E-BOOK

AQUAENTREPRENEURSHIP FOR THE SUSTAINABLE FISHERIES SECTOR GROWTH

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PREFACE

The global fisheries and aquaculture sector stands at a critical juncture. On one hand, it offers immense potential for food security, employment generation, and economic development—especially in coastal and rural communities. On the other, it faces unprecedented challenges such as climate change, overfishing, habitat degradation, and the socio-economic vulnerability of traditional fishing communities. Against this backdrop, the emergence of aquaentrepreneurship entrepreneurship focused on sustainable innovation in the aquatic ecosystem—offers a beacon of hope.

This book, "Aquaentrepreneurship for the Sustainable Fisheries Sector Growth," aims to bridge the gap between traditional fisheries practices and the evolving demands of sustainability, innovation, and inclusive economic growth. It recognizes that sustainable development in the fisheries sector is no longer just a policy aspiration, but a necessity that calls for creative business models, responsible resource management, and empowered local communities.

The book brings together insights from research, real-world case studies, policy frameworks, and entrepreneurial success stories from diverse aquatic environments. It offers a roadmap for emerging and established stakeholders—ranging from small-scale fishers and aquaculture farmers to investors, educators, policymakers, and environmentalists—who seek to build resilience, profitability, and sustainability into fisheries-based enterprises.

The editors hope that this book inspires a new generation of aquaentrepreneurs to see the water not just as a source of livelihood, but as a space of innovation, responsibility, and renewal.

Editors

Shahaji Phand
Sushrirekha Das

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Fisheries Development: Scope, Importance and Business Opportunities

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Abstract

Fisheries development plays a vital role in ensuring food security, livelihood generation, and sustainable economic growth, particularly in coastal and rural regions. With increasing global demand for protein-rich food, the fisheries sector encompassing capture fisheries, aquaculture, and allied industries has emerged as a key area for both public policy and private investment. This chapter explores the wide scope of fisheries development, highlighting its significance in enhancing nutrition, supporting biodiversity, and empowering marginalized communities. It also examines the growing opportunities for entrepreneurship, technological innovation, and export potential in the sector. Emphasis is placed on sustainable practices, value chain integration, and government initiatives that can unlock the full economic and ecological potential of fisheries. The analysis concludes by identifying strategic interventions required to transform fisheries into a dynamic driver of inclusive growth.

Key Words: fisheries, food security, aquaculture, growth

Introduction

Fisheries development represents a vital pillar of the blue economy, encompassing activities related to the cultivation, harvesting, processing, and marketing of fish and other aquatic organisms. With the increasing demand for protein-rich food and the growing emphasis on sustainable livelihoods, the fisheries sector has emerged as a significant contributor to food security, economic development, and rural employment. Fish is a valuable source of animal protein and is now considered a health food. This has also increased consumer demand. The fisheries sector plays a significant role in the socioeconomic development of the nation. As it promotes economic growth and social welfare. It has been acknowledged as a significant source of revenue and employment since it fosters the expansion of other related sectors and provides affordable, nutrient-dense food in addition to contributing to India's foreign exchange earnings (Ayyappan and Krishnan, 2004). A significant portion of our nation's economically underprivileged people depends on this industry for their daily needs. Fish workers make up more than 200 million individuals globally, or little under 3% of the world's agricultural labour force. Over 90% of them operate in artisanal, small-scale, or domestic fishing businesses and reside in poor nations (Ainsworth et al., 2021).

Due to factors including rising affluence, expanding urbanisation, globalisation, changing consumption patterns and lifestyles, rising numbers of working women, etc., fish and fishery products are becoming an increasingly important part of the diets of Indians (Albert et al., 2014). In contrast to meat, fish has less taboos connected with it and is a nutritious diet due to its high protein, vitamin, and mineral content, as well as its low fat level. Fisheries and aquaculture, however, have a lot of unrealized potential that might significantly improve lifestyles and contribute to the empowerment of women (Bennett et al., 2021). The use of new and inventive production technology, the management and utilisation of underutilised water sources, and effective marketing tactics are all necessary for the future development of aquaculture. To maximise the sector's potential, proper post-harvest handling, loss prevention, and sanitary primary processing are essential (Robert et al., 2021). To provide enough returns for the fishermen and fish growers as well as to provide excellent quality fish to the public at competitive rates, concurrent marketing arrangements must be arranged.

1. Status of the Fisheries Sector in India

In India, fishing is one of the oldest professions. The national economy may be proud of the fishing industry. The importance of this industry is two-fold: it has the capacity to create jobs and export goods. Fisheries sector has been recognized the "Sunrise Sector", which has had excellent double-digit average annual growth of 175.45 lakh tonnes in 2022-23, marking an 81% increase compared to 95.79 lakh tonnes in 2013-14. This positions India as the third-largest fish-producing nation globally, accounting for approximately 8% of the world's fish production.

The business has enormous development potential and produced a record-breaking 142 lakh tonnes of fish in FY 2019–20. During the last 9 years, the annual fish production of India has increased from 95.79 lakh tons (at the end of 2013-14) to an all-time record of 162.48 lakh tons (at the end of 2021-22) i.e. an increase of 66.69 lakh tons. Additionally, it has helped to support the livelihoods of more than 28 million people in India, particularly in marginalised and disadvantaged groups, and it has aided in promoting socioeconomic growth. India is the third largest fish producing country, contributing 8% to the global fish production and ranks second in aquaculture production. The fisheries and aquaculture production contributes around 1% to India's Gross Domestic Product (GDP) and over 5% to the agricultural GDP. The importance of the fishing and aquaculture industries has been shown by India's Blue Revolution. To achieve the Sustainable Development Goals (SDGs) and enhance the standard of living and economic security of people living in rural regions while also generating additional chances for livelihood, the Indian government has established a comprehensive strategy. The total fisherfolk population of the country is 3.52 million having 0.72 million active fishermen. There are about 2, 39,000 fishing crafts engaged in marine capture fisheries, of which 59,000 are mechanized crafts, 76,000 motorized and the rest non-mechanized. The marine fish production of the country has been increasing from a meager of 0.05 million to 3.94 million t over the last 62 years.

Table 1**.** Indian fishery resources – a glance

Marine Resources		**Inland Resources**	
Length of coastline	8118	Total inland water bodies (lakh ha.)	73.59
Exclusive economic zone (EEZ) million Sq. Km	2.02	Rivers & canals (lakh km)	1.95
Continental shelf (million sq. km.)	0.5	Reservoirs (lakh ha.)	31.5
Number of fish landing centres	1537	Tanks and ponds (lakh ha.)	24.14
No. of fishing villages	3432	Flood plain/derelict waters (lakh ha.)	7.98
No. of fishermen families	8747	Brackish water (lakh ha.)	12.40
Fisher folk population	3574704		

2. Inland aquaculture

Inland aquaculture in India has experienced substantial growth, solidifying its role as a pivotal component of the nation's fisheries sector. This expansion is characterized by increased production, significant economic contributions, and supportive government initiatives. The fisheries sector, with inland aquaculture as a significant contributor, plays a crucial role in India's economy. In the fiscal year 2022-23, the sector achieved a record fish production of 175.45 lakh tonnes, contributing approximately 1.09% to the country's Gross Value Added (GVA) and over 6.72% to the agricultural GVA.

Fish production in India has witnessed a tremendous growth by showcasing a production increase from 0.75 million MT during 1950-51 to the current production of 14.1 million MT. Till 2000, marine fish production dominated India’s total fish production. At present, the market size is over INR 650 billion and expected to reach INR 1950 billion by 2027, growing at the rate of 18% CAGR. The fish & sea food industry also earned revenue of over INR 46662.85 crore in 2019-20 through exports. However due to practice of science-based fisheries, Inland fisheries in India has seen a turnaround and presently contributes ~70 % of total fish production. Recognizing the potential of inland aquaculture, the Indian government has launched several initiatives to support its development. The Pradhan Mantri Matsya Sampada Yojana (PMMSY) aims to enhance fish production and create employment opportunities in the fisheries sector. Inland aquaculture in India has emerged as a dynamic and vital sector, marked by significant production increases, economic contributions, and supportive policies. Continued focus on sustainable practices and technological advancements is essential to maintain this growth trajectory.

2.1 Tanks & Ponds

India has around 2.36 million Ha of Tanks & Ponds area where culture-based fishery is predominant and contributes to the maximum share in total fish production. The current production from tanks and pond is 8.5 million MT. As a major contributor towards production, the Department has prioritized to expand the horizontal area under tanks and ponds to achieve a target production of 13.5 million MT.

In view of that, the Department has sanctioned proposals from different states to provide necessary impetus for leveraging innovative technologies. Accordingly, below sanctions have been made under PMMSY with the total project cost Rs 36,031.70 Lakhs.

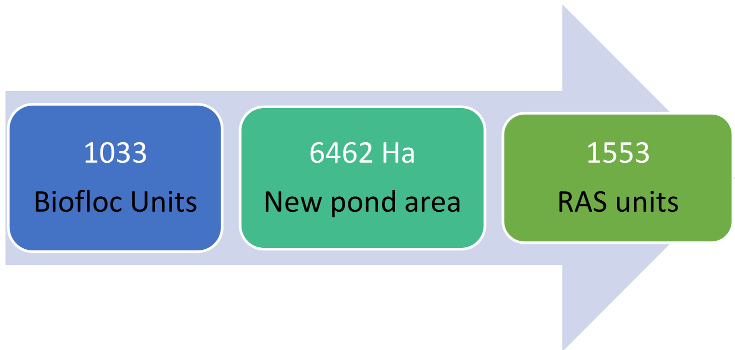

Figure. 1 Status of inland fisheries sector

3. Scope and Opportunities of Startups in fishery sector:

The world's population is expected to increase to 9.8 billion people in 2050, placing an even greater burden on the planet's food supply. India, blessed with a vast coastline of 7,516.6 km and extensive inland water resources, offers substantial scope for fisheries development. The aquaculture industry has the potential to be extremely important in supplying the rising demand for protein across the world. With its significant contribution to the socioeconomic development of the nation, the fishing industry has grown to be a significant source of revenue and employment, and it also encourages the expansion of other related small, medium, and large-scale sectors. Translating the findings of study in the fields of fisheries and other agricultural areas. With a focus on research and development activities towards improvement of current practises and development of new technology to ensure sustainable supply of high quality products to meet growing demand from both national and international markets, both in terms of volumes and value addition, the industry has already significantly contributed to employment generation and exports. The sector includes:

- **Marine Fisheries**: Exploiting fishery resources in coastal and deep-sea waters.
- **Inland Fisheries**: Utilizing rivers, lakes, reservoirs, ponds, and wetlands for capture and culture fisheries.
- **Aquaculture**: The controlled breeding and rearing of aquatic species such as fish, shrimp, and mollusks in tanks, ponds, and cages.
- **Ornamental Fish Farming**: Cultivation of decorative fish species for domestic and international markets.

