In view of the huge potential for cage farming in the marine, estuarine and coastal waters of the country, ICAR- CMFRI is publishing the special publication on 'Economic viability of cage fish farming in India'. The book covers the economic viability aspects of different species of fishes in the marine, estuarine and coastal waters in the country. I hope this book will be a valuable resource for the various stakeholders for undertaking successful cage farming activities and also guide the financial institutions, development departments and policy makers for appropriate decisions for boosting cage farming activities in the country. I appreciate the efforts taken by the authors for bringing out this timely publication.

Dr. A. Gopalakrishnan
Director, CMFRI

Contents

I. Introduction

Cage aquaculture involves rearing of fish growout in enclosed structures which allow free exchange of water. Eventhough fish farming in cages was in practice since late 1800s in the South East Asian countries, the technology gained popularity among the fish farmers and fisherfolk in India only in the recent past. The Central Marine Fisheries Research Institute (CMFRI) is the pioneer in developing open sea cage faming in India and popularising the technology through frontline demonstrations in different maritime states. Cage fish farming is a low impact farming practice with high economic returns which provides 10-12 times yields when compared with pond fish culture (Rao *et al.*, 2013). With successful demonstrations in the sea, cage culture was also introduced in the estuarine and coastal waters in different parts of the country. Cage farming is currently being practiced successfully by the fisherfolk and fish farmers in Kerala, Tamil Nadu, Karnataka, Goa and Gujarat.

Cage farming offers tremendous scope for boosting the fish production in the country from the marine, estuarine and coastal waters of the country. The vast water resources and conducive environmental conditions in the coastal waters are excellent for large scale cage farming. Multispecies cage farming can be developed in a commercial way with minimum investment in the country. Cage farming could be taken up as a highly profitable alternate avocation by the fishermen individually or in groups. The comparatively low initial investment cost and recurring expenditure, ease of operations, short duration of culture and high returns per unit volume makes cage aquaculture a widely accepted farming practice.

Economic viability plays a crucial role in successful adoption of any farming technology. The initial investment and recurring expenditure associated with development and maintenance of infrastructure are low in cage farming when compared to shore based farming practices. Gross income realised through cage farming is high since high value fishes having great demand in the domestic as well as export markets are cultured. The market opportunities for cage farmed fishes are plenty both in the domestic and export sectors owing to its superior quality and freshness. Economic viability and financial feasibility analysis helps the farmers and fisherfolk for making investment decisions and efficient allocation of scarce resources to achieve the maximum economic benefits. The economic indicators also assist in developing lending policies, repayment options or subsidies to the sector by policy makers or financial institutions. CMFRI has standardised cage farming protocols for different types of cages in sea, estuaries and coastal waters. The factors affecting the economic viability of cage farming and the indicative economics of cage farming for different dimensions of cages calculated based on costs and revenues in a single farming season are discussed in the given sections.

II. Factors affecting economic viability of cage farming

The economic viability of cage farming depends on the availability and selection of suitable sites, capital and operational expenses, yield, market potential, promotional schemes and policies of government.

1. Site selection for cage farming

Selection of suitable site for cage farming is a very important criteria considering the economic viability of cage farming. It decides the success of cage farming as well as capital investment, operational expenses, yield and mortality rates. Areas prohibited for aquaculture activities by the regulatory authorities should be avoided for installation of cages. The site should be away from other uses like navigational routes, fisheries, tourism or marine protected areas etc. In the case of open sea cage farming, care need to be taken to ensure appropriate lease rights or legally valid authorisation to the fishermen groups, self-help groups, or fishermen cooperatives prior to installation of cages. Environmental or topographical aspects in the site also should be given due weightage before selecting the cage sites. The major factors considered for selection of cage sites consists of depth of water body, carrying capacity, water quality requirements, winds, waves, currents, tides and bottom substrate. Geographical information systems can be effectively applied for the analysis of environmental issues in coastal zones for assessing suitability for aquaculture activities.

1.1. Depth of water bodies

The usual depth of a cage is 4-6 m and a depth of water of 6-10 m at low tide is ideal for seacage farming. Sufficient depth under the cage is necessary in order to maximise water exchange, avoid oxygen depletion, accumulation of waste etc. The selected sites should be free from industrial, domestic or agricultural pollutants.

1.2. Environmental carrying capacity

The carrying capacity is the maximum level of production that a particular site is expected to sustain. Intensive farming results in accumulation of wastes and deterioration of water quality which may lead to mortality of fishes. Less intensive farming may lower the productivity. It is extremely necessary to assess the carrying capacity of the sites to ensure economically viable and sustainable production systems.

1.3. Water quality requirements

Ensuring proper quality of water is an essential criteria for any aquaculture activity. The major water quality parameters considered for site selection in cage farming consists of temperature, salinity, dissolved oxygen, pH, turbidity, inorganic nitrogen, total inorganic phosphorous, chemical oxygen demand, chlorine, heavy metals, and pesticides.

