PEN AND CAGE CULTURE FOR PRODUCTION ENHANCEMENT IN INLAND OPEN WATERS

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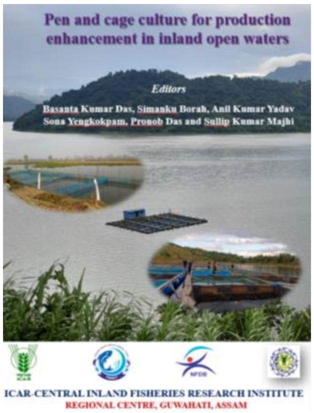

"Pen and cage culture for production enhancement in inland open waters"

This is a limited edition publication of ICAR-CIFRI titled "Pen and cage culture for production enhancement in inland open waters" prepared by financial assistance from NFDB, Hyderabad for the benefit of fisheries professionals.

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Preface

Pen and cage culture are types of enclosure culture usually practiced in open waters like floodplain wetland, river and reservoir. A pen is enclosed on all sides except bottom whereas cage is totally enclosed on all sides. Pen and cage culture technology was successfully demonstrated and perfected by ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI), Barrackpore, India as an avenue for additional fish production in floodplain wetlands parallel to enhancement of their capture fisheries/fish stock enhancement. The Institute have developed and commercialized two technologies on enclosure culture i) CIFRI GI cage and ii) CIFRI HDPE pens. The pens are ready-to-install, made of low-cost, high-density polyethylene (HDPE) nets and fibre-reinforced plastic (FRP) poles, which are easier to install and more durable than traditional net-lined bamboo pens. Successful demonstration of the technology was made in floodplain wetlands and reservoirs of North-east India.

Floodplain wetlands and reservoirs are potential fisheries resources, on which a large number of fisheries depends for their livelihood. The estimated fish production potential of floodplain wetland is 1000-1500 kg/ha/yr and that of reservoirs range from 100-500 kg/ha/yr. However present production is much lower than the potential. Fisheries management such as fish stock enhancement are already in practice for enhancing their fish production. The major constraints in stocking water bodies of North-east India are non-availability of fingerlings of desired size in required quantities nearby the sites, high cost of fingerlings and high mortality associated with transportation stress. As such, *in situ* raising fry to fingerlings in the water bodies itself through enclosure culture for their subsequent release in the wetlands is a viable option. Over the past few decades, there has been considerable increase in fish yield rates from wetlands of the region as a result of adoption of fisheries enhancement protocols. ICAR-CIFRI had demonstrated stock enhancement in open waters by using fingerlings reared in pens and cages. The Institute has put more thrust on human resource development and outreach of its technologies. In this context, we are organizing a capacity building programme (short-term) with financial assistance from NFDB, Hyderabad under PMMSY for fisheries officials of Northeast Region with a plan to share the knowledge and information with the officials. The publication entitled “Pen and cage culture for production enhancement in open waters” is prepared for use by the fisheries professionals of the region.

Editors

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ECONOMIC FEASIBILITY OF ENCLOSURE CULTURE IN INLAND OPEN WATERS

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INTRODUCTION

Enclosure culture, also known as cage culture or pen culture, refers to the practice of rearing aquatic organisms in netted enclosures or pens installed in natural water bodies such as rivers, floodplain wetlands, lakes or reservoirs. In recent years, there has been increasing interest in the economic feasibility of enclosure culture, particularly in inland open waters. This chapter aims to explore the economic aspects of enclosure culture in such environments, analysing its potential benefits, challenges, and factors influencing its feasibility.

ECONOMIC DRIVERS OF ENCLOSURE CULTURE

Growing demand for aquatic products

The increasing global demand for aquatic products, driven by population growth, rising incomes, and shifting dietary preferences, serves as a significant economic driver for enclosure culture. As traditional capture fisheries struggle to meet this growing demand, aquaculture, including enclosure culture, emerges as a sustainable solution to bridge the supply-demand gap. Consumers' preferences for fish, shrimp, and other aquatic products, continue to rise, particularly in regions experiencing rapid urbanization and dietary transitions. Enclosure culture facilitates the efficient production of high-quality aquatic products to meet this demand, contributing to economic growth, employment generation, and food security.

