Economic Analysis of Mariculture Operations

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India is the third largest fish producing country in the world and occupies second position in global aquaculture production (DAHDF, 2022). The fish production in the country reached 14.73 million t in FY 2020-21 and recorded an outstanding double-digit annual growth of 10.87 per cent since 2014-15. Fisheries sector contributes about 1.24 per cent to the country's GVA and over 7.28 per cent to the agricultural GVA (Economic survey, 2021-22).

Aquaculture is one of the fastest growing animal food sectors and a significant contributor to the global economy. Global aquaculture production including algae reached 214 million t, generating a first sale value of $406 billion in 2020 (FAO, 2022). Mariculture is the culture of organisms in an aquatic medium or environment which may be completely marine, or sea water mixed to various degrees with fresh water. Mariculture hold huge prospects for boosting the fish production and livelihoods across the globe. Mariculture technologies had evolved in India in the 1970^{s} with the introduction of sea weed farming followed by bivalve mariculture in the 1980^{s}. However commercial mariculture began in the country only in the 1990^{s} with mussel and edible oyster farming by the self-help groups in Kerala. The potential mariculture technologies in the country consist of seed production and farming of finfishes (cobia, pompano, sea bass, groupers, snappers, breams and ornamental fishes), shell fishes (mussels, oysters, clams, lobsters, green tiger shrimp, blue swimmer crab, ornamental shrimps) and seaweeds. These technologies offer immense scope for generating substantial revenues and fish production for the country.

Economic analysis occupies crucial role in assessing the prospects of any technology and it helps in devising policies on public expenditure, promotional schemes, subsidy programmes as well as private investment decisions for achieving the desired progress in technology adoption. The economic analysis in mariculture consists of cost-benefit analysis of mariculture operations, economic efficiency analysis, risk analysis and socio-economic impact analysis. Price of aquaculture products and economic viability are key indicators for adoption decisions of innovative aquaculture technologies. The profitability aspects of various mariculture activities, prospects for enhancing production, income and employment and constraints in mariculture expansion are discussed in the following sections. Table 1 presents the economic indicators of a mariculture enterprise.

Indicators of economic performance of a mariculture enterprise

Sl.No.	Economic Indicators
1.	**Initial investment** a)Fixed installations b) Major accessories c) Minor Accessories d) Others
2.	**Total Investment**
3.	**Fixed cost** a)Depreciation b)Insurance c) Interest on fixed capital d) Administrative expenses
4.	**Total Annual Fixed cost (A)**
5.	**Operating costs** a) Cost of seeds b) Cost of feeds c)Costs of harvesting , labour and other costs d) Interest on working capital
6.	**Total Operating or Variable cost (B)**
7.	Total cost of production [(4)+(6)]
8.	Yield of the fish variety (in kg)
9.	Gross revenue [(8) * Price per kg]
10.	Net profit [(9)-(7)]
11.	Net operating income [(9)-(6)]
12.	Cost of production (₹/kg)[(7)/(8)]

Economic and financial feasibility indicators

1.	Net profit	Gross revenue-Total cost (include operational expenses, depreciation and Interest on fixed capital)
2.	Operating ratio	Operating cost/Gross revenue
3.	Input-output ratio	Input cost/ Gross revenue
4.	Return on investment (ROI)	Net profit/Initial investment
5.	Payback period (in years)	Initial Investment /Annual net profit
6.	Net present value(NPV)	$\sum_i Bi/ (1+r)^i\}-\{\sum_i Ci/1+r)^i$
7.	Benefit -cost ratio(BCR)	$\{\sum_i Bi/ (1+r)^i\}/ \{\sum_i Ci/1+r)^i\}$
8.	Internal 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.

Finfish mariculture in India

Mariculture of finfishes in India started with open sea cage farming in 2005 by the ICAR-Central Marine Fisheries Research Institute through development of HDPE cage structures suitable for farming in the open sea. Further refinement of the technology through development of cost effective cages, hatchery techniques for high value finfishes and standardisation of culture protocol paved the way for popularisation of the technology in all the maritime states. Cage farming technology has advantage over other aquaculture technologies in terms of high yield, low initial investment cost, easy maintenance and limited space requirements. Successful cage farming demonstrations were carried out in different maritime states of the country which led to the popularisation of the technology. The major finfishes suitable for marine cage farming in India consists of seabass, cobia, pompano, groupers, snappers, shrimps and lobsters. Integrated multitrophic aquaculture consisting of culture of finfishes along with seaweeds and mussels were also proved successful in various regions of the country. Development of hatchery techniques for high value finfishes, culture protocols, low capital investment, vast areas suitable in marine, estuarine and coastal waters, economic viability and socio-economic feasibility contributed to the success of the technology in the country.

Economics of open sea cage farming

Investment and annual fixed cost of 6m dia HDPE cage for open sea cage farming

	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

Asian sea bass, cobia and silver pompano are the major species cultured through cage farming. 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. 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 open sea yielded gross revenue of ₹10 lakhs and net profit of ₹5.59 lakhs during a culture period of 7 months. (Table).