- **Seaweed and Shellfish Culture**: Growing seaweed, mussels, oysters, and other species with high nutritional and commercial value.

The diverse climatic zones and water bodies across the country provide immense potential to enhance fish production and develop sustainable aquaculture systems. The goal of fishpreneurship development is to increase business people's ability and desire to plan, organise, and run their businesses in the fisheries sector. Commercial fish farming, seed production, the development and export of fish and fish products, the breeding and marketing of ornamental fish, and the sale of aquatic plants are only a few industries with enormous potential. A fishpreneurship can be launched in a variety of industries. Fishermen that possess particular traits are the best people to learn from and imitate if one wants to become a successful fishpreneur. Such qualities required for a good fishpreneur include consistency (though fishing is not guaranteed to produce a catch, fisherman go out regularly), meticulous utilisation of assets and resources (like a fisherman repairing and maintaining his boat and net meticulously), community oriented activities, teamwork (fishing is essentially a teamwork), and willingness to change.

- ❖ **Fishpreneurship**:

  In fishpreneurship the pond construction, brood stock maintaining units, hatcheries and allied activities, feed manufacturers, input industries for treatment of water, chemicals, medicines, pro-biotic, equipments ranging from aerators, generators, pumps of various types, etc.
- ❖ **In post-harvest fisheries sector**:

  Fishpreneurship development is possible include; Pre-processing Units, Ice Plants, Peeling sheds, processing units, fish meal and fish oil manufacturers, fish drying units, fish curing units, fish canning units, cold storages, quality assessors, etc.
- ❖ **Marketing Sector:**

  There are diverse opportunities which include; Fish Wholesalers, Middlemen, Fish Retailers, Fish Vendors, Fish transporters, Cold Chain Related Personnel, Buyers from various processing units, etc. Online marketing of fish is also a growing business.
- ❖ **Fishery Based Enterprises:**

  Value added products preparation, preparation of dried fish products, fish processing unit, ready to eat fish product development, ready to cook fish product development, ornamental fish culture enterprise, mussel culture, clam collection, edible oyster culture, pearl culture, mud crab culture, Fertifish unit, net building, aqua tourism, fish vending/ selling, cage farming, fish and shrimp culture, fish feed production and many more.

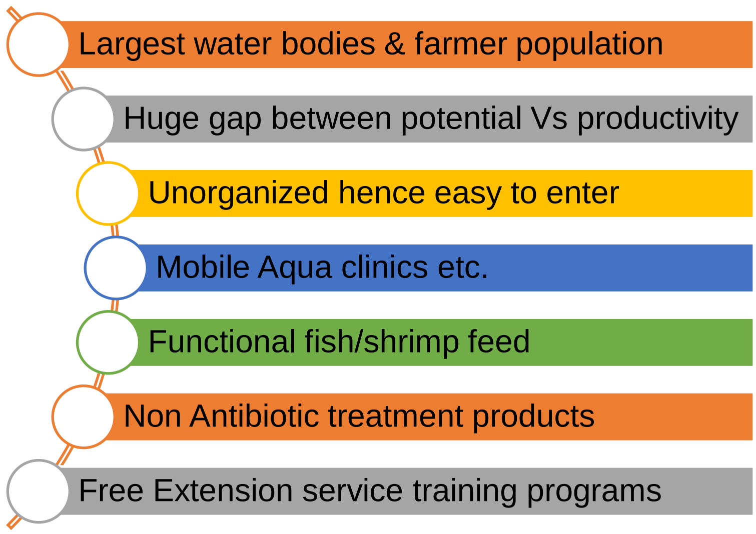

Figure 2. Opportunities in fishery and aquaculture sector

4. Importance of the Fisheries Sector

The fisheries sector plays a pivotal role in the socio-economic and nutritional well-being of millions of people around the world. As a critical component of the global food system, it contributes significantly to economic development, food and nutritional security, employment generation, and environmental sustainability. Especially in coastal and developing countries, the fisheries sector supports the livelihoods of entire communities and forms the backbone of local economies. The fisheries sector holds immense importance across economic, social, nutritional, and environmental dimensions. Economically, it plays a crucial role in contributing to national income, especially in countries with extensive coastlines, inland water bodies, and high levels of rural population. It provides direct and indirect employment to millions of people, supporting livelihoods in both coastal and inland regions. Fishers, fish farmers, traders, processors, and workers involved in ancillary activities like boat-making and net-weaving depend on the sector for their sustenance. In many developing countries, fisheries are a key source of income for marginalized communities, promoting inclusive growth and rural development.

4.1. Economic Contribution

The fisheries sector contributes approximately 1.09% to India's Gross Value Added (GVA) and more than 6.72% to agricultural GVA. It is among the fastest-growing sectors, with annual growth rates averaging over 10% in recent years.

4.2. Livelihood and Employment

Fisheries provide livelihoods to over 30 million people in India, particularly in coastal and rural communities. It supports employment across various segments, from fishing and aquaculture to processing, transportation, and retail.

4.3. Nutrition and Food Security

Fish is a rich source of high-quality animal protein and essential micronutrients. It plays a crucial role in combating malnutrition and improving dietary diversity, especially in regions with limited access to other protein sources.

4.4. Export Earnings

India is a major exporter of fish and seafood products, with marine products such as shrimp and frozen fish accounting for significant foreign exchange earnings. The country ranks third in overall fish production and second in aquaculture globally.

4.5. Environmental Sustainability

When managed responsibly, fisheries can contribute to environmental conservation by promoting biodiversity, maintaining ecosystem balance, and utilizing underutilized water resources.

5. Business Opportunities in Fisheries

With growing demand for fishery products and advancements in technology, there are numerous business prospects in the sector:

5.1. Fish Farming

Entrepreneurs can invest in pond-based or tank-based aquaculture, with species such as carp, tilapia, pangasius, and catla offering profitable returns.

5.2. Shrimp and Prawn Culture

India is a global leader in shrimp exports. The cultivation of species like *Litopenaeus vannamei* in inland and coastal areas is a highly lucrative business.

5.3. Cage Culture

This involves growing fish in floating cages installed in reservoirs, rivers, or coastal waters. It is gaining traction due to its efficient use of space and resources.

5.4. Recirculating Aquaculture Systems (RAS)

RAS is an advanced method that allows fish to be reared in controlled environments with minimal water usage, ideal for urban and peri-urban farming.

5.5. Ornamental Fish and Aquarium Business

The ornamental fish industry is expanding rapidly, with both domestic and export markets showing consistent growth.

5.6. Fish Processing and Value Addition

Processing units, cold chains, and packaging solutions offer substantial business avenues. Ready-to-eat fish products, fish pickles, and dried fish have high market demand.

5.7. Feed and Hatchery Units

There is a growing need for quality fish feed and seed. Establishing hatcheries and feed mills is both economically and strategically rewarding.

5.8. Seaweed and Algal Farming

Seaweed cultivation has vast untapped potential for use in pharmaceuticals, food supplements, biofuels, and cosmetics.

5. Government Support and Policy Framework

6.1 Major Initiatives taken towards Fish Production- (Pradhan Mantri Mastya Sampad Yojana) PMMSY Scheme:

The introduction of promotion and subsidy support programmes for fish farming, price realisation, extension services, and other promotional and developmental measures were the key causes of the inland fisheries' faster expansion. There is still much room to increase production and productivity in Indian fish farming. Under the Ministry of Fisheries, Animal Husbandry and Dairy, a distinct Department of Fisheries was established in anticipation of the great resource potential and export opportunities in the fisheries industry. The Government of India has introduced a number of programmes and schemes, including the restructured umbrella programme "Blue Revolution: Integrated Development and Management of Fisheries," which focuses on increasing fish production and productivity from aquaculture and fisheries resources, both inland and marine sectors, through full potential exploitation of water resources for fisheries development in a sustainable manner, while keeping in mind the biosecurity and environmental protection. The Government of India in May 2020 approved PMMSY with an estimated investment of Rs. 20,050 Crores comprising of Central share of Rs. 9407 Crores, State share of Rs. 4,880 Crores and beneficiaries contribution of 5, 763 Crore for a period of five years from FY 2020-21 to FY 2024-25. The main aim of the scheme intends to double the fish farmer's income and enhance fish production to 220 lakh metric tonnes by 2024-25. The scheme intends to address critical gaps in fish production and modern technology, post-harvest infrastructure, infusion of innovation and modern technology, post-harvest infrastructure & management, modernisation and strengthening of value chain, traceability, establishing a roboust fisheries management framework and fishers' welfare. PMMSY will create a conducive environment for private sector participation, development of entrepreneurship, business models, promotion of ease of doing business, innovations and innovative project activities including start-ups, incubators, etc. in fisheries sector; Fisheries and Aquaculture Infrastructure Development Fund for funding infrastructure projects in fisheries sector with a corpus of Rs.7522.48 crore spreading over a period of five years was created. National Bank for Agriculture and Rural Development (NABARD), National Cooperatives Development Corporation (NCDC) and all Scheduled Banks will serve as Nodal Loaning Entities; Under Rural Infrastructure Development Fund, GoI has permitted NABARD to extend RIDF loans for fisheries related infrastructure such as fishing harbours/jetties and riverine fisheries; Scheme for Agro Marine Processing and Development of Agro Processing Clusters (SAMPADA) with an outlay of Rs.6000 crore for the period of 2016-2020 with aimed at creation of modern infrastructure from farm gate to retail outlet. KCC facility was extended to fish farmers to meet the working capital requirement of fisheries activities including aquaculture.