Decline in capture fisheries

The decline of capture fisheries due to overexploitation, habitat degradation, and climate change further underscores the economic rationale for enclosure culture. With many wild fish stocks reaching or exceeding sustainable limits, there is a pressing need to shift towards alternative sources of production. Enclosure culture offers a sustainable means of aquaculture that reduces pressure on wild fish populations while providing a reliable supply of fish and other aquatic products. By cultivating species within controlled environments, enclosure culture mitigates the environmental impact of overfishing and contributes to the conservation of biodiversity, thereby safeguarding the long-term economic viability of the fisheries sector.

Environmental concerns and sustainability

Increasing environmental concerns related to traditional aquaculture practices, such as pond-based farming, drive the adoption of enclosure culture as a more sustainable alternative. Enclosure culture systems, when properly managed, minimize the discharge of effluents, reduce habitat degradation, and optimize resource utilization, thus enhancing overall environmental sustainability. Additionally, enclosure culture allows for the efficient use of land and water resources, reducing the ecological footprint associated with aquaculture operations. As consumers and regulatory agencies place greater emphasis on sustainability and environmental stewardship, enclosure culture emerges as an economically viable and environmentally responsible approach to aquatic food production.

Government policies and incentives

Government policies and incentives play a crucial role in promoting the economic viability of enclosure culture by providing support, regulation, and financial assistance to aquaculture enterprises. Government offers subsidies, grants, and tax incentives to encourage investment in aquaculture infrastructure, research and development, and market development. Additionally, regulatory frameworks governing aquaculture operations, environmental standards, and food safety regulations can influence the economic feasibility of enclosure culture by providing a conducive business environment and ensuring consumer confidence in aquaculture products. By aligning policies with sustainable aquaculture practices and market demands, governments can foster the growth of enclosure culture as a vital component of the blue economy, driving economic development, rural livelihoods, and food security.

ECONOMIC FEASIBILITY ANALYSIS OF ENCLOSURE CULTURE

Enclosure culture in inland open waters of India holds significant economic potential, but its feasibility depends on various financial factors. This analysis delves into the key components that contribute to assessing the economic viability of enclosure culture ventures in India's open waters.

Capital investment

Capital cost includes the cost of constructing cages or pens, purchasing netting materials, mooring systems, and acquiring necessary equipment such as feeders, and monitoring devices. The approximate cost of single ICAR-CIFRI GI cage and CIFRI HDPE pen is Rs. 73,500 and Rs. 47,675. The capital cost per year is worked out by considering the costs of enclosure culture unit, labour cost for installation and expected life span. Factors influencing capital investment include the size and scale of the operation, the type of enclosure system used, technological requirements, and site-specific conditions such as water depth and accessibility.

Operational costs

Operational costs constitute ongoing expenses incurred in the day-to-day management and maintenance of enclosure culture operations. These include costs associated with feed procurement, labour, equipment maintenance, water quality monitoring, disease management, and regulatory compliance. Operational costs can vary significantly depending on factors such as the species being cultured, stocking density, feed conversion ratios, environmental conditions, and market demand.

Revenue streams

Revenue streams in enclosure culture operations primarily derive from the sale of cultivated fish or other aquatic products. The revenue generated depends on factors such as market demand, species selection, production volume, product quality, and pricing strategies. In addition to direct sales of live or harvested fish, revenue streams may include income from value-added products such as processed fish, fishmeal, or fish oil. Diversification of revenue streams through multiple market channels, including local markets, wholesale markets, direct sales, and exports, can help mitigate market risks and maximize returns on investment.

Return on investment (ROI)

Return on investment (ROI) is a crucial financial metric used to evaluate the profitability and economic performance of enclosure culture ventures in inland open waters of India. ROI is calculated by dividing the net profit generated from the operation by the total capital investment and expressing the result as a percentage. A positive ROI indicates that the enclosure culture operation is generating returns in excess of the initial investment, while a negative ROI suggests financial losses. Achieving a favourable ROI requires careful financial planning, efficient resource management, and strategic decision-making throughout the lifecycle of the enclosure culture operation.

