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Socio-economic Analysis and Farming Practices in Coastal Cage Aquaculture in India

Saju George*, Imelda-Joseph , Shoji Joseph, Anuraj, A, Santosh,B., Sekar,M., Shilta,M.T., Joe,K. Kizhakudan, Tamilmani,G., Kalidas,C., Ambarish P. Gop,Rajesh, N and V.V.R Suresh

ICAR- Central Marine Fisheries Research Institute, Kochi- 682018, Kerala, India

Abstract

This study examines the socioeconomic characteristics, operational dynamics, and farming practices of farmers engaged in cage farming of marine finfish. The findings indicate that cage farming is predominantly male-dominated (75.9%), with most farmers (53.3%) belonging to the 35–50 age group. Regarding occupational characteristics, 49.9% of farmers are primarily fishers, while 31.1% consider cage farming their main livelihood source. Additionally, 56.1% have adopted cage farming as a secondary source of income. Given its capital-intensive nature, 23.6% of farmers have formed partnerships to share the initial investment costs. Furthermore, a significant 83% of farmers expressed interest in joining a Fish Farmer Producer Organization (FFPO) if given the opportunity. Cage farming, being a complex and high-investment technology, is strongly influenced by institutional support, with 84.4% of farmers citing it as a key factor in adoption. Other major influences include economic potential (65.6%) and peer influence (35.4%). Notably, 93.9% of cage farmers have undergone some form of training. Farmers utilize cages of various dimensions, with rectangular (4 x 4 x 3 m^3) and circular (6m diameter, 3m depth) cages being the most popular. The preferred species for cage farming include Asian seabass (Lates calcarifer) (90.6%), Pearl spot (Etroplus suratensis) (34.9%), and Cobia (Rachycentron canadum) (25%). Additionally, 13.2% of farmers practice Integrated Multi-Trophic Aquaculture (IMTA). Fish harvesting is primarily conducted periodically (51.9%). While 63.7% of farmers have maintained the same number of cages, 24.1% have expanded their operations. These findings highlight the critical role of institutional support, financial considerations, and species selection in the adoption of cage farming. To ensure the growth and sustainability of the sector, cage farming requires strong institutional backing, supportive mariculture policies, and cooperative initiatives such as FFPOs. Economic analysis of a composite culture of Asian seabass with Pearl spot in a 4 x 4 x 3 m^3 cage size yielded a benefit-cost ratio (BCR) of 2.11, demonstrating strong financial viability.

Keywords:
Coastal Cage aquaculture, Socio-economics, Asian Seabass, Cage dynamic

***Corresponding author:**
sajushiby@gmail.com

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Introduction

Cage aquaculture involves growing fishes in existing water resources while being enclosed in a net cage which allows free flow of water. It is an aquaculture production system made of floating frame, net materials and mooring system with a round or square shape floating net to hold and culture large number of fishes and can be installed in reservoir, rive, lake or sea. The cage aquaculture sector has grown very rapidly during the last 20 years and is presently undergoing rapid changes in response to pressures from globalisation and growing demand for aquatic products. (Rao *et al*, 2013). World aquaculture has shown stable growth in production volumes over the last three decades (Food and Agriculture Organization, 2022). According to forecasts from the report "The State of World Fisheries and Aquaculture 2022," by 2030, the majority of the growth in the production of food products from aquatic biological resources will be associated with the development of aquaculture. In 2020, global aquaculture production reached a record 122.6 million tonnes, with a total value of USD 281.5 billion (FAO, 2022). In Southeast Asia, countries such as Indonesia and Philippines have been expanding their marine cage farming activities, focusing on species such as grouper and snapper, similar to India's efforts (SEAFDEC, 2020). Presently, mariculture is predominantly small-holder-centric in India. With steady technological advancements and faster adoption among the small-scale fisher community, supposedly, there is potential for sustainable intensification (SI) of farming operations in India's coastal regions (Parapurathu *et al.*, 2023).