Table 1. Water quality requirements for site selection in cage farming

	Particulars	Effects	Preferred range
1.	Temperature	Affects metabolic rate and growth of fishes	26-28^{0}C
2.	Salinity	Affects ionic balance of fishes and growth	25-40 ppt
3.	Dissolved oxygen(DO)	Required to perform the essential functions such as respiration, digestion, assimilation of food, maintenance of osmotic balance and activity	>6 mg l^{-1}
4.	pH	Impacts toxicity of several pollutants in water	7.8-8.4
5.	Turbidity (decreased ability of water to transmit light caused by suspended particles)	High levels of suspended solids causes mortality of fishes	<2 mg l^{-1}.
6.	Inorganic nitrogen	Indicates the degree of pollution and chronic exposure increases susceptibility to diseases and reduces growth	<0.1 mg l^{-1}
7.	Total inorganic phosphorus	Phosphorus is needed for growth of fishes, but excess concentrations results in algal blooms	<0.015 mg l^{-1}
8.	Chemical Oxygen Demand(COD)	It is the amount of oxygen required to oxidise all the organic matter in water	<1 mg l^{-1}.
9.	Chlorine	Toxicity to fish	<0.02 mg l^{-1}.
10.	Heavy metals like Mercury, Lead and Copper	Toxicity to fish	Mercury <0.05 mg l^{-1} Lead <0.1 mg l^{-1} Copper<0.02 mg l^{-1}
11.	Pesticides from agricultural runoff, industrial effluents and aquaculture farms	Bioaccumulation of pesticides such as DDT, Aldrin, Dieldrin, Heptachlor, Chlordane etc. in fish	<0.025 µg l^{-1}.

Source: Rao *et al.*, 2013

1.4. Winds, waves, currents and tides

Moderate wind is beneficial to cage farms whereas strong winds generated by cyclones can destroy the cage structure as well as fish stocked in cages. Areas having strong wind action should be avoided for cage installation. For floating cages in the sea, wind velocity should not exceed 10 knots. Wave height is influenced by wind velocity and wave energy increases proportionately with square of wave height. The maximum limit for wave height is 1m. A weak and continuous current stream is favourable to cage farming whereas excessive current damages floating structures, cages and adversely affect the fish behaviour. The permissible limit of current velocity for cage farming is 0.05-1 ms^{-1}. The current velocity reaches up to 1.2 ms^{-1} in many places in the Indian coast and such areas should be avoided for marine cage farming. Similarly tide amplitude of <1m preferred for marine cage culture. Monsoon season is avoided for marine cage farming as the current velocity is unpredictable during this period.

1.5. Bottom substrate

A sandy or gravel bottom is generally preferred for cage installation whereas a muddy or rocky bottom cause difficulties for safe anchorage of cages (Rao *et al.,* 2013)

2. Components of costs and revenue in cage farming

The cage production system consist of a floating structure, net materials and mooring system with round or square shaped net cage to hold and grow fishes and can be installed in sea, lakes, rivers or reservoirs. The major components of cost in cage farming are capital and operational costs. The capital cost component includes investment in cage frame, nets, accessories, mooring, and installation charges. The other items included under capital cost consist of miscellaneous items for storage and transportation of feed and fish. Annual fixed cost is calculated from total investment cost based on depreciation and interest on fixed capital. The depreciation for cage frame is calculated for an expected life of 7 years for sea cages and 5 years for backwater and estuarine cages. The depreciation on nets, floats and accessories were calculated for an expected life of 5 years. The major operational cost components includes costs of feed, seed, labour charges for feeding and harvesting and maintenance costs for cage frame and accessories. The costs and revenues in open sea, estuarine and brackishwater areas showed variations with respect to size and materials used for cage frame, accessories and mooring system, types of fish cultured, stocking density, feed and maintenance costs.

Table 2. Components of costs and revenues in cage farming

I.	Capital Investment
1.	Cost of cage frame
2.	Cost of nets
3.	Cost of floats and accessories
4.	Mooring and installation charges
	Total fixed cost(1+2+3+4)
5.	Depreciation (20%)
6.	Interest on fixed capital (12%)
	Annual Fixed cost (5+6) –A
II.	Operational costs
7.	Cost of seed
8.	Cost of feed
9.	Labour charges
10.	Boat hiring, harvesting and miscellaneous expenses
11.	License fee
	Total operational cost (7+8+9+10+11) -B
	Total cost(A+B)
III.	Returns
12.	Production (kg)
13.	Price(₹/kg)
	Gross revenue(12x13)

The following economic indicators were calculated based on costs and revenues in cage farming.

Table 3. Economic indicators

1.	Net profit	Gross revenue-Total cost
2.	Operating ratio	Operating cost/Gross revenue
3.	Net present value (NPV)	$\sum_i Bi/ (1+r)^i\}-\{\sum_i Ci/1+r)^i$
4.	Benefit cost ratio (BCR)	$\{\sum_i Bi/ (1+r)^i\}/\{\sum_i Ci/1+r)^i\}$
5.	Internal rate of return (IRR)	$NPV= \sum_i Bi/(1+r)^i-\sum_i Ci/1+r)^i=0$

Note: Bi is the total revenue in year i, Ci is the total costs in year i, i is the no of years of farming and r is the discount rate.

IRR of an investment is the discount rate at which the net present value of costs (negative cash flows) of the investment equals the net present value of the benefits (positive cash flows) of the investment.

2.1. Capital Investment

2.1.a. Cage frame and accessories: A fish cage system consists of 4 components, namely the floating collar, cage net, anchor and the mooring system. Floating type cages are practiced in Indian waters. Sea cages are preferably circular-shaped as they can withstand sea conditions better than rectangular or square shapes. Circular cages also make most efficient use of materials and lowest cost per unit volume. The cage frame should be made of strong, durable and non-toxic materials. The cage frame for open sea can be made from galvanised iron (GI), High Density Poly Ethylene (HDPE), Poly Vinyl Chloride (PVC), aluminium, timbre or plastic materials. Metals and wooden frame require coating with water resistant paint.