Fish farmers (individual & groups/partners/share croppers/tenant farmers), self-help groups, joint liability groups are eligible for availing the KCC facilities. The interest subvention on KCC for fisheries farmers upto Rs.2.00 lakh @ 2 per cent per annum at the time of disbursal of loans and additional interest subvention @ 3 per cent per annum in case of Prompt Repayment Incentive; and National Fisheries Policy, 2020 aims at comprehensive development of the fisheries sector through appropriate interventions to address the critical gaps with an overarching goal for growths in exports, increase in farmer's income and better choice for consumers.

Fig.3 Scopes in fisheries sector

6.2 Role of the National Fisheries Development Board (NFDB)

The National Fisheries Development Board (NFDB), operating under the Ministry of Fisheries, Animal Husbandry and Dairying, Government of India, plays a pivotal role in promoting sustainable growth and modernization of the fisheries sector, particularly inland aquaculture. It serves as a key institution in the implementation of strategic initiatives, policy support, and sectoral development.

Policy Implementation and Institutional Coordination

NFDB acts as the nodal agency for the execution of flagship government programs such as the Pradhan Mantri Matsya Sampada Yojana (PMMSY). It facilitates seamless coordination between the Central and State governments, ensuring effective delivery of schemes aimed at enhancing fish production, income generation, and sectoral sustainability.

Financial Support and Incentive Mechanisms

The Board administers a range of financial assistance programs, providing grants and subsidies for:

- Establishment of hatcheries and rearing ponds
- Expansion of pond aquaculture systems
- Development of fisheries infrastructure including cold chains and fish retail markets

It prioritizes projects that integrate technological innovation, environmental sustainability, and livelihood improvement.

Capacity Building and Human Resource Development

NFDB undertakes extensive capacity-building initiatives by organizing training programs, workshops, and exposure visits for fish farmers, entrepreneurs, and officials. It partners with research institutions, universities, and training centers to promote the adoption of modern, sustainable aquaculture practices.

Infrastructure Development

The Board plays a critical role in facilitating the creation of fisheries infrastructure, including:

- Fish seed production and rearing facilities
- Feed manufacturing units
- Processing, storage, and marketing infrastructure
- Digital platforms to enhance market access and traceability

Promotion of Technology and Innovation

NFDB actively promotes the adoption of advanced technologies such as Recirculating Aquaculture Systems (RAS), biofloc technology, and cage culture. It provides technical advisory services and incentives to encourage the deployment of climate-resilient and resource-efficient aquaculture systems.

Research, Data Management, and Policy Support

The Board funds and collaborates on research projects focused on genetic improvement, disease management, feed optimization, and production enhancement. It also plays an important role in data collection, monitoring sectoral performance, and providing inputs for evidence-based policymaking.

Focus on Sustainability and Social Welfare

NFDB integrates environmental and social dimensions into fisheries development by:

- Advocating eco-friendly practices and biodiversity conservation
- Supporting fisher and farmer welfare programs, including insurance coverage, health initiatives, and social security measures.

7. Challenges in Fisheries Sector

Major barriers to the expansion of marine capture fisheries include limited room for growth owing to territorial water overcapacity, lax regulation, ineffective management, and the persistence of traditional fishing methods. Other factors limiting the expansion of the capture fisheries include a lack of skilled labour, poor processing and value addition, wastage, inadequate traceability and certification, inadequate infrastructure, especially fishing harbours, landing centres, cold chain and distribution systems, and poor distribution and processing. Some of the major limiting constraints in inland capture fisheries are the seasonal nature of fishing operations, reduced populations in natural waterways, problems with tenure and lease rights, use of antiquated technology for harvesting, and poor capital input.

Low levels of investment, insufficient institutional credit, high cost of credit, inadequate infrastructure for pre-production, production, post-harvest, and processing facilities, low adoption of technologies, low input culture system, lack of diversity in culture practises and species, lower productivity, and poor physical condition of resources (especially the water quality and quantity). There is a huge gap in the fish seed production and its availability in the country. A significant barrier to the fishing sector's expansion into export and international markets is the processing and value addition required to comply with food safety standards.

8. Strategies to Overcome the Constraints in Fisheries Sector:

- Aquaculture needs to be treated at par with agriculture in terms of water, power tariff, tax benefits, subsidy, insurance and credit.
- Strengthen and modernize value chain including creation of fisheries infrastructure to increase shelf life, reduction of post-harvest losses and production of value added products.
- Promote community partnerships, private participation and effective cooperative movement in fisheries sector.
- Modernization of fishing vessels to handle storage and quality preservation of fish.
- Fishing harbours and fish landing centres play a vital role in ensuring safe fish landing, berthing of fishing vessels, pre-processing and auctioning.
- There is a need for diversification of fish production in other areas like integrated fish farming, cold water fisheries, riverine fisheries, capture fisheries, brackish water fisheries, etc.
- Expansion of area under aquaculture has to become an important option to boost fish production.
- Promotion of cluster approach as a key strategy for focused and concentrated development of aquaculture with emphasis on creation of integrated production and processing clusters with supporting infrastructure.
- There is a need for availability of quality seed and feed for sustained growth in inland fish production in the long run.

Conclusion

For millions of people, particularly in rural areas, fishing and aquaculture remain significant sources of food, nutrition, work, and money. In actuality, the industry supports the livelihoods of approximately twice as many individuals along the value chain and about 16 million people at the primary level. By 2022, the industry has the incredible potential to treble the incomes of fishermen and fish growers. The fisheries sector in India stands at a transformative juncture, emerging as a cornerstone of economic development, food security, and inclusive growth. With an extensive coastline, vast inland water resources, and diverse climatic conditions, India possesses unparalleled potential to expand and diversify its fisheries and aquaculture activities. Over the past decade, the sector has evolved from a traditional livelihood activity into a dynamic, technology-driven industry. It has consistently demonstrated robust growth, not only in terms of production and export but also in its ability to generate employment, uplift rural communities, and contribute to national income. Inland aquaculture, in particular, has shown phenomenal progress, helping to bridge the gap between supply and growing consumer demand for protein-rich food.

The government's proactive initiatives such as the Blue Revolution and the Pradhan Mantri Matsya Sampada Yojana alongside private sector participation, are creating an ecosystem conducive to innovation, entrepreneurship, and investment in fisheries. This has opened up a wide array of business opportunities ranging from small-scale fish farming to large-scale processing and export operations. Furthermore, the role of fisheries in addressing critical global challenges like climate change, biodiversity conservation, and rural poverty has come into sharp focus. Sustainable fisheries management, eco-friendly aquaculture practices, and integrated value chain development must be prioritized to ensure long-term resilience of the sector. Through a multi-faceted approach encompassing financial support, infrastructure development, innovation promotion, and capacity building, the NFDB significantly contributes to the growth, modernization, and sustainability of India's inland aquaculture sector. Its efforts enhance the sector's role in ensuring food security, employment generation, and rural economic development, while aligning with broader national goals of a sustainable and resilient Blue Economy. In conclusion, the future of fisheries development in India is both promising and pivotal. By leveraging its natural resources, embracing modern technologies, empowering fishing communities, and fostering strategic collaborations between stakeholders, India can emerge as a global leader in sustainable fisheries and aquaculture. The sector holds the key to achieving several Sustainable Development Goals (SDGs), especially those related to zero hunger, decent work, economic growth, and life below water—making it not just a means of livelihood, but a driver of holistic and sustainable national development.

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Chapter-2

Entrepreneurship opportunities in Ornamental fishery

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Abstract

Ornamental fish keeping is one of the most popular hobbies in the world next to photography. There is tremendous economic opportunity and prospects for ornamental fishes in both domestic and international markets. These fishes are peaceful, generally tiny, attractive and compatible to live with other ornamental fishes. They require only a minimal space, manpower, attention and capital investment compared with the culture activities of edible fishes and also they fetch more price than the food fishes. There is a great employment opportunities and entrepreneurship in ornamental fish sector such as: breeding activities, fabrication of aquarium glass tanks, aquascaping, aquarium plants propagation and trade, live feed culture and collection, production of artificial feeds (pellets, flakes, granules and tablets), making and marketing of aquarium accessories (aquarium toys, filters, aerators, pumps, air stones, heaters, thermostats, nets, decorative stones, rocks, gravel and background posters), production of chemicals and medicines for the treatment of diseases, synthetic hormones for induced breeding of ornamental fishes, setting up of aquarium shop and consultancy services. Indian ornamental fish trade is contributed by both freshwater (90%) and marine fishes (10%). To overcome these challenges both the state and central governments have taken several initiatives towards the development of fisheries sector through various organizations and schemes. The Government of India has allocated 576 crores for catalyzing the growth of ornamental fish industry through The Pradhan Mantri Matsya Sampada Yojana (PMMSY).