India's blue economy goals and policy initiatives strongly emphasize the expansion of mariculture as a key strategy to boost marine fish production. The mariculture sector in India predominantly involves marine finfish cage farming in floating cages located in coastal and offshore waters and has emerged as a promising aquaculture practice aimed at enhancing fish production and meeting the rising demand for seafood (Gopalakrishnan *et al.*, 2022.). The Indian government, recognizing the potential of this sector, has been actively promoting it through policy support, subsidies, and capacity-building initiatives. The key species farmed include Asian seabass, groupers, and snappers (Gopalakrishnan, *et al*. 2022). This practice not only contributes to food security but also provides livelihood opportunities for coastal communities (Government of India (GoI), 2017).

The ICAR-CMFRI has been instrumental in advancing cage culture across diverse regions and species in India, significantly improving the livelihoods of coastal communities (Mojjada *et al.*, 2012a, 2012b, 2013; Philipose *et al.*, 2013; Ghosh *et al.*, 2016; Joseph and Gopalakrishnan, 2017). Today, cage-based finfish farming has emerged as a supplementary income source for fishers and coastal residents. Several species, including *Rachycentron canadum* (Cobia), *Trachinotus blochii* (Silver pompano), *Etroplus suratensis* (Pearl spot), *Lates calcarifer* (Seabass), Genetically Improved Farm Tilapia (GIFT), and *Lutjanus argentimaculatus*, are cultivated in cages.

Open-sea cage culture was started in the year 2007 with *Lates calcarifer* (Asian seabass), leading to the development of region-specific innovations in cage design, mooring systems, and farming techniques. This initiative also resulted in the establishment of standardized guidelines, breeding protocols, larval production methods, and grow-out technologies for several priority marine finfish species (Rao *et al.*, 2013). Apart from seed production technology developed by CIBA, for Asian seabass *L calcarifer* ICAR-CMFRI, has developed hatchery technology for 10 marine food fishes from the prioritized finfish and shellfish species that could be targeted for future expansion of mariculture production in the country (Ranjan *et al.,* 2017). Currently, in India, cage farming has been reported to be economically viable, with initial support from different agencies, and research institutes in establishing cage culture. It is spreading rapidly in the country, aided by the adoption of the technology by small-scale famer entrepreneurs, self-help groups and fisher societies (Gopalakrishnan *et al.*, 2019; Aswathy *et al*. 2020; Jena *et al.*, 2022). There is demand for marine finfishes by consumers, and demand peaks during trawl ban periods and festivals. The cage farmers are tapping into these opportunities by growing customer-demanded fishes in cages and supplying them at competitive rates. These cage culture farmers have created a niche for themselves among consumers.

Despite the development thrust given to the sector, the influence of demographic patterns, farming technology and institutional frameworks in addition to sustainable practices remains critical to the long-term success and growth of marine finfish cage farming in India. The present study provides a comprehensive assessment of marine finfish cage farming enterprises, the socioeconomic profile of the entrepreneurs, their cultural practices, and the constraints they face in cage farming and their operational assets and features.

Materials and Methods

Study area and data collection

This study focused on new mariculture hotspots emerging in the country across four maritime states namely Kerala, Karnataka, Tamil Nadu, Andhra Pradesh. The sample population comprised fish farmers actively engaged in cage culture operations. Locations for data collection were selected based on the criteria of a significant presence of operational mariculture units. A simple random sampling method was employed to select fishers with a minimum of 2–3 years of experience in cage culture. Pretested questionnaires were used for data collection.

Asian seabass is the preferred species for aquaculture due to its ability to adapt to diverse water conditions, fast growth, strong market demand, and reliable seed availability. While cage fish farmers are increasingly adopting other species such as Pearl spot, tilapia, red snapper, carangids, cobia, pompano, and lobsters, their adoption is limited primarily by seed supply constraints. Therefore, farms cultivating these species were specifically included for the study, given the challenges in their production. To ensure a well-stratified sample, farmers were selected based on their experience and the number of cages they operated, representing both small- and large-scale farming operations.