Cage frames are fabricated to withstand rough conditions in the Indian seas. HDPE pipe PE100 or B/C Class GI pipes (1.5”) are preferred for cage frames. HDPE cages are light weight and long lasting whereas galvanised iron cages are cost effective. HDPE cages are recommended for open sea cage farming in India and GI cages for protected bays, estuarine waters and brackish water areas. Square cages are commonly used for coastal cage farming. Based on trials conducted in various locations and techno-economic feasibility, CMFRI has identified 6m diameter cage as the ideal size for sea cage farming. The 6m dia GI cage is provided with a hand rail of 100-120 cm tall connected using vertical and diagonal supports above the base collar. For floatation, 10 barrels of 200 l capacity filled with 30 lb air are used. The GI cage structure is coated with single coat epoxy primer and double coat epoxy paint to prevent corrosion (Philipose and Sharma, 2012, Rao *et al.*, 2013).

2.1.b. Cage nets: The cage designs developed by CMFRI consist of three types of nets. The outer predator net to protect fishes from predators, an inner net for stocking fishes and a bird net for protecting the stock from birds. Cage nets are made of HDPE and the mesh size varies with the size of fish stocked. Outer net is essential to prevent entry of predators into the cage. Considering the strength, durability and cost factor, usually braided HDPE netting of 3 mm thickness and 60 mm/ 80 mm mesh size is recommended. The recommended dimension of predator net is 7 m diameter and 6 m depth.

Hapa/ nursery and growout nets are essential for fish rearing at different stages of their growth. Fine meshed velon, nylon or HDPE material of 10-16 mm mesh size is used as hapa/nursery nets. Grow-out nets are normally made of twisted HDPE twine of 1.5-2 mm thickness and is 18 mm/25 mm/40 mm/60 mm mesh size depending on the size of the fish stocked. A protective bird net of nylon/ HDPE of 60-100 mm mesh size must be overlaid on the cage to prevent predatory birds.

2.1.c. Mooring System: Mooring system/assembly holds the cage in desired position and at desired depth using mooring lines, chains and anchors. Gabion boxes (mesh boxes filled with rocks or concrete blocks) of 3 m x 1.5 m x 1m filled with 3-5 tonnes of dead weight and mild steel mooring chains of 10-14 mm can be used for mooring. An alternate mooring line of 22 mm pp rope or 20 mm iron rope is also required for providing additional safety to the cage in the sea. Fixed mooring system is recommended for estuaries and back waters. In fixed mooring long posts are driven into the bottom bed and the cage is attached directly either with ropes or with metal hooks or tyres. The expected life span of cage structure with mooring system is assumed as 7 years and that of nets and floats as 5 years with additional annual costs of maintenance.

2.2. Operational costs

The major components in operational cost consists of feed, seed, labour charges, boat hiring, harvesting and maintenance costs for cage frame and accessories.

2.2.a. Seeds: Cobia (*Rachycentron canadum*), Silver Pompano (*Trachinotus blochii),* Asian Seabass (*Lates calcarifer*), Snappers (Lutjanus sp.), Groupers (*Epinephelus* sp.) and Spiny Lobster (*Panulirus* sp.) are suitable species for sea cage farming. The seed cost vary with size of fingerlings and stocking density. The average cost per seed varies from ₹20-50 for cobia, pompano and seabass depending on the size of the fingerlings. The seeds of cobia, pompano, Asian seabass and groupers are produced by a few government owned and private hatcheries in the country.

2.2.b. Feeds and feeding: Like in any other aquaculture operations, in cage farming also a significant share in the operational expenses goes for feeds and feeding. Feed costs constitute nearly 50-75% of operational expenses. By developing cost effective feeds and judicious scheduling of feeding the economic benefits of cage farming can be maximized. It also minimizes feed wastage and environmental pollution. The recommended feeding rate is 10% of the body weight for juveniles which can be reduced to 3% as fish grows with progress in culture. The cost of feed varies from ₹20-25/ kg for trash fish and ₹75-90/kg for formulated feed. Proper storage of feeds is essential to maintain the quality. Cold storage preservation or freezers are preferred for storage of feeds to maintain quality (NFDB, 2018, Rao *et al*., 2013).

2.2.c. Cage maintenance: Cage maintenance involves routine monitoring for adjusting the feeding, monitoring of environmental parameters, diseases or predators to minimise operational costs to achieve maximum economic benefits. The entire structure including cage frame and mooring needs to be routinely inspected and necessary maintenance and repairs should be carried out. Timely exchange of net cage by replacing with fresh one, cleaning of nets and mending of damaged nets are also essential to ensure water quality and to facilitate faster growth of fishes.

III. Economic viability of sea cage farming

Open sea cage farming was initiated in India by the CMFRI in 2007 with the support of Ministry of Agriculture, Government of India and National Fisheries Development Board (NFDB). CMFRI has conducted successful cage farming demonstrations in Kerala, Tamil Nadu, Andhra Pradesh, Karnataka, Goa and Gujarat. With the development of low cost cages, seed production techniques for high value finfishes, participatory mode of cage farming and promotional schemes of State and Central Government Organisations there was a rapid expansion in cage farming among the fisherfolk and fish farmers in the country.