Key words: aquarium, ornamental fish, breeding, enterprenurship

Introduction

The Sumerians were the earliest known aquarists who reared fishes in artificial ponds around 4,500 years ago. The records of Egypt and Assyria also showed the practice of fish keeping. The Chinese were pioneers in breeding fishes successfully as early as 2000 BC. The breeding techniques of goldfish were then introduced to Japan and they standardized the breeding and rearing techniques of goldfish. Japanese are now the largest exporters of goldfish. Around 500 BC, records of ancient Babylonians showed that they kept ornamental fishes in ponds. The ancient Romans were the first to keep marine aquarium and also to keep ornamental fishes as pets at homes. The Chinese were the forerunners in the art of ornamental fish keeping and goldfish were the first ornamental fish to be kept. During 968-975 AD ornamental fish culture gained popularity among rich and the consumption of ornamental fishes were completely banned. By 1510, the culture and breeding of goldfish has become more common to people all over the world.

In 1853, Philip Henry Gosse made the first public aquarium combined with a water fountain placed at Regents Park Zoological Gardens, England, and he was the first to use the term "aquarium". Later, aquarium keeping has become popular in France (1859), Germany (1864) and the United States (1900). Dr. Johnston in 1842 introduced the first glass marine aquarium and in 1850 first freshwater aquarium was introduced. During that period marine aquarium were more popular than the freshwater aquarium. The first display aquarium was opened to the public in 1853 at Regent's Park in London, and in1856, private enterprise displayed aquarium at the American Museum in New York City. By 1928 there were 45 public aquariums throughout the world. In India, the first aquarium was established in the 20th century. Taraporewala Aquarium in Mumbai is India's oldest aquarium which hosts both marine and freshwater ornamental fishes. The VGP Marine Kingdom in Chennai is the largest walk-through aquarium in India with 70-metre acrylic tunnel. The aquarium features five concept zones namely Rainforest, Gorge, Mangrove, Coastal and Deep Ocean.

Scope and benefits of ornamental fish keeping

- Freshwater and marine ornamental fishes fetch more price than food fishes.
- Provides opportunity for both small scale and large-scale entrepreneurs.
- Minimal requirement of space, manpower, attention and capital investment compared with the culture activities of edible finfishes and shellfishes.

- Ornamental fishes are compatible to live with other fishes.
- Ornamental fishes are peaceful, generally tiny and attractive.
- Skilled ornamental fish technician can maintain aquaria at hotels, airports, parks and other public places.
- The rich diversity of ornamental fishes and favorable climatic conditions for breeding and rearing provides a great scope for ornamental fish production in India.
- Keeping aquarium at home gives pleasure to all at home, reduces stress and blood pressure and brings psychological benefits to consumers of various age groups.
- Activities such as culture, breeding, export and import of ornamental fishes bring direct employment; and the supply of accessories like filters, aerators, natural plants, artificial plants, live feed, artificial feed, etc. brings indirect employment.
- The social and economic status of the women can be improved by running small home aquarium units, providing livelihood security for rural women and also augment national income.

Entrepreneurship opportunities in fisheries sector

1. Fabrication of aquarium glass tanks

An aquarium is a closed container which displays the aquatic organism in a natural environment. It is easy to make a glass aquarium tank with some basic materials like glass panes, silicon rubber and squeezing gun, adhesive tapes, polythene tapes, glass cutter etc. Since there is a demand for glass tanks over acrylic tanks for small aquarium, there is much scope for glass tank fabrication business.

2. Aquascaping

Aquascaping is an art of arranging aquatic plants, rocks, stones and drift wood in an aesthetic manner within an aquarium. There are different types of designs and styles that are being followed in aquascaping *viz*. Dutch style, Jungle style, Biotopes style, Palydarium style, Iwagumi style, Japanese style, etc. Aquascaping mainly requires a glass tank, soil, aquatic plants, carbon dioxide cylinder, filter and lighting. In India, most of the accessories used in aquascaping are imported and quite expensive. There is great scope for young innovative entrepreneurs in aquascaping.

3. Aquarium plants propagation and trade

Aquarium plant culturing/cultivation and propagation are emerging as employment generating industries in aquarium trade. The plants play a very important role as oxygen generators and absorbs CO_2 and other harmful gases. They provide shelter, shade and hiding place for smaller fishes and spawning site for brooders. They act as a food for herbivorous fishes. Aquatic plants are broadly classified into floating plants (*Lemna* sp., *Eichornia* sp., *Pistia* sp., *Azolla* sp., *Wolffia* sp., etc.), emergent plants (*Nymphaea* sp., *Nelumbo* sp., etc.), submerged plants (*Hydrilla* sp., *Aponogeton* sp., *Potomogeton* sp., *Ludwigia sp*., *Ceratophylum* sp., *Myriophylum* sp., *Cabomba* sp., etc.) and marginal plants (*Cryptocoryne* sp., *Echinodorus* sp., *Ipomoea* sp. etc.). Aquarium plants have a very good market in Europe and the US. Artificial aquarium plants also are in demand in the domestic market, as they do not need any maintenance and adds beauty to the aquarium.

4. Culture and breeding activity

Starting of culture and breeding unit will not depend upon sophisticated or complicated equipment but they depend mainly on the knowledge of the habits and biology of fishes. Some livebearers prefer to breed in hard alkaline water, whereas fishes like tetra, angel, discus, oscar and loaches prefer acidic water. Egg layers like fighter fish, danio, goldfish and rosy barb can tolerate a wide range of waters. Captive bred clown fishes are hardier, disease resistant and easily adjust to marine aquarium than the fishes collected from the wild. The success of ornamental fish culture and breeding depends on the quality of brooders, infrastructure, sufficient water, electricity supply, feed management, water quality management and disease management. Though the Indian climatic conditions favor the breeding and rearing of ornamental fishes, the activities are highly restricted to a few states like West Bengal, Tamil Nadu, Kerala, North East states, Maharashtra, Madhya Pradesh, Rajasthan and Uttar Pradesh. The ornamental fish breeders in India breed mostly exotic varieties rather than the indigenous varieties of freshwater, marine and brackish water ornamental fishes.

5. Entrepreneurship through making and marketing of accessories

There is a great scope for young entrepreneurs in culture and collection of live feed. Live feeds like Daphnia, Tubifex and mosquito larvae can be collected from the waterbodies and supplied to the farmers. Cost-effective artificial feeds can be prepared for brooders and young ones. Production of ornamental fish feeds in the form of flakes, pellets, granules and tablets is a good opportunity for young entrepreneurs. There is also scope for entrepreneurs in making and marketing of aquarium accessories like aquarium toys, filters, aerators, pumps, air stones, heaters, thermostats, nets, decorative stones, rocks, gravel and background posters. There is a demand for the production of health-related items like chemicals, antibiotics and medicines for the treatment of diseases and synthetic hormones for induced breeding of ornamental fishes.

6. Setting up of an aquarium shop

Aquarium shops is the place where sale of ornamental fishes takes place. Young entrepreneurs can start their business in setting up of an aquarium shop with some basic knowledge in maintenance of aquarium fishes. Fish feeds and other aquarium accessories can also be made available in the shop for sale.

7. Consultancy/services

A skilled technician can earn without any investment, just by giving consultancy/service to individual aquarium at home and public aquaria.

Ornamental fish diversity in India

India has a rich diversity of freshwater and marine ornamental fishes. Around 195 indigenous varieties were reported from the North East region and the Western Ghats, out of which 155 have ornamental value. Around 400 species were recorded from marine ecosystem.

Major indigenous freshwater ornamental fishes

Some of the major freshwater ornamental fishes are: *Channa micropeltes* (Snake head), *Puntius denisonii* (Red line torpedo fish), *Channa gachua* (Brown snake head), *Barilius canarensis* (Jerdon's baril), *Channa striatus* (Snake head), *Gonoproktopterus curmuca* (Redtail silver shark), *Gonproktopterus thomassi* (Nilgiri shark), *Horabagrus brachysoma* (Yellow catfish), *Horabagrus nigricollaris* (Black collared catfish), *Dawkinsia arulius* (Arulius barb), *Puntius amphibius* (Scarlet banded barb), *Lates calcarifer* (Giant sea perch), *Wallago attu* (Killer catfish), *Nemacheilus triangularis* (Zodiac loach), *Puntius* *filamentosus* (Indian tiger barb), *Puntius mahecola* (Malini's barb), *Channa marulius* (Peacock snake head), *Pangasius pangasius* (*Pangas* catfish) , *Channa orientalis* (Snake head), *Barilius bakeri* (Blue spotedhill trout), *Xenentodon cancila* (Pipe fish), *Amblypharyngodon mola* (Brass fish), *Macrognathus aral* (Spiny eel), *Notopterus notopterus* (Grey feather back), *Etroplus suratensis* (Pearl spot), *Garra gotyla* (gotyla – sucker head), *Nandus nandus* (Leaf fish), *Ompok bimaculatus* (Butter catfish), *Puntius bimaculatus* (Two spot barb), *Pseudosphromenus cupanus* (Spiketail paradise fish), *Aplocheilus lineatus* (Striped panchax), *Devario malabaricus* (Malabar danio), *Anabas testudineus* (Climbing perch), *Pseudetroplus maculatus* (Orangechromide), *Mystus vittatus* (Striped loach), *Puntius sophore* (pool barb), *Chela dadiburjori* (Burjor's brilliance), *Haludaria fasciata* (Melon barb), *Eleotris fusca* (Bicolor goby), *Aplocheilus blockii* (*green panchax***)**, *Mastacembelus armatus* (Marble spiny eel), *Pethia ticto* (Ticto barb), *Puntius vittatus* (Silver barb), *Opsarius barna* (Silver hill trout), *Carinotetraodon travancoricus* (Puffer fish), *Rasbora daniconius* (Slender rasbora), *Parambassis ranga* (Indian glass fish), *Esomus danrica* (Flying barb), *Aplocheilus* sp.(Red panchax), *Lepidocephalichthys thermalis* (Loach), *Oryzias melastigma* (Blue eyes).