Results and discussion

Socio-economic characteristics of cage fish farmers

The study revealed significant insights into the demographics and characteristics of cage owners and farmers involved in the sector (Table 1). Predominantly, cage ownership is skewed towards males, constituting 75.9% of all owners, while females accounted 24.1%. Within the farming community, the largest proportion, comprising 53.3%, fell within the 35-50 age bracket, highlighting a mature workforce engaged in this sector. Younger farmers aged between 20 and 35 represented 25.5% of the sample, indicating a notable entry of youth into cage farming. Education played a pivotal role among cage farmers, with 98.6% having some sort of formal education. The distribution among educational levels revealed that a significant number of farmers had attained higher secondary education (29.2%), followed by those with secondary education (25.9%) and graduate-level qualifications (22.6%) respectively. This demographic data on education suggests involvement of a potentially skilled and knowledgeable workforce capable of adopting and implementing modern mariculture practices.

Family dynamics among farmers also varied widely, with 49.5% of the farmers having smaller families of up to 4 members only and 40.1 % having families with 4-6 members. A smaller proportion of 10.4 %, had more than 6 members indicating larger households.

Occupation: The figure 1 shows whether cage farming is a primary or secondary occupation for the farmers. Among the respondents, approximately 49.9% were engaged in fishing as their primary occupation, whereas 31.1% had taken cage farming as their major occupation, and 19.8% respondents were having some other occupations (like auto driving/ private job) as their primary source of livelihood. Among the respondents, approximately 56.1% considered cage farming as their secondary enterprise.

Membership in Societies and FPOs

It was found that approximately 49.1% of farmers are members of cooperative societies, indicating a significant level of participation and interest in collective initiatives. FPOs are relatively newer entities that aim to strengthen the collective bargaining power of farmers and improve their access to markets and resources. The analysis revealed that only 1.9% of the farmers were members of Fish Farmers Producer organisation (FFPO), as these institutions have come into existence recently. An impressive 83% of farmers have expressed their keen interest in establishing or joining FFPOs, underscoring the strong demand within the community for dedicated platforms that can effectively address the challenges and specific needs confronted by cage farmers.

Cage Farming Characteristics

The study revealed the following findings regarding experience in cage farming as shown in figure 2: 40.6 % of farmers had 3–5 years of experience, 34 % had 1–3 years, and 25.5 % had more than 5 years of experience. In terms of cage ownership (Fig. 2), the distribution was as follows: 44.3 % owned a single cage, 27.8 % owned two cages, 10.8 % owned three cages, and 17 % owned four or more cages. This data indicates that the majority of cage farmers operate with only one cage. A key reason for this trend is that most farmers continue with their first cage—often provided through various

Table 1: Socio-economic characteristics of the cage farmers

Socioeconomic characteristics	Number (n)	Percentage (%)
Gender		
Male	161	75.9
Female	51	24.1
Age group		
20-35	54	25.5
35-50	113	53.3
>50	45	21.2
Mean age (Years)	42	
Education		
Read only	3	1.4
Primary	44	20.8
Secondary	55	25.9
Higher Secondary	62	29.2
Graduate	48	22.6
Family size		
Up to 4 members	105	49.5
4-6 members	85	40.1
Above 6 members	22	10.4
Major occupation		
Cage farming	66	31.1
Fishing	104	49.9
Others	42	19.8
Secondary Occupation		
Cage farming	119	56.1
Fishing	45	21.2
Others	48	22.6
Membership in Co-operative Societies and Producer organisations		
Cooperative societies	104	49.1
Farmer Producer organization	9	1.9
Fish farmer producer organization (FFPO)	0	0
Number of farmers interested in forming FFPO	176	83

