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CAGE CULTURE AS AN EMERGING ECONOMIC VENTURE IN THE BLUE AGRIBUSINESS LANDSCAPE : A REVIEW

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ABSTRACT

Cage culture is an improved aquaculture system that allows fish to be raised in net enclosures suspended in open water in natural bodies such as reservoirs, lakes, rivers, and coastal seas. Because of the free exchange of water in the open environment, a cage culture system provides for good water management oxygen and waste removal, and the ecological balance of the environment. As the global capture fisheries are currently over-exploited and the demand for fish protein is increasing, cage culture offers an improved competitive option to improve food security. India, with its ample resources from inland and coastal waters, has the potential to easily develop cage aquaculture. Government support such as the Pradhan Mantri Matsya Sampada Yojana (PMMSY) and Blue Revolution Plan as well as support from the Indian Council of Agricultural Research (ICAR) and National Fisheries Development Board (NFDB) are facilitating adoption of the practice through financial government subsidies, training, and providing infrastructure. Economically, cage aquaculture is viable for freshwater and marine species, including Tilapia, Pangasius, Seabass, and Cobia. Profitability is established through cost–benefit analysis, showing ratios above 1.9 and internal rates of return exceeding 90%, indicating strong investment feasibility for small and medium-scale farmers. Marketing studies describe three channels connecting producers to consumers with intermediaries such as commission agents, wholesaler/retailers, and food service operators. Short channels yield higher marketing efficiencies and producer shares in consumer price, while longer channels generate more value-added benefits.

Cage culture contributes to socio-economic growth by creating rural jobs and benefiting vulnerable communities through dedicated government schemes. While issues such as large capital investment, technical knowledge limitations, environmental risks, and volatile market prices need to be dealt with, cage aquaculture approaches ecological sustainability, economic profitability and social inclusion. Given the principles behind the development of the Blue Economy and climate-smart aquaculture, cage culture is arguably a scalable and resilient solution to underpin the strengthening of the fisheries sector in India and contributes to the goals of sustainable development.

Keywords **:** Cage aquaculture, marketing efficiency, Blue Economy, PMMSY, sustainable fisheries, value chain, economic analysis. etc.

Introduction

Cage culture refers to a more sophisticated aquaculture system where fishes are cultivated in net enclosures or cages that are in open natural water bodies including lakes, reservoirs, rivers, estuaries, and marginal coastal seas. The design of cage culture allows water to flow freely and creates a mechanism for the exchange of oxygen and removal of waste by-products, sustains healthy fish growth, and restores some functioning of the ecosystem. Cage culture has emerged as a popular method of fish production globally, as it is viewed as a sustainable system to increase fish production without requiring as much land use and infrastructure. As capture fisheries have

been over-exploited and demand for fish protein is steadily growing, cage culture is an alternative method of aquaculture contributing food security on a global scale. Cage culture is more efficient, and less land demanding compared to traditional pond aquaculture, it is modular and has lower capital investment, suitable for small-scale farmers and large-scale commercial applications (NFDB, 2016).

With expansive inland and marine water resources at our disposal - including reservoirs total 3.15 million hectares and floodplain wetlands total 800,000 hectares that are, yet, untapped-India has immense promise for the growth of cage aquaculture. Government interventions designed to promote cage culture nationwide such as Pradhan Mantri Matsya Sampada Yojana (PMMSY), Blue Revolution, and support from institutional sources including National Fisheries Development Board (NFDB) and the Indian Council of Agricultural Research (ICAR) are or have been essential in promoting cage aquaculture across countries. These government schemes offer funds and training efforts and capital inputs to assist in realizing the economic and nutritional value from India's aquatic resource base in addition to generating farmer acceptance (NFDB, 2016).