Cobia (*R. canadum*) is another fast growing fish preferred for open sea cage farming. It attains weight upto 4-5 kg within one year. 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. Cobia farming in 6m dia HDPE cage yielded 2.4 t and realised a net profit of 3.44 lakh per cage. The benefit - cost ratio was 1.58 for a project period of 7 years at 15% discount rate.

Economic analysis of open sea cage farming
(Cage size: 6 m dia x 5 m depth)

	Particulars	Seabass	Amount (₹) Cobia
I.	Annual fixed cost (A)	83429	83429
II.	Operating costs (B)		
1.	Cost of seeds	90000	25000
2.	Cost of feed	200000	200000
3.	Labour charges @ ₹6000/month for 7 months	42000	42000
4.	Boat hire & fuel charges	10000	10000
5.	Harvesting & miscellaneous expenses	15000	15000
6.	Total operating cost(B)	357000	292000
7.	Total cost(A+B)	440429	375429
III.	Returns		
8.	Production	2.5 t	2.4 t
9.	Gross revenue	1000000	720000
10.	Net profit	559571	344571
11.	Cost/ kg of fish(₹)	176	156
12.	Price/ kg of fish(₹)	400	300
13.	Operating ratio	0.36	0.41
14.	Pay-back period(years)	0.53	0.87
15.	NPV	1752593	1003930
16.	B-C Ratio	1.86	1.58
17.	IRR	95%	68%

Source: Aswathy *et al*., 2020

Cage farming in the coastal waters

Cage farming has great potential for augmenting fish production in the coastal and brackish water areas of the country. The major species suitable for culture in the brackish water are Asian seabass (*Lates calcarifer)*, pearlspot (*Etroplus suratensis)*, tilapia (*Oreochromis sp.*), mullet (*Mugil* cephalus), red snapper and caranx. The recommended size of cages in the coastal waters considering the operational efficiency and profitability is $48m^3$($4x4x3m^3$). 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 average stocking density of the selected cage farm units was 1400 numbers of seabass and 500 numbers of pearl spot. Seabass was fed with trash fish whereas formulated feed was given for pearl spot. The culture period varied from 7-10 months. The average production per cage was 1500 kg of seabass and 67 kg of pearl spot. For Tilapia farming, the average production was 2880 kg in a 128 m^3 cage, with a gross revenue of ₹4,32,000. The B-C ratio was higher for seabass (1.55) compared to tilapia farming (Table).

Economics of coastal cage farming

	Particulars	**Sea bass with Pearl spot** $4x4x3m^3$	**Tilapia** $8x4x4\ m^3$
I.	**Capital investment**		
1.	Cage structure including floats, nets and cage frame	65000	80000
2.	Accessories: Freezer, baskets	20000	20000
	Sub Total	85000	100000
3.	Depreciation (20%)	17000	20000
4.	Interest on FC (12%)	10200	12000
5.	**Annual Fixed cost(A)**	27200	32000
II.	**Operational costs**		
6.	Licence fee	1500	1500
7.	Seeds	51500	30000
8.	Feed(Trash fish/ floating feed)	156700	1,80,000
9.	Labour cost	42000	36000
10.	Harvesting and miscellaneous expenses	20000	10000
11.	**Total operational cost(B)**	**271700**	**257500**
12.	**Total cost(A+B)**	**298900**	**289500**

III.	**Returns**		
13.	Production	1567 kg	2880 kg
14.	Gross revenue	626800	432000
15.	Net profit	327900	1,42,500
16.	Cost/ kg of fish(₹)	191	101
17.	Price/ kg of fish(₹)	400	150
18.	Operating ratio	0.43	0.60
	Payback period(years)	0.26	0.70
19.	NPV	635760	119351
20.	B-C Ratio	1.55	1.11
21.	IRR	90%	31%

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

Source: Aswathy *et al.*, 2020

A macro level economic impact assessment of the sea cage farming technology using economic surplus model indicated that the technology holds huge potential in terms of economic benefits and welfare to the society. The net present value (NPV) during 2005 to 2030 period was estimated at ₹5260 crores and the return to research investment was 48%. Though the technology holds immense potential for augmenting fish production and generating revenues, the large scale commercialisation is constrained by lack of suitable mariculture policies and regulations. The prospects of cage aquaculture in India lies in developing cost effective technologies for seed production, feed and hatchery technologies as well as enabling environment in terms of institutions and polices.

Economics of bivalve farming

Bivalves dominate the global aquaculture sector and a significant share of bivalve production comes from aquaculture. Global production of marine bivalves for human consumption is more than 15 million t per year consisting of mussels, edible oysters, scallops and clams. China is the largest producer of marine bivalves, accounting for 85% of the world production. India's bivalve production in 2021 stood at 98,000 t (CMFRI, 2022). The international trade of bivalves got momentum in recent years with increased demand for frozen mussels and oysters. Though bivalve mariculture was initiated in India in the 1980s commercial bivalve mariculture was successful only by the mid-90s with edible oyster and mussel farming by the self-help groups in Kerala (Mohamed, 2015).