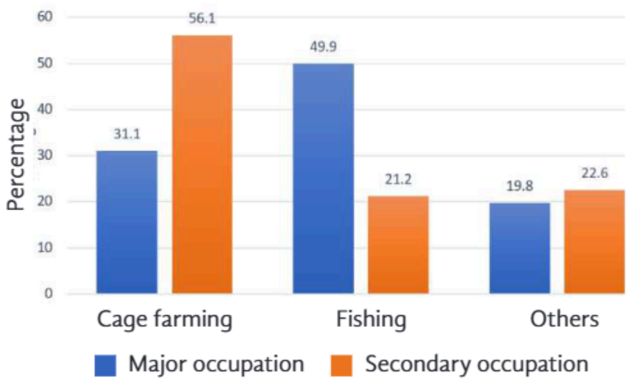

Fig 1. Occupational profile of the respondents

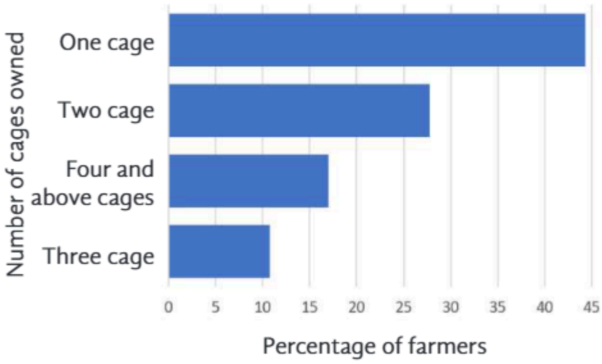

Fig 2. Distribution of cage farmers according to number of cages owned

government support schemes—due to the high investment costs required for additional cages. Discussions with farmers revealed that the absence of insurance support and difficulties in obtaining credit are major obstacles to expanding their operations. Additionally, cage farmers remain highly vulnerable to climate variability, which can cause severe crop losses. Despite these risks, they are still not covered under any insurance schemes, further exacerbating their financial insecurity.

Table 2: Attributes related to cage farming

Number of cages owned	**Number**	**Percentage**
One cage	94	44.3
Two cages	59	27.8
Three cages	23	10.8
Four and above cages	36	17.0
Cage Culture (Mode of operation)		
Single ownership	162	76.4
Partnership mode	50	23.6
Cage culture Initiation		
Own initiated	22	10.4
ICAR-CMFRI initiated	159	75.0
Other agency	31	14.6
Reason for starting cage farming		
Institutional support	179	84.4
Seeing the economic potential	139	65.6
Influence of peers	75	35.4
Better employment opportunity	47	22.2

Table 2 presents attributes of cage farming practices, including the number of cages owned, mode of operation, the agency responsible for initiating cage farming, and the reasons for starting cage farming

Cage Ownership

The study revealed that 76.4% of farmers engaged in cage farming as sole proprietors, while 23.6% opted for a partnership approach. Cage farming inherently requires substantial initial investments, including costs for cage construction, equipment, and operational expenses. To meet these financial demands, many farmers adopt partnership arrangements, allowing them to pool resources, share financial responsibilities, and distribute risks. This collaborative approach not only reduces the capital burden but also strengthens risk mitigation, making it especially prevalent among farmers pursuing larger-scale cage farming ventures.

Cage farming initiation: A significant 75.0 % of farmers ventured into cage farming with crucial support from the ICAR-CMFRI, providing a leading role in assisting farmers in this endeavour and conducting training programmes and demonstrations to boost farmer confidence in cage farming techniques. A total of 14.6% of cage culture initiatives received support from other agencies, such as the Department of Fisheries and *Krishi Vigyan Kendras* (KVKs). These agencies played a substantial role in enabling a portion of farmers to enter the cage farming arena. In contrast, approximately 10.4% of the farmers reported launching their cage culture endeavors independently, relying solely on their initiative and resources.