Break-even analysis

Break-even analysis is a valuable tool for determining the point at which total revenue equals total costs, indicating the level of production or sales required to cover all expenses without generating a profit or incurring a loss. Break-even analysis helps enclosure culture operators identify the minimum production volume or sales target necessary to achieve profitability. Factors influencing the break-even point include fixed costs, variable costs, unit selling price, and contribution margin. By conducting break-even analysis, enclosure culture operators can make informed decisions regarding pricing strategies, production targets, and resource allocation to maximize profitability and mitigate financial risks.

A possible structure of enterprise budget for seed rearing in cages is given in Table 1.

Table 1. Enterprise budget for enclosure culture operation

Item	**Description**	**Unit**	**Quantity**	**Unit price (₹)**	**Total (INR)**
Gross revenue (gr)					
Sales of species 1	Average revenue of species 1	kg	q_A	p_A	$gr_A = q_A$ x p_A
Sales of species 2	Average revenue of species 2	kg	q_B	p_B	$gr_A = q_B$ x p_B
Total gross revenue (TGR)		INR			TGR = gr_A + gr_B
Variable (operational) costs (vc)					
Fingerlings	Average expenditure of fish used for stocking	no.	q_1	p_1	$vc_1 = q_1$ x p_1
Feed	Average expenditure of feed	kg	q_2	p_2	$vc_2 = q_2$ x p_2

Formalin/ KMnO4	Average expenditure of this disinfectant/ sanitizer	kg	q_3	p_3	$vc_4 = q_3 \times p_3$
Labour	Avg. remuneration paid to labours involved in fishing operations (feeding, harvesting, monitoring, etc.)	no.	q_4	p_4	$vc_4 = q_4 \times p_4$
Maintenace and repairs	Avg. expenditures made on various maintenance and repairs on the cage farm during the year	INR			vc_5
Interest on operating loan	Avg level of interests paid to lenders of operating fund	%	q_6	p_6	$vc_6 = q_6 \times p_6$
Total variable costs (TVC)		INR			$TVC = vc_1 + \ldots + vc_6$
Fixed costs (fc)					
Interest on capital investment loan	Avg level of interests paid to lenders of capital investment	%	q_7	p_7	$fc_7 = q_7 \times p_7$
Other fixed costs	Avg level of other fixed costs not identified above	INR			fc_8
Depreciation of fixed assets	Avg. level of estimated annual reductions in the value of fixed assets	INR			fc_9
Total fixed costs (TFC)		INR			$FC = fc_7 + fc_8 + fc_9$
Total costs (TC)		INR			$TC = TVC + TFC$
Gross margin (GM)		INR			$GM = TGR - TVC$
Net returns (NR)		INR			$NR = TGR - TC$

FACTORS INFLUENCING ECONOMIC FEASIBILITY OF ENCLOSURE CULTURE

Economic feasibility of enclosure culture depends on various factors, ranging from site selection to technological advancements. This section explores the key influences on the economic viability of enclosure culture ventures.

Site selection

Site selection plays a pivotal role in determining the economic feasibility of enclosure culture. Factors such as water quality, depth, temperature, currents, accessibility, proximity to markets, and infrastructure availability must be carefully considered. Suitable sites should have adequate water flow for oxygenation and waste removal, minimal pollution risks, and favourable environmental conditions for the growth and health of cultured species.

Environmental factors

Environmental considerations significantly impact the economic feasibility of enclosure culture. Factors such as water quality, habitat suitability, biodiversity, and ecosystem health influence the success of culture operations and the sustainability of aquatic resources. Poor water quality, pollution, habitat degradation, and climate change can adversely affect the growth, survival, and productivity of cultured species, leading to increased mortality rates, disease outbreaks, and production losses.

Market demand and pricing

Market demand and pricing dynamics play a crucial role in determining the economic feasibility of enclosure culture ventures. Factors such as consumer preferences, purchasing power, dietary trends, and competition from alternative protein sources influence the demand for cultured aquatic products. Understanding market trends, identifying niche markets, and establishing effective marketing strategies are essential for maximizing revenue streams and profitability.