The economic indicators of cage farming varies with cage size, species of fish, stocking density, quantity and cost of feed, expenses for cage maintenance, survival rate, yield and prices of fish. Circular cages of 6m diameter and 5m depth is recommended by CMFRI for farming in Indian waters. The recommended stocking

Fig.1. Sea cage farming

density varies from 3000 numbers of Asian seabass or 1000 numbers of cobia or 4500 numbers of silver pompano in a sea cage of 141 m^3 to yield maximum economic benefits. Under favourable farming conditions sea bass grow to a size of 1.5 kg, cobia 3 kg and silver pompano 0.5 kg within a culture period of 7 months (Table 4).

Table 4. Recommended stocking density and weight at harvest in a 6 m diameter, 5 m deep cage (141 m^3) for a culture period of 7 months

Species	Stocking density (Nos)	Weight at harvest (kg)
Sea bass	3000	1.5
Cobia	1000	3
Pompano	4500	0.5

The indicative economics of sea cage farming of cobia, pompano and sea bass for circular HDPE cages of 6 m dia is discussed below. The initial investment for 6m dia HDPE cage frame with mooring and accessories in the open sea is ₹3 lakhs. The annual fixed cost calculated with an expected life of 7 years at 12% interest rate is ₹83,429 (Table 5).

Table 5. Investment and annual fixed cost of 6m diameter HDPE cage in the open sea

	Particulars	Amount(₹)
I.	Capital investment	
1.	Cost of HDPE cage frame	140000
2.	Mooring materials	80000
3.	Nets (2 Inner net and one outer net with ballast pipe)	80000
	Sub Total	300000
4.	Depreciation	47429
5.	Interest on fixed capital	36000
6.	Annual fixed cost(A)	83429

3.1. Cobia

Cobia (*R. canadum*) is one of the most preferred fishes for mariculture in the world. It has a very fast growth rate and attains weight upto 4-5 kg within one year. The species is very much suitable for farming in floating as well as submerged cages and fetches high price both in domestic and export markets. Cobia has been successfully cultured in the open sea in various maritime states of the country through frontline demonstrations of CMFRI and participatory cage farming with the involvement of fisherfolk. The indicative economics of cobia farming in 6m dia HDPE having an average yield of 2.4t realised a net profit of 3.34 lakh per cage. Sea cage farming of cobia proved to be an economically viable technology generating an internal rate

Fig.2. Cobia harvested from sea cages

of return of more than 60% and benefit -cost ratio of more than one calculated for a project period of 7 years with 15% discount rate (Table 6).

Table 6. Economic performance of open sea cage farming of cobia in ₹.(Cage dimension: 6 m dia x 5 m depth, Culture period: 7 months)

	Particulars	Amount(₹)
I.	Annual fixed cost(A)	83429
II.	Operating costs	
1.	Seed (Cost of 1000 numbers of cobia seeds @ ₹25/seed & transportation charges)	25000
2.	Feed (Cost of 10 tonnes of low value fishes @ ₹20,000/tonne)	200000
3.	Labour Charges @ ₹6000/month for 7 months	42000
4.	Boat Hire & Fuel Charges	10000
5.	Harvesting & Miscellaneous Expenses	15000
6.	Total operating cost (B)	292000
7.	Total cost(A+B)	375429
III.	Returns	
8.	Production (weight at harvest 3kg with 80% survival rate)	2400kg
9.	Gross revenue @₹300/kg	720000

10.	Net profit	344571
11.	Cost/ kg of fish(₹)	156
12.	Price/ kg of fish(₹)	300
13.	Operating ratio	0.41
14.	NPV(₹)	1003930
15.	BCR	1.58
16.	IRR	68%

Note: The feed cost in the case of formulated feed will be @ ₹90/kg @FCR value of 1:2

3.2. Sea bass

Asian seabass, *Lates calcarifer* which has fast growth rate, tolerance to varying salinity levels, crowding and temperature variations is highly suitable for cage farming in marine, estuarine and coastal waters. The well-established hatchery and nursery rearing protocols and good market price makes it a candidate species for large scale cage farming. CMFRI has standardised culture of seabass in different types of cages in the marine, estuarine and brackishwater areas with good economic returns (Rao *et al.*, 2013). The culture of seabass in HDPE cages of 6m dia in the

Fig.3. Asian seabass

open sea yielded gross revenue of ₹10 lakhs and net profit of ₹5.59 lakhs within a culture period of 7 months. The average cost of production was ₹176/kg whereas the average market price was ₹400 /kg. The high B-C ratio (1.86) and internal rate of return (95%) makes it a highly viable species for cage farming (Table 7).

Table 7. Economic analysis of open sea cage farming of Asian sea bass (Cage size: 6 m diameter x 5 m depth, Culture period: 7 months)

	Particulars	Amount (₹)
I.	Annual fixed cost (A)	83429
II.	Operating costs	
1.	Seed (Cost of 3000 Numbers of seabass seeds @ ₹30/seed & Transportation charges)	90000
2.	Feed (Cost of 10 tonnes of low value fishes @ ₹20,000/tonne)	200000
3.	Labour Charges @ ₹6000/month for 7 months	42000
4.	Boat Hire & Fuel Charges	10000
5.	Harvesting & Miscellaneous Expenses	15000
6.	Total operating cost(B)	357000
7.	Total cost(A+B)	440429
III.	Returns	
8.	Production	2.5 tonnes
9.	Gross revenue @₹400/kg for 2.5 tonnes	1000000
10.	Net profit	559571
11.	Cost/ kg of fish(₹)	176
12.	Price/ kg of fish(₹)	400
13.	Operating ratio	0.36
14.	NPV	1752593
15.	BCR	1.86
16.	IRR	95%

3.3. Silver Pompano

CMFRI has developed the seed production technology of silver pompano *Trachinotus blotchi* in India. Silver pompano is one of the most preferred fishes for sea cage farming due to its fast growth, high survival rate, salinity tolerance, good meat quality and high market demand (Gopakumar *et al.*, 2012). Pompano requires highly nutritive feed and CMFRI has successfully demonstrated farming using the extruded floating pellet feed. The FCR varies from 1.8-2.0 using pellet feed (Jayakumar *et al.*, 2014).