Experience in cage farming

The largest group of farmers, comprising 40.6% of the respondents, had 3-5 years of experience in cage farming. This indicates that a significant majority of the farmers surveyed had acquired a substantial amount of knowledge and practical expertise over a period of 3-5 years. Following this group, there were farmers with other levels of experience. Approximately 34.0% of the farmers had 1-3 years of experience, suggesting a significant number of relatively newer entrants in the cage farming industry. Additionally, 25.5% of the farmers had more than 5 years of experience, indicating that a smaller but notable group of individuals had been involved in cage farming for an extended period. In summary, the data reveal that the largest percentage of farmers fell within the 3-5 years of experience category, followed by those with 1-3 years of experience and those with more than 5 years of experience.

Trainings in cage farming: Of the total respondents, 93.9% indicated that they had attended training programs related to cage farming. This suggested a high level of interest and engagement in seeking knowledge and skills through training opportunities for such specialized farming. Most farmers (76.4%) reported attending training conducted by the ICAR-CMFRI. This indicated that the ICAR-CMFRI played a significant role in organizing training programs specifically tailored to the needs of cage farming practitioners. There were also other agencies involved in imparting training, such as the KVKs and the Department of Fisheries. Approximately 7.1% of the total respondents stated that they attended trainings conducted by KVK, and approximately 6.3% attended trainings organized by other agencies, such as the Department of Fisheries. In summary, the data highlight that a significant number of respondents attended training in cage farming, with CMFRIs being the primary source of such training. However, training conducted by KVK and the Department of Fisheries also played a notable role in providing knowledge and skills to individuals or organizations involved in cage farming.

Factors responsible for starting cage farming: According to the provided data, individuals who started cage farming cited several reasons for their decision.

a) **Institutional support:** A majority of 179 respondents (84.4%) stated that institutional support played a crucial role in their decision to start cage farming as shown in Figure 3. This indicates that support from organizations, such as government agencies or research institutes, provided them with the necessary resources, guidance, and assistance to initiate their cage farming operations.

b) **Seeing the economic potential**: A majority (65.6%) of the respondents mentioned that they started cage farming after recognizing its economic potential. This indicates that they identified the financial benefits and profitability associated with cage farming, which encouraged them to invest in this venture.

c) **Influence of peers:** Approximately 35.4% of the respondents mentioned that the influence of peers played a significant role in their decision to start cage farming. This suggests that seeing others successfully engaged in cage farming motivated these individuals to pursue it as well.

d) **Better employment opportunities:** Approximately 22.2% of the respondents cited better employment opportunities as a reason for starting cage farming. This suggests that individuals recognize the potential for income generation and job creation in the cage farming sector, motivating them to pursue improved livelihoods.

In summary, the data revealed that individuals who started cage farming were influenced by multiple factors. The influence of peers, institutional support, the recognition of better employment opportunities, and the perception of the economic potential of cage farming were all significant drivers in their decision-making process.

Types of cages, fish species and farming systems:

The most commonly employed cage type in aquaculture, comprising 35.3% of the instances, was the rectangular cage with dimensions of 4x4x3 metres. This indicates that a significant portion of the surveyed cage aquaculture operations preferred this specific cage size and shape for their farming activities. Following the 4x4x3 m cages, the next most employed cage type was the circular cage with a diameter of 6 metres, accounting for 26.7% of the instances. These circular cages were also popular among aquaculture practitioners, albeit slightly less prevalent than the 4x4x3 m rectangular cages. Notably, rectangular cages with dimensions of 3x2x2 m and 6x3x2 m were also used in aquaculture, with 18.8% and 5.8% of the instances, respectively. These cages provide options for farmers with different space requirements or