Innovative progress in cage design and construction, as well as in feed formulation and health management, has further increase the efficiency and productivity of cage culture. Fish species such as Pangasius, Tilapia, Seabass, and Cobia have shown promising growth performance in both freshwater and marine environments. Cage culture has also provided alternative livelihood sources for rural and coastal communities, particularly in Gujarat, Kerala, Andhra Pradesh, and Jharkhand, where both cooperative and community-based models have proven viable. Cage aquaculture has the potential to increase fish production in India immensely with effective management, disease control, and market facilitation that will reduce post-harvest loss, increase exportability, and endow benefits in all three pillars of the country's blue economy - economic, ecosystem, and social (NFDB, 2016).

Scope

The practice of cage culture is a sustainable and financially feasible means of aquaculture with vast possibilities, especially in places with limited land resources and many water bodies. Cage culture is important ecologically, economically and socially, representing a potential method of satisfying the growing global demand for fish protein. One important advantage of cage culture is the efficient use of existing natural water resources, including reservoirs, lakes, rivers, estuaries and coastal areas. Cage culture does not require land digging or major impacts to the existing ecosystem, as with pond farms and cages, during cage culture is conducted in existing natural water areas; this means less impact on the environment. Cage culture also promotes very high stocking densities and increased fish production per unit of area (Radhakrishan *et al.*, 2019).

Cage culture allows the rearing of several species, including freshwater fish such as carp, tilapia, and catfish, as well as high-value marine species, in both domestic and export markets, such as seabass, cobia, and pompano, thus promoting commercial feasibility. Cage culture also represents an affordable, accessible, and manageable floating cage system to generate livelihoods for small-scale and marginal farmers in rural and coastal regions. With technological innovations such as automated feeding systems, disease management tools and submersible cage designs, the possibilities of cage culture are expanding through better productivity, enhanced survivability, and offshore mariculture in rough sea conditions. From a policy perspective, cage culture is seen by governments and policymakers alike, as a strategic manner to enhance fish production that requires no additional land use, that adheres to tenets of the Blue Economy, food security and climate-smart aquaculture. Cage culture offers a scalable, environmentally sustainable, and economically sound means of aquaculture that in conjunction with planning, technical support, and regulatory frameworks can be greatly utilized in terms of supporting sustainable fisheries and improving livelihoods for aquaculture subscription status and replacing wild catches (Radhakrishan *et al.*, 2019).

Economics

The cage frame, nets, floats, mooring, and a deep freezer are all included in the Rs. 85,000 total fixed cost of putting up a low-cost cage culture system. After depreciation and interest are taken into consideration, annual fixed costs come to Rs. 27,200. Feed, seed, labour, and harvesting account for the majority of the Rs. 48,600 in operating expenses. All in, the price comes to Rs. 75,800. The net profit from a 300 kg fish production is Rs. 74,200, with gross revenue of Rs. 1,50,000. The selling price is Rs. 500/kg, the cost per kg is Rs. 252, and the BCR is 1.92, according to key metrics (Shilta *et al.* 2023).

Table 1 : Economics of low-cost cage culture

Sr. No.	Particulars	Amount (Rs.)
	Capital Investment	
1	Cost of cage frame (1.25-inch B class pipe with ISI)	25,000.00
2	Cost of nets	30,000.00
3	Cost of floats (8 numbers per cage) and accessories	10,000.00
4	Mooring (2 nos. of 20 kg GI anchors) & installation	5,000.00
5	Deep freezer	15,000.00
	Total Fixed Cost (1+2+3+4+5)	**85,000.00**
6	Depreciation (20%)	17,000.00
7	Interest on Fixed Capital (12%)	10,200.00
	Annual Fixed Cost (6+7)	**27,200.00**
	Operating Costs	
8	Seed (300 seabass @ Rs.30/seed + transportation)	9,000.00
9	Feed (1085 kg trash fish @ Rs.20/kg + 60 kg pellet feed)	28,000.00
10	Labour (2 hrs/day @ Rs.1200/month for 8 months)	9,600.00
11	Harvesting & Miscellaneous Expenses	2,000.00
	Total Operating Cost (8+9+10+11)	**48,600.00**
	Total Cost (Annual Fixed + Operating)	**75,800.00**
	Returns	
12	Production	300 KG
13	Gross Revenue (@ Rs.500/kg for 300 KG)	1,50,000.00
14	Net Profit	74,200.00
15	Cost/kg of Fish	□252.00
16	Price/kg of Fish	□500.00
17	Operating Ratio	0.32
18	Net Present Value (NPV)	□2,31,256.00
19	Benefit-Cost Ratio (BCR)	1.92
20	Internal Rate of Return (IRR)	99.50%