Fig.4. Harvested Silver Pompano

Table 8. Economic analysis of open sea cage farming of Pompano (Cage size: 6 m diameter x 5 m depth, Culture period: 7 months)

	Particulars	Amount(₹)
I.	Annual fixed cost	83429
II.	Operating costs	
1.	Seed (Cost of 4500 Numbers of pompano seeds @ ₹20/seed)	90000
2.	Transportation	10000
3.	Feed (Pellet feed@ ₹76/kg (FCR: 1.8:1))	273600
4.	Labour Charges @ ₹6000/month for 7 months	42000
5.	Boat hire & fuel Charges	10000
6.	Harvesting & Miscellaneous Expenses	15000
7.	Total operating cost(B)	440600
8.	Total cost(A+B)	524029
III.	Returns	

	Particulars	Amount(₹)
9.	Production (Weight at harvest: 0.5 kg (90% survival)	2 tonnes
10.	Gross revenue @₹350/kg for 2 tonnes	700000
11.	Net profit	175971
12.	Cost/ kg of fish(₹)	262
13.	Price/ kg of fish(₹)	350
14.	Operating ratio	0.63
15.	NPV	217266
16.	BCR	1.09
17.	IRR	25%

Cage farming of pompano in HDPE cages of 6m dia yielded gross revenue of ₹7 lakhs with a stocking density of 4500 nos/ cage and 90% survival. Even though the returns are comparatively lesser than cobia or sea bass culture, the farming is economically feasible with a BCR of 1.09 and IRR 25% (Table 8).

The country with a coastline of 8139 km including protected bays and islands, sea cage farming offers tremendous scope for boosting the fish production. Sea cage farming is a boon to the marine capture fisheries sector of the country which at present experiences serious setback due to overexploitation, climate change and unregulated fishing activities. The decline in marine catches coupled with rising fishing costs affected the livelihood security of coastal fisherfolk and sea cage farming could be promoted successfully as an alternate avocation for enhancing their income.

IV. Economic viability of cage fish farming in the coastal waters

Cage farming has great potential for augmenting fish production in the coastal and brackish water areas of the country. India is bestowed with 1.2 million ha of brackish water areas mostly in the states of Kerala, Karnataka, Goa, Maharashtra, Odisha and West Bengal**.** The major species suitable for culture in the brackish water are Asian seabass (*Lates calcarifer)*, pearlspot (*Etroplus suratensis)*, tilapia (*Oreochromis sp.*), mullet (*Mugil* cephalus.), redsnapper and caranx. Mullet and Tilapia can be grown in cages with low input cost in terms of seed and feed. Seed production techniques for mullet, redsnapper (*Lutjanus argentimaculatus*) and *Caranx* sp are not developed in the country and these fishes are cultured through capture based aquaculture, whereby the juveniles of the fishes are caught alive and allowed to grow to marketable size in cages.

Fig.5. Cage farming in the coastal waters of Kerala

The cage dimensions adopted by the farmers varied widely for farming in the coastal waters from 2x2x1.5m^3 (6m^3), 4x4x2m^3 (32m^3), 8x4x2m^3 (64m^3), 4x4x4m^3 (64m^3), 8x4x4m^3 (128m^3) and 6x6x4m^3 (144m^3). The recommended size of cages in the coastal waters considering the operational efficiency and profitability is 48m^3 (4x4x3m^3). The stocking density varied with cage volume and species of fishes in the coastal areas. In coastal waters composite culture of seabass along with pearl spot is preferred as the latter helps in cleaning of nets, provides better market opportunities and returns to farmers.

The economic performance of cage farming of different species of fishes in various cage dimensions were calculated for comparing the profitability. Composite farming of seabass along with pearlspot was found to be more profitable than farming of single species. Pearlspot grows faster under cage farming conditions and has very tasty flesh and good market potential. Based on economic feasibility, CMFRI has recommended square GI cage of 4x4x3m^3 (48m^3) for the coastal waters. However cage size adopted by the farmers varied depending on the depth of water, ease of operations and resource availability. A standard 48 m^3 cage with a recommended stocking density of 1400 numbers of seabass along with 500 numbers of pearl spot yielded gross revenue of ₹6.27 lakhs and net profit of ₹3.28 lakhs in a 7 months culture period. The farming received an internal rate of return of 90% and B-C ratio of 1.55 (Table 9).