Table 3: Types of cages, fish species and farming systems involved

Types of Cages Employed	Number	Percentage
Rectangular		
6 x 4 x 3 m	16	3.4
6 x 3 x 2 m	27	5.8
5 x 5 x 5 m	18	3.9
4 x 4x 3 m	164	35.3
3 x 2 x 2 m	87	18.8
2 x 2 x 2 m	20	4.3
Circular		
6 m diameter	124	26.7
3 m diameter	8	1.7
Major finfish species farmed		
Asian Sea bass (*Lates calcarifer*)	192	90.6
Pearl spot (*Etroplus suratensis*)	74	34.9
Tilapia (*Oreochromis mossambicus*)	2	0.9
Red snapper (Lutjanus argentimaculatus)	28	13.2
Cobia (*Rachycentron canadum*)	53	25.0
Orange spotted Grouper (*Epinephelus coioides*)	11	5.2
Indian Pompano (*Trachinotus mookalee*)	21	9.9
IMTA		
Number of farmers doing IMTA	56	
Seaweed	10	17.9
Sea weed + Pearl oyster	2	3.6
Mussel	8	14.3
Mussel + seaweed	12	21.4
Mussel + oyster	4	7.1
Lobster	13	23.2
Crab	7	12.5

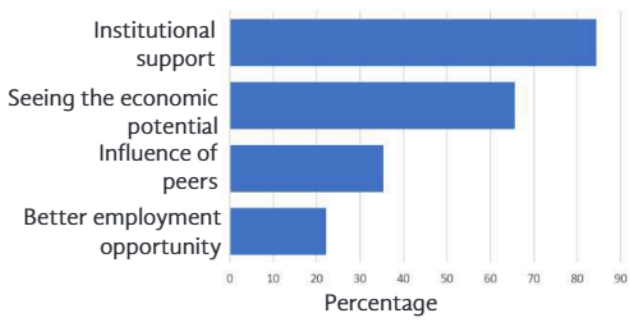

Fig 3. Reasons for starting cage farming

species preferences. Other cage types, such as 5x5x5 m rectangular cages, 2x2x2 m rectangular cages, and 3 m diameter circular cages, were utilized to a lesser extent, comprising 3.9%, 4.3%, and 1.7% of the instances, respectively. In summary, the most widely employed cage type was a rectangular cage with dimensions of 4x4x3 m, followed by a circular cage with a diameter of 6 metres. These findings highlight the preferences of aquaculture practitioners regarding cage sizes and shapes for their farming operations. The details of the types of cages involved are given in Table 3.

The data provided highlight the major fishes farmed in cage culture in the surveyed area, along with their corresponding numbers and percentages (Table 3). With 192 instances, sea bass is the most commonly farmed fish, accounting for 90.6% of the total. The sea bass is a popular choice in aquaculture due to its high market demand, favourable growth characteristics, good seed availability and culinary value. Pearl spot is another significant farmed fish species, with 74 instances, representing 34.9% of the total. In many cases, the pearl spot is grown along with the seabass in the outer rings, and it also helps prevent biofouling. Tilapia is farmed in only 2 instances, making up 0.9% of the total. Although its presence is minimal in this dataset, tilapia is a globally farmed fish known for its rapid growth and tolerance to diverse environmental conditions (FAO,2019). Red snapper is farmed in 28 instances, accounting for 13.2% of the total. This popular marine fish is valued for its firm white flesh and is sought after in both local and international markets. Cobia is farmed in 53 instances, representing 25.0% of the total. Cobia is a fast-growing, carnivorous fish known for its mild flavour and versatility in culinary preparations. Grouper is farmed in 11 instances, comprising 5.2% of the total. Grouper species are highly valued for their taste and are often marketed as premium seafood products. Pompano is farmed in 21 instances, accounting for 9.9% of the total. This fish is favoured for its delicate flavour, firm texture, and suitability for various cooking methods. In summary, the data indicate that sea bass is the most extensively farmed fish, followed by pearl spot, red snapper, cobia, pompano, grouper, and tilapia. These fish species are chosen for their market demand, taste, growth characteristics, and adaptability to aquaculture systems.