Mussel and edible oyster farming are practiced by the coastal fisherfolk in Kerala, Karnataka, Goa and Maharashtra. Stake culture, on-bottom culture, long-line culture, raft culture, rack culture etc. are followed for mussel and oyster farming. Lack of proper marketing opportunities currently constrains the mussel and edible oyster industry in the country. Mussel and oyster farming are economically viable farming practices with low initial investment and recurring expenses. A net return of about ₹88,000 per unit of 200 seeded strings can be obtained through rack method of green mussel farming (Table). The technology adoption of oyster farming technology was low due to lack of consumer demand and difficulty in post- harvest handling.

Economics of of green mussel farming(rack method) in Kerala

Particulars	Details of expenditure (rack of 200 seeded strings)	Amount (₹)
Initial investment		
Rack construction (Poles and rope)	20 bamboo poles @ ₹300/pole; 4 kg of 3-4 mm rope @ ₹ 250 / kg	7,000
Labour charges for rack construction	4 man days @ ₹750/man day	3,000
Gross fixed cost		10,000
Operational costs		
Seed & associated costs in stocking	200 kg of seeds@ ₹50/kg cloth, rope, coir etc.	15,500
Labour charges for stocking	8 female labourers @ ₹400 / person	3,200
Rack maintenance charges	5 man days @ ₹750/man day	3,750
Harvesting charges	2 man days @ ₹ 750/ man day	1,500
Miscellaneous	Canoe hiring and other costs	2,550
Interest on fixed capital	12 % per annum	1,200
Depreciation	33.3 % per annum	3,300
Total cost		31,000
Revenue		
Gross revenue	Total harvest of 1.4 t / rack @ ₹85/kg	1,19,000
Net operating income		88,000
B-C Ratio		3.83

Source: Shinoj *et al.*, 2017

Economics of seaweed farming

The seaweed industry in India is worth $600 million and the sector provides employment to nearly 20,000 people (www.asiafarming.com). India has the potential to produce around 9.7 million t of seaweed per year (CMFRI, 2022). Government of India has earmarked ₹640 crore exclusively under the Pradhan Mantri Matsya Sampada Yojana (PMMSY) for promotion of seaweed farming in the country (CMFRI, 2022). Sea weeds have good market demand for manufacturing agar, agarose, carrageenan and alginates. *Kappaphycus alvarezii* is the major species cultured in India and the farming is widely carried out by floating bamboo raft, longline or monoline and tube net. The economics of *Kappaphycus* farming using raft method is discussed in Table.

Costs and returns of seaweed (*Kappaphycus alvarezii*) cultivation

Particulars	Unit of 45 rafts (5 cycles/ year)
Initial investment (@₹1300/raft)	**58500**
Depreciation	19500
Interest on fixed capital (12%)	7020
Annual fixed cost(A)	**26520**
Operational costs (B)	
Seeds (60kg/ raft @ ₹8/kg)	21600
Recurring expenses(labour, transportation, and miscellaneous expenses)@ ₹220/raft/cycle	49500
Total cost (A+B)	**97620**
Annual dried seaweed production(100 kg/raft)	4500 kg
Price of dried seaweed (₹/kg)	50
Annual revenue	225000
Annual net profit	127380
B-C Ratio	2.3

Note: Calculated based on Johnson *et al*. (2020)

Marketing opportunities and challenges for mariculture

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.

The major bottleneck in commercial bivalve mariculture in India is inadequate processing infrastructure and constraints in marketing. There is no sustained demand for bivalve products in the domestic supply chain. In addition, stringent quality control measures set by EU, the major importer of bivalve products restricts the international trade. The bivalve mariculture sector needs a revamping through development of value chains consisting of depuration units, value added products and promotion of international trade (Mohamed, 2015).

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 of the country with the technical support from CMFRI. These cage farms could yield an aggregate fish production of 5,250 t generating aggregate net benefit of ₹105 crores to the cage fish farmers (calculated at an average net profit ₹3.5 lakhs per cage). Central Government and fisheries departments in various states provide financial assistance for promotion of various mariculture operations. Vast unutilised areas in the sea, estuarine and brackish water areas offer promising scope for augmenting the fish production through cage farming in the country. Though there is vast scope for large scale commercialisation of finfish mariculture in India the sector is at present constrained by the lack of suitable mariculture policy and regulations, multiuser conflicts in inshore cage farming, water pollution, environmental problems, lack of insurance facilities and non-availability of quality seeds (Aswathy *et al*., 2020).

Inshore mariculture activities proved to be highly economically viable and offer immense scope for enhancing the livelihoods of coastal population consisting of fishers, fish farmers, women self-help groups and rural youth. Most of the mariculture technologies are green technologies with low carbon footprint. Sea leasing policies for inshore and offshore mariculture along with development of cost- effective technologies for offshore mariculture, adequate supply of seeds through development of hatcheries with public-private participations, development of cost effective and innovative feeds as well as provisions for insurance coverage are essential for boosting the mariculture sector of the country.

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