4.1. Composite culture of seabass with pearlspot

Table 9. Economics of composite culture Sea bass with Pearl spot (Cage Dimension 4x4x3 m^3 (48m^3) Culture period: 7 months)

	Particulars	Amount(₹)
I.	Capital investment	
1.	Cage frame (1.25 inch B glass pipe with ISI)	25000
2.	Mooring and Floats(8nos for each cage)	15000
3.	Nets	25000
4.	Freezer and accessories	20000
5.	Sub Total	85000
6.	Depreciation (20%)	17000
7.	Interest on FC (12%)	10200
8.	Annual Fixed cost(A)	27200
II.	Operational costs	
9.	Licence fee	1500
10.	1400 seabass seeds @ ₹30/seed	42000
11.	500 Pearlspot seeds @ ₹15/seed	7500

	Particulars	Amount(₹)
12.	Nursery rearing (Hapa)	2000
13.	Feed(Trash fish/ floating feed)6000 kg@₹25/kg and 134 kg pellet feed@₹ 50/kg	156700
14.	Labour 2 hrs/day@₹100 for 7months	42000
15.	Harvesting and miscellaneous expenses	20000
16.	Total operational cost(B)	271700
17.	Total cost(A+B)	298900
III.	Returns	
18.	Production((1500 kg seabass and 67 kg pearlspot)	1567kg
19.	Gross revenue(@₹400/ kg of fish)	626800
20.	Net profit	327900
21.	Cost/ kg of fish(₹)	191
22.	Price/ kg of fish(₹)	400
23.	Operating ratio	0.43
24.	NPV	6,35,760
25.	BCR	1.55
26.	IRR	90%

Note: Depreciation on cage frame and accessories were calculated using straight line method with an expected life of 5 years. The financial indicators such as NPV, BCR and IRR were calculated for a project period of 5 years at 15% discount rate.

Fig.6. Cage farming in 4x4x3m^3 cages

Large cages of $8x4x4m^3$ size can be installed in brackish water areas with sufficient depth. The economic viability of composite cage farming of seabass with pearlspot was also analysed for comparing the profitability. The gross revenue realised was ₹12 lakhs by stocking 3000 numbers of seabass and 1000 nos of pearlspot. The internal rate of return was 104% with a benefit cost ratio of 1.62 (Table 10).

Table 10. Economics of composite culture of seabass with pearl spot in coastal waters (Cage dimension $8x4x4m^3$, culture period: 7 months)

	Particulars	Amount(₹)
I.	Capital Investment	
1.	Cage structure including floats, nets and cage frame	80000
2.	Accessories- freezer, baskets	20000
	Sub total	100000
3.	Interest on FC (12%)	12000
4.	Depreciation (20%)	20000
5.	Annual fixed cost-A(3+4)	32000
II.	Operational costs	
6.	License fee	1500
7.	Labour@ ₹12000/month for 7 months	84000
8.	Seed (sea bass 3000nos @₹30 and Pearlspot 1000nos@₹15)	105000
9.	Feed (11520 kg trash fish @₹25/kg for seabass(FCR:4:1) and 240 kg pellet feed @₹ 50/kg for pearlspot(FCR:2:1))	300000
10.	Miscellaneous expenses :transport, harvest	25000
11.	Total Operational cost(B)	515500
12.	Total cost (A+B)	547500
III.	Returns	
13.	Production (Seabass 2880 kg & Pearlspot 120 kg)	3000 kg
14.	Gross Revenue (@₹400/kg)	1200000
15.	Cost/ kg of fish(₹)	183
16.	Price/ kg of fish(₹)	400
17.	Net profit	6,52,500
18.	Operating ratio	0.43
19.	NPV	13,17,389
20.	BCR	1.62
21.	IRR	104%

The department of fisheries, Government of Kerala provide financial assistance for self- help groups for promoting cage farming in the brackish water areas. The recommended size of cages for receiving financial assistance was $6m^3$ for a unit consisting of 10 cages per each self-help group. The economic viability of such small size cages was also assessed in the brackish water areas in Kerala. These types of cages are suited for locations where the depth of open water bodies are low. The small size also facilitate easy maintenance of cages at a lower cost. The stocking density adopted was 200 numbers of seabass along with 20 numbers of pearlspot. The farming was economically viable even though yielded comparatively lower returns compared to bigger sized cages. The gross revenue realised was ₹77,880 with an IRR of 50 %(Table 11).

Table 11. Economics of Composite culture Sea bass with Pearlspot (Cage Dimension 2x2x1.5 m^3 ($8m^3$), Culture period: 7 months)

	Particulars	Amount(₹)
I.	Capital investment	
1.	Cage structure including floats, nets and cage frame	20000
2.	Accessories- freezer, baskets	10000
	Sub total	30000
3.	Interest on FC (12%)	3600
4.	Depreciation (20%)	6000
5.	Annual Fixed cost(A)	9600
II.	Operational costs	
6.	Licence fee	750
7.	Seed(Stocking density 200 Seabass + 20 Pearlspot)	6300
8.	Labour cost @₹1200/month for 7months	8400
9.	Feed (FCR 3:1) 576 kg trash fish @₹ 25/kg	14400
10.	Miscellaneous expenses transport, harvest	5000
11.	Total Operational cost(B)	34850
12.	Total cost (A+B)	44450
III.	Returns	
13.	Production(192 kg seabass and 2.7 kg Pearl spot)	194.7 kg
14.	Gross Revenue (@₹400/kg)	77880
15.	Cost/ kg of fish (₹)	228
16.	Price/ kg of fish (₹)	400
17.	Net profit	33430
18.	Operating ratio	0.45
19.	NPV	51150
20.	BCR	1.30
21.	IRR	50%

Note: Labour cost was calculated with the assumption of 2hrs /day of work by 2 persons for managing 10 small cage units

Fig.8. Cage farming in $2x2x1.5m^3$ cages in the brackish water areas

4.2. Tilapia

Tilapia is the second most farmed fish in the world. It has high tolerance to variable water quality and can grow in both freshwater and low saline environments. Nile tilapia, *Oreochromis niloticus* is the most farmed Tilapia in India. World Fish and partners developed an improved strain of tilapia, called Genetically Improved Farmed Tilapia (GIFT) which is fast growing and adaptable to a wide range of