(Source: Shilta *et al.* 2023)

With a significant net present value (Rs. 2,31,256) and a high internal rate of return (99.5%), low-cost cage cultivation turns out to be economically viable. The benefit-cost ratio above 1 indicates profitability. Despite moderate operating costs, high market prices for fish ensure strong returns. The low operating ratio (0.32) suggests good efficiency. This model is highly feasible for small-scale fish farmers with limited capital.

Economics of mariculture

The marine cage culture system for a 115 m³ farm involves a stocking density of 3,745 fish, using 9,082 kg of feed and producing 2,090 kg of fish. Labour usage is around 80 days. The total fixed cost is Rs. 74,875 with an annual cost of Rs. 4.9 lakh, while operational costs reach Rs. 4.15 lakh. Gross revenue from production is Rs. 9.9 lakh, resulting in a net profit of Rs. 4.99 lakh for the 115 m³ farm. The 1 m³ scale offers similar patterns at a lower scale with a net profit of Rs. 4,333 (Shilta *et al.,*2023).

Table 2: Economics of marine cage culture

Particulars	115 m³	1 m³
General Farm Data		
Stocking Density (no.)	3,745	32
Feed (kg)	9,082	79
Production (kg)	2,090	18
Labour Days	80	0.7
Fixed Cost		
Cost of Cage Structure	Rs. 1,91,416.70	Rs. 1,659.00
Freezer & Accessories	Rs. 16,133.30	Rs. 139.80
Depreciation	Rs. 49,968.70	Rs. 433.10
Interest on Fixed Capital	Rs. 24,906.00	Rs. 215.90

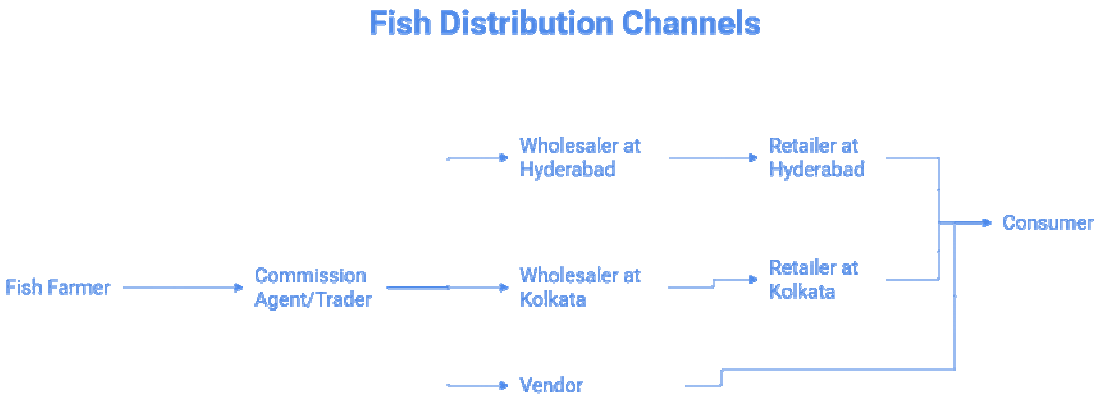
Annual Fixed Cost	Rs. 74,875.00	Rs. 649.00
Total Fixed + Operational Cost	Rs. 4,90,471.80	Rs. 4,250.90
Operational Cost		
Seed	Rs. 91,168.80	Rs. 790.20
Feed	Rs. 2,33,978.30	Rs. 2,027.90
Labour	Rs. 64,533.30	Rs. 559.30
Other Expenses	Rs. 25,916.70	Rs. 224.60
Total Operational Cost	Rs. 4,15,597.10	Rs. 3,602.00
Returns		
Gross Revenue	Rs. 9,90,429.00	Rs. 8,584.10
Net Profit	Rs. 4,99,957.20	Rs. 4,333.10