Puntius denosonii

Barilius canarensis

Channa striatus

Puntius arulius

Puntius filamentosa

Xenentodon cancila

Devario malabaricus

Punitus fasciatus

Rasbora daniconius

Barilius bakeri

Chela dadiburjori

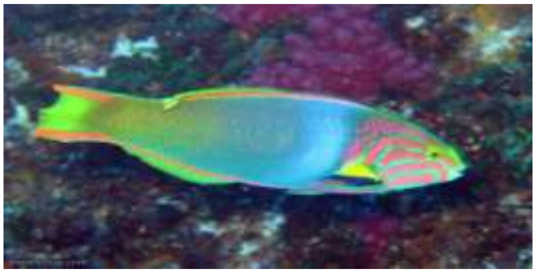
Macropodus cupanus

Figure 1. Indigenous Freshwater Ornamental Fishes (Source: Creative Commons)

Major indigenous marine ornamental fishes

Some of the major marine ornamental fishes are: *Pomacanthus imperator (*Emperor angel fish), *Gymnothorax sp.* (Moray eels), *Narcine timlei* (Black spotted numb fish), *Pomacanthus semicirculatus* (Blue angel fish), *Heniochus acuminatus* (Pennet coral fish), *Arothron* sp. (Puffer fish), *Thalassoma lunare* (Moon wrasse), *Cephalopholis sp.* (Coral-cod), *Zanclus cornutus* (Moorish idol), *Chelonodon patoca* (Milkspotted puffer), *Chaetodon collare (*Redtail butterfly fish), *Diodon hystrix* (Porcupine Fish), *Pterois* sp. (Lion fish), *Epinephelus* sp. (Grouper), *Scarus ghobban* (Parrot fish), *Chaetodon vagabundus* (Vagabond butterflyfish), *Chaetodon auriga* (Threadfin butterflyfish), *Acanthurus nigrofuscus* (Brown surgeonfish), *Lutjanus* sp. (Snapper), *Siganus* sp. (Rabbit fish), *Cantherhines pardalis* (Honeycomb file fish), *Platax teira* (Long fin bat fish), *Plectorhinchus gibbosus* (Harry hotlips), *Terapon* sp. (Croaker), *Ostracion cubicum* (Yellow box fish), *Sargocentron rubrum* (Soldier fish), *Odonus niger* (Trigger fish), *Amphirion* sp. (Clown Fish), *Myripristis murdjan* (Pinecone soldier fish), *Canthigaster bennetti* (sharpnose puffer), *Halichoeres* sp. (Wrasse), *Platax orbicularis* (Orbicular batfish), *Plotosus lineatus* (Striped eel catfish), *Chromis viridis* (Damsel fish), *Apogon* sp. (Cardinal fish), *Pomacentrus caeruleus* (Blue damsel), *Abudefduf saxatilis* (Sergeant major).

Pomacanthus imperator



Thalassoma lunare

Arothron meleagris

Zanculus cornutus

Chaetodon collare

Scarus ghobban

Platax teira

Myripristis murdjan

Pomacentrus caeruleus

Siganus puellus

Apogon nigrofasciatus

Odonus niger

Figure. 2 Indigenous Marine Ornamental Fishes (Source: Creative Commons)

Major indigenous brackishwater ornamental fishes

Brackishwater ornamental fishes include *Monodactylus argenteus* (silver moony), *M. sebae* (African moony), *Scatophagus argus* (spotted butterfish), *Etroplus suratensis* (Green chromide), *E. maculatus* (Orange chromide) and *Ambassis* sp. (glassfish).

Monodactylus argenteus

Monodactylus sebae

Scatophagus argus

Etroplus suratensis

Pseudetroplus maculatus

Ambassis nalua

Figure 3: Indigenous Brackishwater Ornamental Fishes (Source: Creative Commons)

Commonly preferred exotic live bearers and egg layers in India

Some of the exotic live bearers and egg layers are: *Poecilia reticulata* (Guppy), *Poecilia latipinna* (Molly), *Xiphophorus helleri* (Swordtail), *Xiphophorus maculatus* (Platy), *Carassius auratus* (Goldfish), *Cyprinus carpio koi* (Carp), *Puntigrus tetrazona* (Tiger Barb), *Betta splendens* (Fighter fish), *Hyphessobrycon serape* (Tetra), *Balantiocheilos melanopterus* (Silver Shark), *Pterophyllum scalare* (Angelfish), *Epalzeorhynchos bicolor* (Red-tailed black shark),*Labeo erythrurus* (Rainbow shark).

Poecilia reticulata

Poecilia latipinna


Xiphophorus hellerii


Xiphophorus maculatus


Carassius auratus


Cyprinus carpio koi


Hyphessobrycon serpae


Balantiocheilos melanopterus


Pterophyllum scalare


Epalzeorhynchos bicolor


Labeo erythurus


Puntigrus tetrazona

Figure 4. Exotic Ornamental Fish Varieties (Source: Creative Commons)

The most beautiful marine and freshwater ornamental fishes

The world's most beautiful marine ornamental fishes include *Synchiropus splendidus* (Mandarin Dragonet), *Pomacanthus imperator* (Juvenile Emperor Angel Fish), *Pterois* sp. (Lion Fish), *Balistoides conspicillum* (Clown Trigger Fish), *Taenianotus tricanthus* (Leaf Scorpion Fish), *Amphiprion ocellaris* (Black Clownfish), *Cryptocentrus leptocephalus* (Pink Spot Shrimp Goby), *Paracanthurus hepatus* (Blue Tang), *Acanthurus olivaceus* (Orange-Band Surgeonfish) etc. Some of the world's most beautiful freshwater ornamental fishes are *Symphysodon* sp. (Discus), *Fundulus* sp. (Killifish), *Betta splendens* (Fighterfish), *Mikrogeophagus ramirezi* (German Blue Ram), *Poecilia wingei* (Endler's Livebearer), *Melanotaenia boesemani* (Boeseman's Rainbow Fish), *Trichogaster* sp. (Gourami), *Cichla ocellaris* (Peacock Cichlid), *Poecilia reticulata* (Fantail Guppy), *Amphilophus* sp. (Flowerhorn Cichlid).

Synchiropus splendidus

Symphysodon discus

Pomacanthus imperator

Aphyosemion striatum

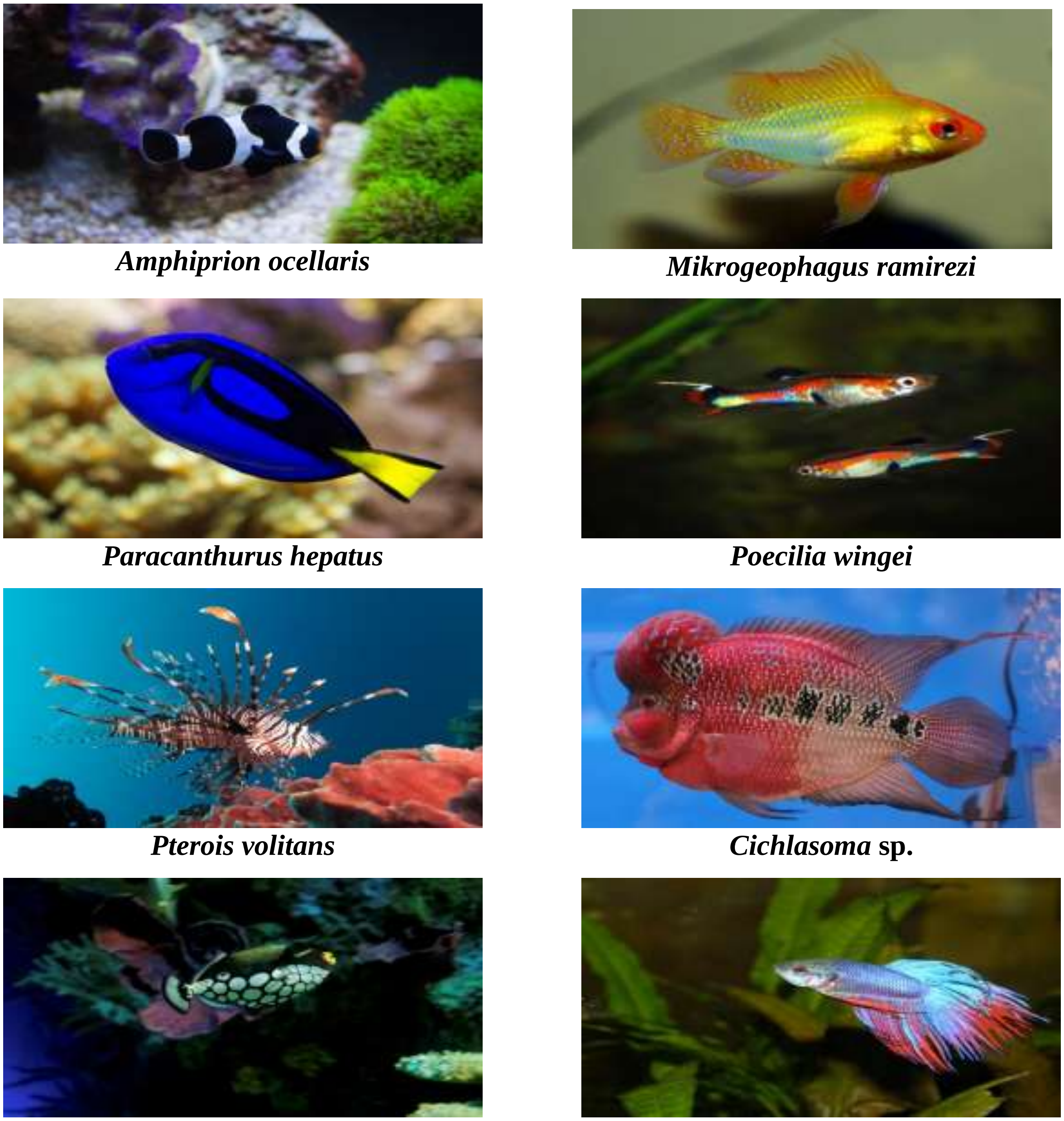


Figure 5. Beautiful Ornamental Fishes (Left: Marine; Right: Freshwater) (Source: Creative Commons)

Status of ornamental fisheries in India

Indian ornamental fish trade is contributed by both freshwater (90%) and marine fishes (10%). Cultured freshwater ornamental fishes contribute 98% and wild collections by 2%. In the case of marine ornamental fishes 98% are from captured source and only 2% contribution is from cultured fishes. In spite of having a rich biodiversity of ornamental fishes, India's contribution to international trade is less than 1%. The exporters of Indian fishes target China, USA, Japan, EU, Middle East and South East Asia. About 90% of Indian exports go from Kolkata followed by 8% from Mumbai and 2% from Chennai. There are around 35 Marine Products Export Development Authority (MPEDA) authorized Ornamental Fish Exporters in India.