Integrated Multitrophic Aquaculture (IMTA): Approximately 13.2% of the farmers were involved in IMTA. Of the 212 surveyed cage farmers, a total of 56 farmers were currently practising IMTA. Seaweed cultivation was adopted by 10 out of the 56 surveyed farmers, accounting for approximately 17.9% of the total. Seaweed is known for its ability to absorb excess nutrients, contributing to water quality improvement in IMTA systems. Two farmers, representing 3.6% of the total, were engaged in the combination of seaweed and pearl oyster cultivation. This combination allows for nutrient absorption by seaweed while also providing a habitat for pearl oysters. Mussel farming was practised by 8 farmers, accounting for approximately 14.3% of the total. Mussels are filter feeders that effectively remove particulate matter and excess nutrients from water, thus helping cage farmers avoid additional income generation. A combination of mussel and seaweed cultivation was observed among 12 farmers, representing 21.4% of the surveyed population. This combination maximizes the nutrient cycling and waste assimilation potential of IMTA systems. Four farmers (7.1%) were engaged in the cultivation of both mussels and oysters. This combination allows for the removal of excess nutrients by mussels and the simultaneous development of valuable oyster crops. The largest group of farmers, consisting of 13 individuals (23.2%), focused on lobster cultivation. Lobsters are considered valuable species in aquaculture due to their high market demand. Approximately 7 farmers (12.5%) were involved in crab farming as part of their IMTA practices. Crabs play a crucial role in the food chain and contribute to maintaining ecosystem balance in IMTA systems.

Cage Dynamics and Harvest

Table 4: Cage dynamics and Harvest

Dynamics of number of cages maintained	**Number**	**Percentage (%)**
Farmers keeping constant the no. of cages over 5year period	135	63.7
Farmers increasing no. of cages over 5 year period	51	24.1
Farmers who have decreased (over 5year period)	10	4.7
Farmers maintaining more than 2 cages maintained	62	29.2
Harvesting Details		
Frequency of Harvest		
One time harvest	97	45.8
Periodic harvesting	110	51.9
Harvest coinciding with festival	42	19.8
Production details	**Stocking density**	**Harvest (kg)**
Mean harvest of Seabass in 4x4x3 m^3 cages	500	600
Mean harvest of Pompano in 6 m dia cages	800	900
Mean harvest of cobia in 5x5x5 m^3 cages	700	800
Average Price realized for Cage farmed fish		**Mean Price realised (Rs) per kg**
Sea bass		425
Pearl spot		500
Tilapia		220
Red snapper		300
Cobia		400
Pompano		320

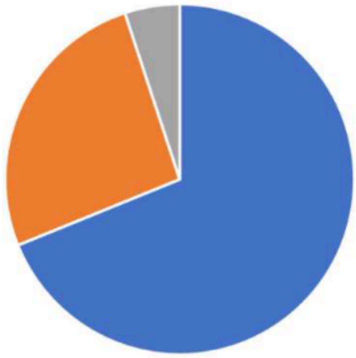

Fig 4. Dynamics of number of cages maintained.

Dynamics of Cage Numbers: A significant majority of farmers (63.7%) have maintained the same number of cages for the past 3-5 years as depicted in Table 4. A notable (24.1%) of farmers chose to increase the number of cages they maintained over a 3–5-year period. This suggests a growth or expansion in their farming operations. A small fraction of farmers (4.7%) decided to reduce the number of cages they maintained over the 3-5-year period. It was also found that sixty-two farmers (30%) maintained more than 2 cages.

Harvesting Details: The provided data outline the harvesting details in the given context, including the number of instances and their corresponding percentages.

One-time harvest: There were 97 instances, accounting for 45.8% of the total. This indicates that a significant portion of the farming operations practiced a one-time harvest approach, where the entire stock is harvested in a single event. **Periodic harvesting:** Periodic harvesting was reported in 110 cases, representing 51.9% of the total. In this approach, the harvest is carried out periodically at specific intervals, allowing for staggered harvesting and continuous supply. **Harvest coinciding with festival:** Forty-two instances, comprising 19.8% of the total, mentioned that their harvesting activities coincided with festivals. This suggests that farmers strategically time their harvest to align with festive occasions, potentially for increased market demand or cultural reasons.