Fig.7. GIFT Tilapia

environments. Tilapia is sturdy and has good disease resistance which can be grown at a low cost with pellet feed.Even though it is mostly grown in pond culture system, it can be successfully grown in cages. The state departments of fisheries have leasing and licensing procedures for culture of Tilapia in open water bodies (NFDB, 2015). Tilapia can be grown successfully in the coastal water cages with good economic returns. 6000 numbers of Tilapia can be stocked in a GI cage of 8x4x4 m^3. The initial investment cost of 8x4x4 m^3 cage is ₹80,000. The average yield obtained for a culture period of 6 months is 2880 kg with net profit of ₹1.36 lakhs. The farming is economically viable with BCR of 1.11 and IRR 31 %(Table 12).

Table 12. Economics of Tilapia culture in coastal water cages
(Cage dimension: 8x4x4 m^3, Culture period: 6months)

	Particulars	Amount (₹)
I.	Capital investment	
1.	Cage structure including floats, nets and cage frame	80000
2.	Accessories: Freezer, baskets	20000
	Sub total	100000
3.	Interest on FC (12%)	12000
4.	Depreciation (20%)	20000
5.	Annual Fixed cost(A)	32000
II.	Operational costs	
6.	Licence fee	1500
7.	Seed (6000 nos@₹5)	30000
8.	Labour(@₹6000/month for 6 months)	36000
9.	Feed(3600kg@₹50/kg)	1,80,000
10.	Harvesting &Miscellaneous expenses	10000
11.	Total Operational cost(B)	2,57,500
12.	Total cost (A+B)	2,89,500
III.	Returns	
13.	Production(kg)	2880 kg
14.	Gross Revenue(@₹150/kg)	4,32,000
15.	Net profit	1,42,500
16.	Cost/ kg of fish(₹)	101
17.	Price/ kg of fish(₹)	150
18.	Operating ratio	0.60
19.	NPV	1,19,351
20.	BCR	1.11
21.	IRR	31%

V. Economic viability of cage farming in the estuarine waters

The estuarine waters in India are highly productive and serve as habitat for many fish nurseries. Climate change and anthropogenic activities led to salinization of estuaries and decline in fish catches which has affected the livelihood security of small scale fishermen depending on estuarine fisheries. Cage fish farming in the estuarine waters can be recommended as a livelihood security option for the small scale fisherfolk depending on estuarine fisheries. Seabass, snappers, pearl spot and carangids can be reared in the estuaries. The Central Marine Fisheries Research Institute has also taken up the initiative for popularising cage fish farming in the estuarine waters in the country. The most popular cage dimension suited to the estuaries in the south west coast of India is of 6 x 2 x 2 m^3 with GI pipe as frame and netlon net as inner and outer net cages. Usually nylon ropes are used as mooring ropes and sand bags are used for anchoring the cages. The stocking density is 50 nos/m^3 and the fishes are usually grown upto 10 months.

Fig.9. Redsnapper

The economic indicators calculated for seabass and redsnappers in 6 x 2 x 2 m^3 GI cage is depicted in Table 13. The commercial seed production of red snappers, *L.argentimaculatus* is not developed in the world and is usually cultured under capture based aquaculture. It has good flesh quality and adapt well in various salinities and temperatures. The farming yielded gross revenue of ₹4.62 lakhs and net profit of ₹1.98 lakhs for a culture period of 10 months. The high net returns, BC ratio and internal rate of return proved cage farming an economically viable enterprise in the estuarine waters also.

Table 13. Economics of cage farming in the estuarine waters (Cage dimension: 6m x 2m x 2m (24m^3), Species cultured: red snapper and seabass, Culture period: 10 months)

	Particulars	Amount (₹)
I.	Capital Investment	
1.	Cage frame	20000
2.	Nets	15000
3.	PP Rope, barrels and installation charges	15000
4.	Accessories- freezer, baskets	10000
	Sub total	60000
5.	Interest on FC (12%)	7200
6.	Depreciation (20%)	12000
7.	Annual fixed cost(5+6)	19200
II.	Operating costs	
8.	Labour@ ₹6000/month	60000
9.	Seed cost and Transportation charges	59000
10.	Feed cost (5280kg trash fish and fish cutting waste ₹20/kg)	105600
11.	Miscellaneous expenses : transport, harvest	20000
12.	Total Operational cost(B)	244600
13.	Total cost (A+B)	263800
III.	Returns	
14.	Total production	1,320 kg
15.	Gross revenue@ ₹350/kg	462000
16.	Net profit	198200
17.	Cost/ kg of fish(₹)	199
18.	Price/ kg of fish(₹)	350
19.	Operating ratio	0.53
20.	NPV	305971
21.	BCR	1.30
22.	IRR	59%

Note: Economic indicators were calculated based on Sujitha Thomas & Dinesh Babu, 2016

VI. Marketing opportunities and challenges

Efficient marketing channels are essential components of economically sustainable farming activities. The declining catches from marine capture fisheries together with growing demand for quality fish products in the country offers enormous opportunities for marketing of farmed fishes. The cage farmed fishes are primarily sold through local fish markets or at farm gates and fetch a premium price owing to their superior quality and freshness. Various institutional organisations including CMFRI, State fisheries departments, Cooperative banks and Non-Governmental Organisations involved in promoting cage farming in the country also undertake market promotion activities through online portals, live fish sales or fish harvest melas. However large scale expansion of cage farming necessitates exploring better marketing opportunities in the domestic and overseas markets. Capacity building of small scale fishermen or fish farmers in the country to improve the entrepreneurial capabilities, market promotion through fishermen/farmers co-operatives or Farmer Producer Companies(FPOs), better storage and transport infrastructure and value added products etc. need to be promoted for tackling the future marketing challenges.