India has exported ornamental fishes worth 1.25 USD million in the year 2020-2021. The top 10 countries which imported ornamental fishes during 2020 – 2021 are Indonesia, China, Hong Kong SAR, Taiwan, China, Japan, Malaysia, Singapore, Germany, United Arab Emirates and Jordan. The Kolkata air cargo, Bombay air cargo and Cochin air cargo are the major parts of India from where the ornamental fishes are exported. The domestic trade of ornamental fishes is mainly dominated by the production and marketing of low value ornamental fish viz., gold fish, koi carps, sharks, gourami, angels, barbs, live bearers (mollies, sword tails, guppy, platies).

Both the exotic and indigenous ornamental fishes are being marketed in India but the exotic varieties dominate the domestic market. Already 288 exotic varieties have been recorded in the Indian market and more than 200 species of these freshwater fishes are bred in different parts of India. In Tamil Nadu, Kolathur in Chennai district is the hub for ornamental fish production. In Kerala it is mainly concentrated in Ernakulam and Trissur districts. In Kolkatta, ornamental fish production takes place in Nadia, Hooghly and Howrah districts. In recent times the ornamental fish production activity has been extended to others states like Madhya Pradesh, Rajasthan, Uttarakhand, Punjab and Himachal Pradesh.

Diversity and status of ornamental fisheries in Tamil Nadu

One hundred and fifty-six ornamental fishes under eight orders, 27 families and 68 genera have been recorded from streams, rivers, canals, reservoirs, irrigation tanks and cold-water lakes of Tamil Nadu. Out of the 156 species, 14 species are endemic to Tamil Nadu, 131 species are endemic to the Indian sub-continent and 11 are exotic species. Cyprinidae (45.5%) is the most dominant family represented by 71 species belonging to 22 genera, followed by Nemacheilidae (2 genera and 9 species), Ambassidae (3 genera and 8 species) and Cichlidae (4 genera & 7 species) In Tamil Nadu, Kolathur near Chennai where the business activities related to ornamental fish production are highly concentrated, supports small and large-scale production of ornamental fishes, distribution to local and international market, production and distribution of aquarium accessories, production and sale of live and formulated feeds like flakes and pellets. In Kolathur, nearly 1,850 ornamental fish producing units are operating. Major activities like hatchery production of fries, small scale and large-scale units for growing ornamental fishes are carried out here.

Challenges in the Indian ornamental fish sector

India is projected as a sleeping giant in the ornamental fish sector. In spite of having a rich diversity of ornamental fishes, favorable climatic conditions for breeding and rearing and availability of cheap labour, some downsides also exist in this sector.

These are:

- Lack of breeding techniques for indigenous freshwater and marine ornamental fishes on a commercial scale.
- Lack of expertise in captive breeding of marine ornamental fish species, which ultimately creates pressure on wild catch.
- Lack of advanced techniques in packing and transportation of live ornamental fishes in good health and at high survival rates.
- Lack of species-specific feeds for both marine and freshwater ornamentals.
- Lack of expertise in disease identification & treatment.
- Lack of techniques in intensive farming.
- Lack of quality brooders for marine and freshwater ornamental fishes.
- Restriction and lack of incentives in the marketing of marine fishes.
- Lack of species-specific techniques for collection of targeted species from wild.
- Lack of awareness for sustainability since the export of marine ornamental fishes is highly dependent on wild collections.
- Lack of infrastructure for keeping ornamental fishes alive onboard when they get caught along with edible fishes.
- Lack of trained, skilled divers in collecting ornamental fishes from the wild.
- Lack of benchmark data on the availability and abundance of ornamental fish resources.
- High price of marine ornamental fishes and technical requirements for breeding becomes inaccessible to low income people.

- Lack of fishing regulations. There are no closed seasons, catch limits, quotas and banned areas for catching wild freshwater and marine ornamental fishes, as in the case of edible fishes.
- Lack of systematic marketing and access to market information.

Role of government and schemes for ornamental fisheries development in India

Government of India has taken several initiatives towards the development of fisheries sector through various organizations and schemes. They conduct several training programs throughout the country and issue certificates which will help the trainees to give technical services to individuals and public aquariums. The National Skill Development Corporation (NSDC) Certification will help skilled technician to earn without any investment. Both the state and central government have several promotional schemes to encourage aspiring entrepreneurs. Some of the organizations and their roles in the development of ornamental fisheries are:

The Marine Product Export Development Authority (MPEDA): The Marine Product Export Development Authority organizes domestic fairs at various states in the country to disseminate information about the vast potential in the fisheries, aquaculture and ornamental fish sectors. They also conduct various skill development programs in ornamental fish breeding and culture. Breeding units were established in the states of Tamil Nadu, Andhra Pradesh, Kerala, West Bengal, Karnataka, Madhya Pradesh, Maharashtra and Himachal Pradesh. MPEDA has introduced a scheme called "Green Certification" mainly to reduce the pressure on capturing ornamental fishes from the wild to maintain sustainability. MPEDA conducts several "Lab to Farm" projects to transfer the technologies from various organizations to the beneficiaries. They have also introduced a scheme to award incentives for the export of ornamental fishes.

Central Marine Fisheries Research Institute (CMFRI): The Central Marine Fisheries Research Institute has standardized the breeding and seed production techniques of marine ornamental fishes and they supply fingerlings to farmers. CMFRI along with MPEDA has drawn up Green Certification guidelines for marine ornamental fish breeding and reduce dependence on wild collection from coral reef habitats. MPEDA has developed two fish-feed formulations namely, Cadalmin Varna and Cadalmin Varsha. CMFRI is taking a number of research initiatives on broodstock development and standardization, breeding as well as larval rearing of marine ornamental fish species.

National Fisheries Development Board (NFDB): National Fisheries Development Board provides financial assistance towards the development of ornamental fisheries, for the establishment of backyard rearing units, medium scale rearing units, integrated units, aquarium fabrication units and ornamental fish marketing. NFDB provides 50% subsidy for establishing ornamental fish breeding and culture units.

Central Institute of Freshwater Aquaculture (CIFA): Central Institute of Freshwater Aquaculture has successfully standardized technology for breeding and rearing of 16 indigenous ornamental fishes. The major achievement of CIFA in ornamental fish sector includes the development of "Shining Barb" a new variety of Rosy barb (*Pethia conchonius*) over a period of eight years of selective breeding. CIFA has also developed captive breeding technology for an endangered fish, *Dawkinsia tambraparniei,* the Tambraparni barb. CIFA has conducted several national level training programs on freshwater ornamental fish breeding and culture.

National Cooperative Development Cooperation (NCDC): National Cooperative Development Cooperation and NABARD (National Bank of Agricultural and Rural Development) have taken several activities in promoting the development of ornamental fish sector in India by providing financial and technical support.

Pradhan Mantri Matsya Sampada Yojana (**PMMSY):** Department of Fisheries, Government of India has launched a new scheme called Pradhan Mantri Matsya Sampada Yojana (PMMSY) to bring Blue Revolution through sustainable and responsible development of the fisheries sector including welfare of fishers. PMMSY invested of Rs.20, 050 crore for all the states and Union territories for a five years (FY 2020 to 2025). The activities under PMMSY include ornamental and recreational fisheries, development of hatcheries, re-circulatory aquaculture system, construction of grow out and rearing ponds, cage culture, bivalve culture, seaweed culture and raceway farming. PMMSY also provides support for upgradation of fishing vessels, providing boats and nets for traditional fishermen, construction of cold storage, ice plants, feed mills, etc. The (PMMSY) has an allocation of 576 crores for catalysing the growth of ornamental fish industry in India.

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Fostering Aquaculture Entrepreneurship through the Agri-Clinics and Agri-Business Centres (AC&ABC) Scheme

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Abstract

This paper explores the role of the Agri-Clinics and Agri-Business Centres (AC&ABC) Scheme in fostering aquaculture entrepreneurship in India. Focusing on Fisheries Business Units (FBUs) and Fisheries Clinics (FCs), the study presents a detailed state-wise statistical analysis using descriptive metrics, correlation, regression, and cluster analysis. The findings illustrate the critical contribution of trained agri-entrepreneurs to aquaculture development, highlighting regional disparities, performance clusters, and policy implications. This paper provides actionable insights for strengthening fisheries-based enterprises under AC&ABC and promoting sustainable rural livelihoods through aquaculture.In recent years, aquaculture has emerged as a fast-growing sector within India's agriculture landscape, contributing significantly to the rural economy and nutritional security. With increasing demand for fish and seafood, the potential for entrepreneurship in this sector has expanded. The AC&ABC scheme has become a crucial vehicle to channelize this potential by training agri-preneurs and equipping them with the skills, knowledge, and support systems to establish and sustain fisheries-based enterprises.