Average yield and Pricing: The mean harvest for sea bass in 4x4x3 m3 cages was 600 kg, that for pompano in 6 m diameter cages was 900 kg, and that for cobia in 5x5x5 m3 cages was 800 kg. Average Price Received: The average price per kilogram for different cage-farmed fish varied, with sea bass at Rs. 425, pearl spot at Rs. 500, tilapia at Rs. 220, red snapper at Rs. 300, cobia at Rs. 400, and pompano at Rs. 320.

Table 5: Economic Analysis of the Most Common Coastal Cage Aquaculture for Seabass and Pearl Spot Composite Culture (4x3x3 m³)

Particulars	Amount (Rs)
Capital investment	
Cage Frame	30,000
Moorings and floats	20,000
Nets	28,000
Freezers and accessories	20,000
Sub Total	98,000
Depreciation @ 20 %	19,600
Interest on FC @ 12%	11,760
Annual Fixed Cost	**31,360**
Operational costs	
Licence fee	1800
Seed cost (1300 seabass @ 34 & 300 Pearl spot @18)	54,200
Feed cost (6000 kg trash fish and 140 kg pellet feed)	1,68,000
Harvesting and Miscellaneous cost	20,000
Labor cost for 9 months for 2 hours @ Rs. 200	54,000
Total operational cost (B)	2,88,000
Total Annual cost (A +B)	**3,51,360**
Returns	
Seabass (1600 kg) @450 + Pearl spot (45 kg) @490	7,42,050
Net Profit (Rs)	3,90,690
BCR	2.11
Cost of production per kg of fish	211

The economic analysis of a 4x3x3 m³ cage aquaculture system (Table 5) reveals a total capital investment of Rs. 98,000, which includes costs for the cage frame, moorings, nets, freezers, and accessories. After accounting for depreciation and interest on fixed capital, the annual fixed cost amounts to Rs. 31,360. The operational costs for the system, including license fees, seed costs, feed, labor, and miscellaneous expenses, total Rs. 2,88,000 per year. This brings the total annual cost (fixed + operational) to Rs. 3,51,360.

In terms of returns, the system yields 1,600 kg of seabass and 45 kg of pearl spot, generating a total revenue of Rs. 7,42,050. The net profit stands at Rs. 3,90,690, with a Benefit-Cost Ratio (BCR) of 2.11, indicating a highly profitable venture. The cost of production per kg of fish is calculated at Rs. 211/kg. This analysis highlights the financial viability of cage aquaculture, demonstrating a strong return on investment and sustainable profit margins when farmers follow scientific cage farming practices as advocated by Mariculture division of ICAR-CMFRI, Kochi, India. In a similar study on economic analysis, Aswathy *et al* (2020) had reported a BCR ratio of 1.55 in composite cage culture with seabass and Pearl sport in 4x4x3 m³ cage size.

Conclusion

The study concluded that the successful promotion of cage culture in India requires region-specific strategies that consider local conditions such as water resources and market demand. To address the significant gender disparity in participation, targeted interventions to support and empower women are essential. Training programs should be tailored to the age and education levels of farmers to enhance their technical skills. Support for small-scale farmers through credit facilities, technical assistance, and market linkages is crucial. Ongoing institutional support from entities such as the ICAR-CMFRI and KVKs is vital for sustainable development, and collaboration with key institutions such as the CMFRI and DOF should be strengthened for effective knowledge transfer and policy advocacy. Identifying market opportunities for major fish species and streamlining regulatory processes are also important for ensuring the economic viability and responsible practices of cage culture. Addressing these factors will contribute to the sustainable growth of the aquaculture sector. The study found that cage culture farmers were getting a BCR ratio of 2.11 in composite cage culture with seabass and Pearl sport in 4x4x3 m^3 cage size indicating good financial viability.

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