Fig.10. Live fish sale during exhibition at ICAR-CMFRI

VII. Promotional schemes and prospects for cage farming

Cage fish farming has got immense potential for generation of income and employment for the coastal fisherfolk population. At present more than 3000 cages are installed across the maritime states in the country with the technical support from CMFRI. These cage farms could yield an aggregate fish production of 5,250 tonnes generating aggregate net benefits of ₹105 crores to the cage fish farmers (calculated at an average net profit ₹3.5 lakhs per cage). An estimated number of 1.57 lakh mandays will be generated through direct employment in these farms for cage maintenance; harvesting and associated works and another 40,000 man-days will be generated in cage fabrication and associated jobs. The labour income earnings to the workers through direct and indirect employment will be ₹13 crores. The input suppliers and dealers of cage frame and accessories will also be benefitted through cage farming. The estimated economic benefit to the seed and feed suppliers is ₹70 crores. The Infrastructure sector consisting of suppliers of GI and HDPE pipes, net makers and accessories dealers also receive benefits to the tune of ₹36 crores.

Central Government and fisheries departments in various states provide financial assistance for promotion of cage farming. The National Fisheries Development Board (NFDB) provides financial assistance for cage farming of finfish in the marine and brackishwater areas under the Centrally Sponsored Scheme on Blue Revolution: Integrated Development and Management of Fisheries. The total admissible government subsidy (Central + State) will be limited to 40% of the project cost/ unit cost for general category beneficiaries and 60% of the project cost/ unit cost for weaker sections like Scheduled Castes (SCs), Scheduled Tribes (STs), women and their co-operatives(NFDB, 2015). Different state governments also introduced promotional schemes for cage farming. Fish farmer's development agency of Govt. of Kerala provides financial assistance for cage farm units owned by self-help groups having a total 60 Cubic meter volume @ ₹3.00 lakh which includes ₹1.8 lakh as infrastructure cost and ₹1.2 lakh as operational cost. The grant is @ 40% of unit cost for new units and @20% of operational cost for the already established units. Government of Goa provides financial assistance through NFDB. The unit cost is ₹5,00,000/- out of which 40% of the unit cost limited to ₹2,00,000/- for General Category and 60% of the unit cost limited to ₹3,00,000/- for Scheduled Castes(SCs), Scheduled Tribes(STs)and Women(www.fisheries.goa.gov.in). Government of Karnataka also provides financial assistance for promotion of marine and brackish water cage farming through various schemes. The increasing interest shown by the banking sector in the country including the National Bank for Agriculture and Rural Development (NABARD) for extending priority sector lending for cage farming shows the prospects of this sector in the future.

Cage fish farming is a highly profitable venture in the marine, estuarine and brackish water areas of the country. Vast unutilised areas in the sea, estuarine and brackish water areas offer promising scope for augmenting fish production through cage farming in the country. However lack of leasing policies and regulatory measures is a major bottleneck for large scale promotion of cage fish farming in the open sea. Hence there is an urgent need for developing policies and regulatory measures with due weightage to environmental carrying capacity and socio-ecological factors. In addition, insurance schemes for mitigating risks due to natural calamities or anthropogenic activities are also necessary for large scale commercialisation of cage farming in the open sea and coastal waters.

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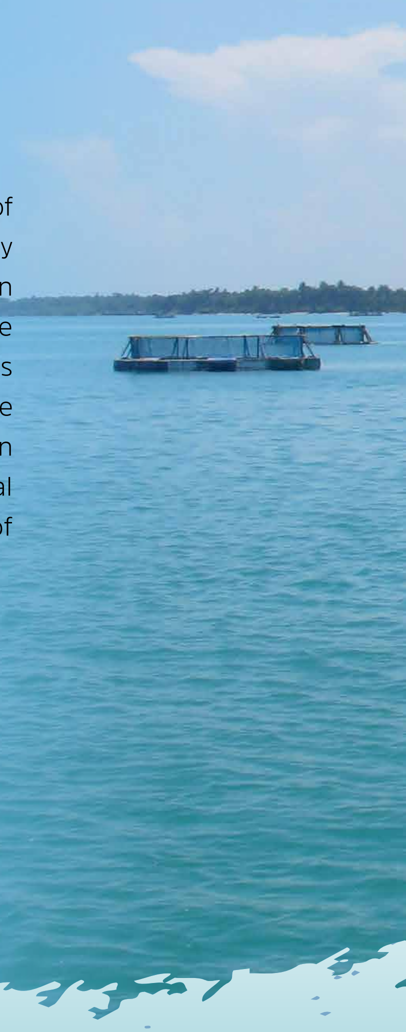
Economic viability of
cage fish farming in India



The CMFRI Special publication on "Economic viability of cage fish farming in India" covers the economic viability aspects of cage farming of different species of fishes in the marine, estuarine and coastal waters based on the investment and operational cost particulars of various types of cages in the country. The factors affecting the profitability of cage farming comprising the site selection particulars, marketing opportunities and promotional schemes are also discussed briefly for the benefit of various stakeholders.

भाकृअनुप
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