Keywords: AC&ABC, Fisheries Clinics, Fisheries Business Units, Aquaculture, State-wise Analysis

1. Introduction:

The Agri-Clinics and Agri-Business Centres (AC&ABC) Scheme, launched in 2002 by the Ministry of Agriculture & Farmers Welfare, supports self-employment among agriculture graduates through enterprise development. Among various agri-ventures, aquaculture-based businesses are gaining traction due to their potential to enhance rural incomes and ensure food security. This paper investigates how the AC&ABC scheme has catalyzed fisheries-based entrepreneurship across Indian states, focusing on Fisheries Business Units (FBUs) and Fisheries Clinics (FCs). The fisheries ventures were classified into two classes based on the services provided and business model as below:

Fisheries-Clinics: Fisheries-Clinics are envisaged to provide expert advice and services to farmers on various technologies including Fish Breeding and Hatchery Operations, Water Quality Testing and Management, Disease Diagnosis and Management, Feed Formulation and Management, Aquaculture Training and Extension Services, Value Addition and Marketing which would enhance productivity and ensure increased income to farmers.

Fisheries Business Centres: Fisheries-Business Centres are commercial units of agriventures established by trained agriculture professionals.

2. Methodology:

State-wise data was sourced from official government reports, capturing the number of trained candidates, ventures established, and fisheries-specific units (FBUs and FCs). Descriptive statistics (mean, median, and mode), correlation coefficients, regression models, and cluster analysis were employed to understand performance patterns and identify development needs.

3. Descriptive Statistics of Fisheries-Based Ventures:

- **Mean:**
  - FBUs: 13.75
  - FCs: 0.88
- **Median:**
  - FBUs: 4
  - FCs: 0
- **Mode:**

- FBUs: 0
- FCs: 0

Interpretation: Most states have very few or no fisheries-specific ventures. The right-skewed data indicates that a few states, like Bihar, Maharashtra, and Tamil Nadu, significantly influence the average.

4. A. Correlation Analysis:

Variable Pair	Correlation Coefficient
Trained vs FBUs	0.635
Trained vs FCs	0.728
Ventures vs FBUs	0.616
Ventures vs FCs	0.722
FBUs vs FCs	0.885

Interpretation:

- A strong positive correlation (0.885) exists between FBUs and FCs, suggesting states that promote commercial fisheries also invest in clinical advisory services.
- Trained candidates and established ventures both show moderate-to-strong correlations (0.616 to 0.728) with fisheries initiatives, indicating a ripple effect of agri-entrepreneurial training into fisheries-specific development.

B. Regression Analysis Summary

Two regression models were constructed to examine how 'Trained Candidates' and 'Ventures Established' predict the number of Fisheries Business Units (FBUs) and Fisheries Clinics (FCs).

For FBUs, the model was significant ($R^2 = 0.481$, $p < 0.001$). 'Trained Candidates' had a positive and significant effect (coef = 0.0228, $p = 0.024$), while 'Ventures Established' had a small negative effect (coef = -0.0411, $p = 0.046$).

For FCs, although the model showed moderate explanatory power ($R^2 = 0.536$), neither predictor was statistically significant. This suggests that other unmeasured factors may influence the number of Fisheries Clinics across states.

C. Cluster Analysis Summary

Hierarchical cluster analysis grouped Indian states into four clusters based on their fisheries-related performance:

- Cluster 1 (26 states): Low-to-moderate engagement in fisheries ventures.
- Cluster 2 (Maharashtra, Uttar Pradesh): High agri-business engagement and strong fisheries presence.
- Cluster 3 (Bihar): High fisheries focus relative to training.
- Cluster 4 (Tamil Nadu): Balanced and exceptional performance across indicators.

These clusters can help direct targeted policy and development interventions.

Cluster 1 : Andhra Pradesh, Tripura, Telangana, Sikkim, Rajasthan, Punjab, Pondicherry, Odisha, Nagaland, Mizoram, Meghalaya, Manipur, Uttaranchal, Kerala, Madhya Pradesh, Jharkhand, Arunachal Pradesh, Assam, Chandigarh, Karnataka, Delhi, Chattisgarh, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Goa, West Bengal

Cluster 2: Maharashtra, Uttar Pradesh
Cluster 3 : Bihar
Cluster 4 : Tamil Nadu

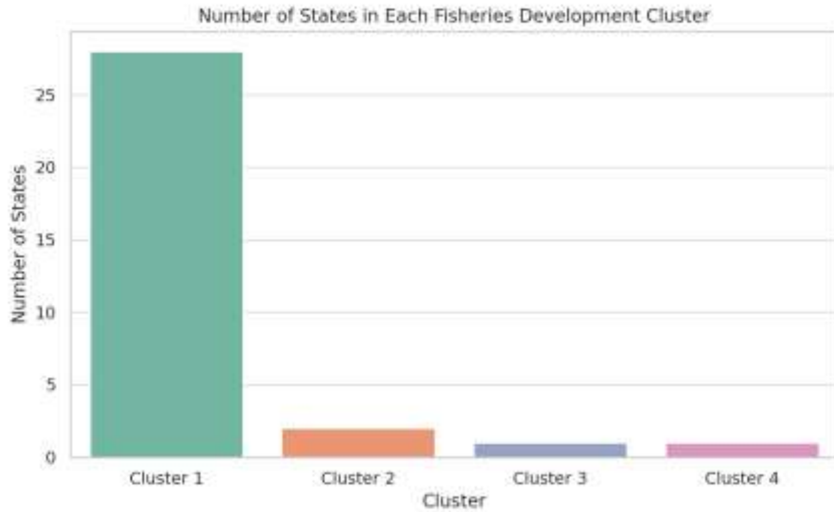

Figure 1: Scatter plots with regression lines for FBUs and FCs.

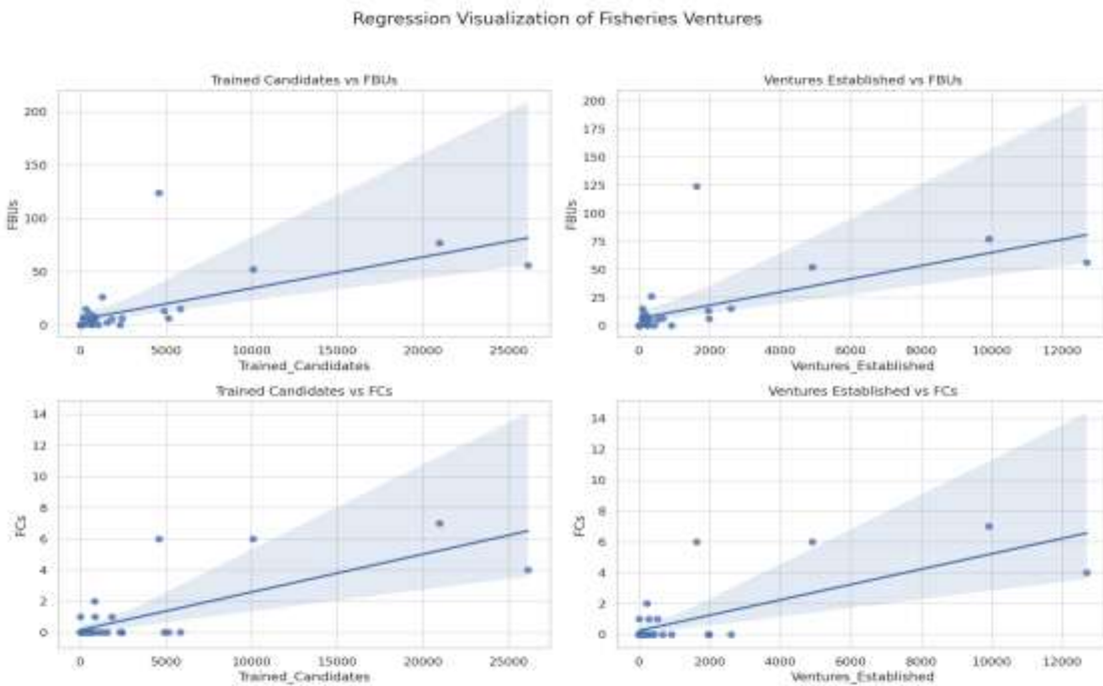

Figure 2: Number of states in each fisheries development cluster.

5. State-wise Comparative Analysis of Fisheries Ventures vs Training and General Ventures:

State	Trained Candidates	Ventures Established	FBUs	FCs
Andhra Pradesh	1838	516	5	1
Arunachal Pradesh	48	3	0	0
Assam	845	281	6	1
Bihar	4575	1627	124	6
Chandigarh	4	2	0	0
Chattisgarh	1036	425	0	0
Delhi	44	6	0	0
Goa	19	10	0	0
Gujarat	2309	916	0	0
Haryana	755	251	3	0
Himachal Pradesh	431	112	2	0
Jammu & Kashmir	1556	191	2	0
Jharkhand	835	222	8	2
Karnataka	4883	1967	13	0
Kerala	304	87	15	0
Madhya Pradesh	5844	2605	15	0
Maharashtra	26127	12692	56	4
Manipur	522	135	11	0
Meghalaya	37	4	0	0
Mizoram	52	0	0	0
Nagaland	187	22	0	0
Odisha	643	116	5	0
Pondicherry	159	88	7	0
Punjab	671	225	0	0
Rajasthan	5150	1979	6	0
Sikkim	9	1	0	0

Tamil Nadu	10086	4913	52	6
Telangana	2431	664	6	0
Tripura	6	2	0	1
Uttar Pradesh	20961	9915	77	7
Uttaranchal	626	212	1	0
West Bengal	1276	343	26	0

(Data as on 31-03-2025)

Interpretation: States with high training and venture establishment like Maharashtra, Tamil Nadu, and Uttar Pradesh show a stronger presence of fisheries-based ventures. Bihar stands out with a high number of fisheries ventures relative to its overall training figures, indicating focused development in this sub-sector.