(Source: Shilta *et al.* 2023)

Marine cage culture is financially rewarding, especially at larger scales like 115 m³. The capital investment is justified by high revenue and net profit margins. Although operational expensesprimarily those related to feed and seeddominate spending, great profitability is the result of effective feed conversion and robust market prices. When compared to returns, labour and fixed costs are still moderate. This model supports scalable and sustainable fish farming.

Marketing Channel

There are 3 major marketing channels observed in the study area, through which fish reached the ultimate consumer. The different marketing channels observed were as follows



(Source: Sindhu *et al.,* 2022)

Fig 1 : Fish Distribution Channel

Table 3: Marketing Cost, Margin, and Producer's Share in Consumer Rupee (Channel-wise)

Particulars (Rs./Kg)	Channel 1	Channel 2	Channel 3
Farmer selling price / Commission agent purchase price	98.82	98.82	98.82
Cost incurred by commission agent	13.77	19.17	12.61
Margin	8.00	12.00	9.76
Commission agent selling price	120.59	129.99	120.59
Cost incurred by wholesaler	12.32	12.25	—
Margin	3.68	6.00	—
Wholesaler selling price / Retailer purchase price	136.59	148.24	—
Cost incurred by retailer	11.06	14.61	—
Margin	5.94	10.00	—
Retailer selling price	153.59	172.85	—
Cost incurred by vendor	—	—	15.51
Margin	—	—	10.60
Vendor selling price	—	—	146.70
Consumer's purchase price	**153.59**	**172.85**	**146.70**
Price spread	**54.77**	**74.03**	**47.88**
Producer's share in consumer's rupee (%)	**64.34**	**57.17**	**67.36**

(Source: Sindhu *et al.,* 2022)

The table shows the marketing cost, margin, and producer's share in consumer rupee across three marketing channels. Channel 1 has a consumer price of Rs. 153.59, with a producer's share of 64.34%, while Channel 2 shows the highest consumer price of Rs. 172.85 but the lowest producer's share at 57.17%, indicating higher intermediary involvement and costs. Channel 3, where the product is sold directly through a vendor, reflects the highest producer's share (67.36%) and the lowest price spread (Rs. 47.88), suggesting greater efficiency and fewer intermediaries. Overall, as the number of intermediaries increases, both the price spread and consumer price rise, reducing the producer's share in the final consumer rupee.

Table 4: Marketing Cost, Margin, Value Addition, and Efficiency of Fish (Channel-wise)

Sl. No.	Particulars	Channel 1	Channel 2	Channel 3
1	Marketing Cost (Rs./kg)	37.15	46.03	28.12
2	Marketing Margin (Rs./kg)	17.62	28.00	20.36
3	Price Received by Farmer (Rs./kg)	98.82	98.82	98.82
4	Marketing Efficiency Ratio	1.80	1.33	2.04
5	Rank	II	III	I

(Source: Sindhu *et al.,* 2022)

The table presents the marketing cost, margin, value addition, and efficiency of fish across three marketing channels. Channel 3 shows the highest marketing efficiency ratio (2.04) with the lowest marketing cost (Rs. 28.12), indicating it is the most efficient channel. Channel 1 ranks second with a moderate efficiency ratio (1.80) and cost (Rs. 37.15), while Channel 2 is the least efficient (1.33) due to the highest cost (Rs. 46.03) and margin (Rs. 28.00). This suggests that channels with fewer intermediaries and lower marketing costs tend to be more efficient, offering better returns to producers and lower prices to consumers.