Regulatory framework

The regulatory framework governing enclosure culture operations significantly impacts their economic feasibility. Regulations related to site permitting, water rights, environmental impact assessments, aquaculture licensing, and product quality standards influence operational costs, compliance requirements, and market access. A conducive regulatory environment that provides clarity, transparency, and stability fosters investor confidence, facilitates business planning, and promotes sustainable aquaculture development. Regulatory frameworks that prioritize environmental protection, animal welfare, and food safety contribute to the long-term viability and social acceptance of enclosure culture ventures.

Technological advancements

Technological advancements play a crucial role in enhancing the economic feasibility of enclosure culture ventures. Innovations in cage design, materials technology, aquafeed formulations, water treatment systems, monitoring devices, and automation technologies improve production efficiency, resource utilization, and disease management practices. Adopting cost-effective, sustainable technologies can reduce operational costs, increase production yields, and enhance overall profitability.

CASE STUDIES

Case Study 1: Cage culture of Indian minor carps in floodplain wetlands

The Central Inland Fisheries Research Institute (CIFRI) initiated an enclosure culture project for species diversification in floodplain wetlands of Assam. Working closely with local fisher communities and government agencies, CIFRI implemented cage culture in Samaguri beel. The project standardized the stocking densities of Indian minor carps in cages through series of experiments. Results showed density-dependent growth, with highest net yield and benefit-cost ratio at 75 fish/m^3 for raising advanced fingerlings of *L. bata* (BC ratio: 1.49) whereas 30 fish/m^3 and 40 fish/m^3 for table fish production of *L. bata* (BC ratio: 1.61) and *L. gonius*, respectively (Yengkokpam et al., 2020; Debnath et al., 2022).

Case Study 2: Pen culture of Indian major and minor carps in floodplain wetlands

CIFRI demonstrated pen culture of Indian major carps and minor in floodplain wetlands (Urpad beel and Borkona beel) of Assam under NEH Component of the Institute. The stocking densities of Indian major carp *L. catla* and minor carp *L. bata* in pens was standardized through experiments. Results showed density-dependent growth, with highest net yield and benefit-cost ratio at 3 yearlings/m^2 for rearing *L. catla* (BC ratio: 1.61) and 7 fry/m^2 for rearing *L. bata* (BC ratio: 1.41) in pens (Borah et al., 2023, 2024). Post pen culture, total monthly income of beel fishers increased by 10.76-179.11% (average increase of 90.57%) in Urpad beel whereas it increased by 6.10%-40.50% (mean increase of 26.93%) in Borkona beel.

Case study 3: Raising stocking materials in pens for culture-based fisheries/ fish stock enhancement in floodplain wetlands.

Culture based fisheries/ fish stock enhancement involves stocking fingerlings of size >10 cm for productivity enhancement. Challenges like inadequate fingerlings and distant hatcheries hinder progress. In-situ raising of stocking materials through enclosure culture in beels offers a solution. Demonstrations carried out by CIFRI in 27 beels during 2013–14 significantly boosted fish yield by 77% in the subsequent year, showing promise for improving productivity. Other studies carried out by CIFRI reported enhanced fish production after adoption of pen culture and culture-based fisheries/ fish stock enhancement protocols (Debnath et al., 2021; Yadav et al., 2021; Borah et al., 2022a). Fish production in Bamuni and Charan beels increase by 117% and 64%, respectively after technological intervention by the Institute. This resulted in doubling per capita fish production (kg/fisher family) and fish production per unit area (kg/ha/year) in Bamuni beel, while it increased by 1.5 times in Charan beel (Borah et al., 2022b).

CONCLUSION

In conclusion, enclosure culture in inland open waters holds significant economic potential but requires careful consideration of various factors to ensure its feasibility and sustainability. By addressing challenges, implementing mitigation strategies, and leveraging opportunities, this practice can contribute to meeting the growing demand for aquatic products while minimizing pressure on wild stocks and promoting economic development of communities inhabiting in the periphery of open waters.

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