Marketing margin

From Table 1, it can be observed that in Channel 1, the commission agents received the higher margin per Kg of fish (Rs. 8.00) followed by retailers (Rs. 5.94) and wholesalers (Rs. 3.68). In Channel 2, similarly the commission agents received the higher margin per Kg of fish (Rs. 12.00) followed by retailers (Rs. 10.00) and wholesalers (Rs. 6.00). While in Channel 3 Vendor received highest margin (Rs. 10.60) than commission agents (Rs. 9.76) (Sindhu*et.al,* 2022).

Producer's Share in Consumer's Rupee

Producers share in consumer rupee was found to be highest for Channel 3 (67.36%) followed by Channel 1 (64.34%) and 2 (57.17%) respectively. There was less number of market intermediaries in the Channel 3 which resulted in the higher producers share in the consumer rupee.

Marketing Efficiency

The marketing efficiencies were calculated for marketing channels identified in the study area using Acharya approach (modified measure of marketing efficiency) and represented in the Table 2. The marketing efficiency was found highest for Channel 3 (2.04%) followed by Channel 1 (1.80%) and least for Channel 2 (1.33%). Thus, Channel 3 was found to be most efficient and Channel 2 as least efficient one. These results are similar to the findings of (Raj *et al*., 2022) who also reported that the marketing efficiency was highest for the shortest marketing channel with a smaller number of intermediaries. Efficiency of the channel decreases there by reducing the producers share in consumer rupee. Hence the farmers can form into groups like Cooperatives or Fish Farmer Producer Organizations by which they can reduce the intermediaries involved and earn the more share in consumers rupee. Bringing awareness in producers and consumers on daily market prices of various fish species will help in developing the marketing of fish.

Supply and value chain

The comprehensive fish marketing and supply chain process, as depicted in Fig. No. 2, illustrates the journey of fish from farm to fork, commencing with the Cage Culture System and concluding with the Consumer. Fish harvested from cage systems are routed through a series of value chain actors, including Wholesalers, Processors, Distributors, and Retailers to the final consumer. This supply chain structure represents a typical flow utilized in organized fisheries and aquaculture wherein each intermediary adds value

to the fish through processing, preserving, packaging, and distribution (Bunkar *et al.*, 2022).

(Source: Bunkar *et al.*, 2022)

Fig. 2 : Supply chain of the fish from Farm to Fork

The figure shows the complete supply chain for cage-cultured fish starting from the farming stage to the consumer. It begins with fish being farmed under controlled aquatic environments in cages to be sold to wholesalers who aggregate and sell the fish to processors. Fish are cleaned, sorted, and also transformed into value-added products which can improve the quality and marketability of fish, at the processing stage. The retailer receives the processed or fresh product via distribution channels and maintains its freshness and quality. Finally, consumers purchase the fish in markets or in retail outlets, thus completing the fish supply chain from "farm to fork." Overall, the figure shows how several players in the cage culture supply chain work together to provide efficiencies, value-added goods, and fish sustainability.

Challenges in supply chain

The fish supply chain is beset by numerous and serious difficulties, which hamper efficiency and sustainability. The principal dilemma is insufficient hygienic landing centres, which affect the quality and safety of fish from the very moment of harvest. In addition, widespread illiteracy and general ignorance towards the wellbeing of fishermen prevents the adoption of improved practices and policies intended to benefit the fishing communities. The poor economic situation of fishers also prohibits investment into more advanced gear, infrastructure or training which would reduce inefficiencies even more. Furthermore, other factors such as inadequate cold storage, uncertain transportation systems, or inefficient preservation, leads to spoilage and post-harvest waste--especially in remote or underdeveloped localities (Bunkar *et al.*, 2022).

Many of these challenges are severe in areas that have limited infrastructure and institutional support. In order to create an operational and viable fish supply chain, we need to consider 3 broad categories of constraints (defined below) that serve to limit efficiency and therefore undermine sustainability; production (ex. lack of training or input resources, etc.), flow (ex. transportation, market access, etc.), and storage (ex. cold chain or preservation facilities). Each of the above constraints can be addressed and thus strengthen and improve the fish supply chain. Furthermore, addressing these areas should lead to both wastage reduction and profitability. Equally important, it would support a more equitable distribution of income throughout the supply chain from fishers up to the final consumers (Bunkar *et al.*, 2022).

Government Scheme

A comprehensive overview of the Government Scheme under PMMSY (Pradhan Mantri Matsya Sampada Yojana)- Installation of Cages in Reservoirs was discussed in the context of inland fish farming. The Government Scheme offers financial assistance to eligible beneficiaries for establishing cage culture units. The standard investment and operational cost for cage culture are estimated at Rs. 1500 per cubic meter. At present, a minimum cage size of 100 cubic meters is required. Individual beneficiaries can avail assistance for an up to 1800 cubic meters of water area, while Co-operative Societies or Self-Help Groups (SHGs) or Joint Liability Groups (JLGs) are eligible for an up to 7200 cubic meters of water area which is calculated on an approx.Sunit of 600 cubic meters per member.

There's a financial assistance program, funded by the state for thirty percent and central government for sixty percent, in regard to marginalized groups such as women and SC/ST (Scheduled Castes/Scheduled Tribes) groups who receive sixty percent assistance, while the general category would receive forty percent. The benefit has a yearly limit to maximize benefit and engagement. The goal of the scheme is to enhance the livelihoods of rural fishers via sustainable aquaculture practices, while also increasing fish production on reservoir resources.

This scheme aims to improve rural livelihoods through collaboration for the benefit of cage culture

technology; and will provide generous financial assistance (and equipment supports) for women and marginalized groups, and for community and co-operative group efforts. The goal of this was to create opportunities of place to improve inclusion, provide increased development opportunity for marginalized groups, and development through cooperation and collective impact. Also, the idea of providing financial assistance (once in a lifetime) is a way to allowed equitable access so more people can develop, or simply the resource goes further or more people gain financial support for equipment or income support for development. The scheme also relates to Blue Revolution (goals) as promoting fish production, gain sustainable rural employment, and maximize use and benefits of the waterbodies, thus enhancing living and economic condition, social inclusion, community, and social and economic development.

Conclusion

Cage culture in India has considerable room and potential for sustainable and scalable aquaculture by efficiently utilizing the underutilized inland and coastal water resource. It has become an enterprise that supports the rearing of high-value fish like seabass, cobia, pangasius, and tilapia, resulting in economic gains for fish production, foreign exchange earnings from fish exports and rural employment. Cage culture is economically feasible as it can deliver better productivity per unit area with less dependence on land and has a potential for income diversification for fish farmers. However, several barriers exist, such as costs of initial investment, feeds, low technical and management skills, and dealing with diseases that limits the small-scale adoption of cage culture as a viable enterprise. More supportive frameworks that provide access to institutional finance, technical capacity building and farmer cooperatives may all contribute to bridging some of these barriers and make cage culture more inclusive and economically viable.

Cage-cultured fish is witnessing an expanding demand in both domestic and international markets; however, problems related to marketing efficiency, refrigeration costs and middlemen minimums are the greatest barriers in determining a fair price for farmers. Developing strong relationships between producers, processors and consumers, using Fish Farmer Producer Organizations (FFPOs), digital marketing systems, and advanced distribution systems may improve farm profitability and curb post-harvest loss. Government funded action like the Pradhan Mantri Matsya Sampada Yojana (PMMSY), Blue Revolution, and Fisheries and Aquaculture Infrastructure Development Fund (FIDF), provide supporting infrastructure, training and funding. If continued support through policy, technology innovation, and community engagement in place, cage culture can reshape India's aquaculture industry for jobs, income, and national food and nutritional security.

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