6. Challenges and Recommendations:

Challenges:

- Shortage of skilled aquaculture professional's
- Limited outreach of diagnostic and extension services

Recommendations:

- Scale up Fisheries Clinics in Cluster 2 and Cluster 4 states
- Design specialized training on hatchery management, disease diagnostics, and feed formulation
- Revising the course curriculum focusing on the aquaculture where the demand is high
- Offer financial and policy incentives for fisheries infrastructure investment

Conclusion:

The AC&ABC scheme has demonstrated its potential in fostering aquaculture entrepreneurship, though the distribution remains uneven. With targeted training and infrastructure development, FBUs and FCs can play a transformative role in rural livelihoods and sustainable aquaculture. Cluster-specific strategies and enhanced clinic coverage are essential for deepening the scheme's impact.

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Chapter-4

Eco Friendly Management in Shrimp Aquaculture

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Abstract

Shrimp farms in India generally known as “Aquaculture hotspots” along the coastal belt covering 1.2 million ha of coastal area out of which about 25% has been already been exploited. Building back the better hotspots for the effective aquatic environment management comes in many tiers. The first tier is the pond water and bottom which comes into contact with the shrimp but there is also the second tier such as the outlet canal and the creek into which sludge and effluent is deposited. Community based ecological mangrove restoration can self-repair the coastal aquaculture hotspots in India. Researchable issues on the thrust areas of coastal aquaculture with an integration of agriculture is highly required. The above are some items are on the wish list which will be discussed in the article to help the industry focus on science in search of a long-term solution under stressed coastal environment.

Key Words: shrimp farming, coastal, ecology, sustainable

Introduction

Large-scale fishing industries turned to farming as a way to meet world demands for seafood towards the decline if global capture fisheries. Many shrimp farmers revived their economic gains through shrimp farming by starting shrimp farms in mangrove forests. Selling land to investors, who rapidly transformed mangrove forests into intensive, destructive shrimp farms, which marginalized the coastal communities who relied on them the most. Indeed, short-term profits were high with production rates up to 40 tonnes/acre; however, the rural poor were unable to build such advanced operations, and therefore practiced traditional and extensive farming methods, which are unsustainable due to lack of resources and education. Traditional and extensive farms construct ponds within mangrove forests by deforesting trees, shrubs, and roots, and by building dikes and canals to get access to water and wild post-larvae shrimp from mangrove estuaries. Local farmers built farms in an attempt to improve their quality of life through increased food security and personal. However, 90% of rural farmers must get loans to start operations, and lack of scientific management results in collapse of ponds, which leaves them empty-handed and in debt. Farmers must abandon the once viable ponds after approximately five years due to poor water quality and sometimes spread of disease, which leaves traditional communities and mangrove forests in ruins. Community based ecological mangrove restoration can self-repair or successfully undergo secondary succession for the revival of coastal aquaculture hotspots in India. Researchable issues on the thrust areas of coastal aquaculture with an integration of agriculture has enormous potential for increasing employment generation and foreign exchange in the country.

Shrimp Farming History, Growth, and System Types

Shrimp farming has rapidly expanded over the last four decades as demands increase with increasing human population size (Stokstad, 2010). Traditionally, global shrimp fisheries supplied most of the world's market with wild-caught shrimp of different species and size. However, over-fishing of the world's oceans led to global fishery collapses, which devastated many countries relying on export revenues for economic stability (Islam et. al., 2001). Some regions experienced a 30% decline in wild fish and shrimp populations. In addition to reduction of natural populations, concerns were also being raised about ecosystem damage caused by various fishery practices. These issues led to the creation and enforcement of regulations by many countries, which put further pressure on fisheries since catch limitations and use of more advanced technologies can be quite costly. As human population and demand for shrimp and other fishery products rose, many investors started looking for alternative ways to supply the masses, and the development of aquaculture, especially shrimp farming, rapidly expanded in a very short period of time (Paez-Osuna et. al., 2003).

While a massive jump in shrimp production was occurring worldwide, large portions of mangrove forests were being cleared to make it possible. In 2015, it was estimated that approximately 1.5 million hectares of global mangrove forests had been converted to shrimp farms (Tenorio et. al., 2015). Rapid conversion of mangrove forests to shrimp farms has taken a huge toll on the once productive and biologically diverse ecosystems, especially due to lack of laws and regulations in countries where production is the highest (Tenorio et. al., 2015).

Since most of the world's shrimp supply comes from developing countries, methods of shrimp farming, as well as their impacts, are an important area of focus (Kelly, 2012).

The Methods for shrimp farming can be classified into four different categories: traditional, extensive, semi-intensive, and intensive (Paul et. al., 2010). These categories are based on intensity of the operation, such as pond size, stocking densities, inputs of feed and fertilizers, and water quality management (Paul et. al., 2010). In general, traditional and extensive farming operations use natural water systems to maintain water quality and recruit natural stocks of post-shrimp larvae. Stocking densities are usually low as are inputs of food and fertilizers. Semi-intensive and intensive operations use water systems that are separate from the natural environment, have high stocking densities, high amounts of chemical inputs and feed, and mechanical aeration systems (Joffre et. al., 2015). Due to the cost and maintenance of supplies and technology in intensive systems, they are used very rarely in developing countries, especially by native and local peoples (Joffre et. al., 2015). For example, 80% of the shrimp farms in India use traditional or extensive farming methods, with only 20% using semi-intensive or intensive operations (Undercurrent News, 2018).

Shrimp farming; Ecological and Socio-Economic Impacts

Countries present in tropical areas have climatic conditions that are ideal for shrimp farming (Joffre et. al., 2015, Paul et. al., 2010). Many of these countries are undeveloped or developing and view shrimp farming as a means to better their quality of life (Islam et. al., 2005). Increased quality of life in these areas refers to decreased poverty and increased food security, as shrimp farming provides employment and economic gains can be used to purchase food and goods. The impacts include reduced area of habitat for thousands of species, reduced availability of land and forest goods (i.e., agriculture, food, fuel, medicine, etc.), nursery and fishery collapse, decreased water quality, loss of protective coastal barrier, decreased shoreline stabilization and land building (i.e., increased rates of erosion), and decreased carbon sequestration and storage (i.e., increased carbon export).In addition, local and native peoples have been greatly impacted by development of shrimp farms and will therefore be included here (Islam et. al., 2005, Joffre et. al., 2015, Kelly, 2012, Tenorio et. al., 2015).

Ecological and Socio-Economic Impacts of destructing coastal aquaculture hotspots

- Habitat loss/Modification

- Reduced availability of wild seed and broodstock
- Spread of diseases
- Use of antibiotics and chemicals
- Aquaculture wastes and coastal pollution
- Salinization of soil and water
- Dependence on fish meal and fish oil
- Reduced area of habitat for Thousands of species
- Decreased water quality
- Decreased shoreline stabilization and land building
- Decreased carbon sequestration and storage
- Impacts to coastal communities

The way forward

For aquaculture to fulfill the promises of food security and poverty alleviation without causing negative environmental and socioeconomic effects, a more holistic approach is required. This must involve other stakeholders to avoid a sectoral focus on aquafarms. The key issues to consider and address are outlined below.

Integrated coastal zone management

The groups vulnerable to the negative effects of shrimp culture generally do not participate in the formulation and implementation of public policies, e.g., determining location of ponds, pens and cages, regulating farm activities, and environmental impact assessment preparation. Community participation in coastal zone management is essential if questions of social equity are to be satisfactorily addressed. In community based coastal resource management, fisher folk and other local residents are the day-to-day managers of resources. Coastal zones should be delineated for fisheries, aquaculture, tourism and other uses through the process of integrated coastal zone management (ICZM). Allocation of activities to locations should be based on the carrying or assimilative capacity of the environment for a given use, protection of community resources, rehabilitation of degraded habitats, stakeholder needs and mechanisms for conflict resolution. The ICZM is based on the concept of the ecological footprint which incorporates not only inputs such as feed and seed, but also outputs, e.g., effluent treatment.

Advanced Culture Systems and Technologies

More advanced, high-tech systems are working towards reducing environmental damage and increasing production by developing closed-system farms inland (Stokstad, 2010). Ponds are constructed with cement and built inside greenhouses, where water is recirculated, aerated, and shrimp are fed biofloc (Stokstad, 2010). Biofloc refers to the use of microbes in nutrient recycling; that is, bacteria and carbon are put into systems to allow the breakdown of ammonium in shrimp feces so it can be recycled and consumed by shrimp (Stockstad, 2010). These systems have significantly reduced ecosystem damage and increased production; however, small-scale farming operations in developing countries cannot afford advanced technology, which is where the majority of farmed shrimp come from (Stockstad, 2010). Therefore, laws and regulations to conserve remaining forests, as well as restoration and development of integrated mangrove-shrimp farms, are the most promising solutions to protect the world's mangrove forests (Ewel, 1998, Islam et. al., 2005, Joffre et. al., 2015, Kelly, 2012, Lee et. al., 2014, Stockstad, 2010, Tenorio et. al., 2015, Thampanya et. al., 2006).

Farm siting

Criteria include such standard physical factors such as water supply, tidal regime, topography, soil quality and climate as well as the capacity of the environment to absorb effluents. More important than fish/shrimp density inside ponds is the farm density in a given area so that the (waste) absorbing or assimilative capacity of the environment is not exceeded. Wide-scale abandonment of ponds is often due to the proliferation of initially successful farms that ultimately overwhelm the system because they do not follow the ecological footprint concept.

Farm and effluent management

Good management of cultured stock, food, water and soil is the first line of defence against diseases and crop failures. Water quality standards should apply equally to influent water in ponds as to drainage waters flushed into adjoining estuarine and marine habitats. Closed and semi-closed water systems that recycle water through a series of reservoirs, treatment ponds (with fish, bivalves and algae) and canals back to production ponds serve to reduce the amount of discharged wastes and minimize the entry of disease organisms from natural waters. Pond sludge may be reduced through the application of probiotics, or by the tilling and drying of the pond bottom. Alternatively, sludge may be collected and stored near the farm for mangrove planting or subsequent transfer to agricultural or forest land. Mangroves can be used to treat shrimp pond effluents with high levels of solids, organic matter and nutrients. Seedlings of various mangrove species survived in an abandoned shrimp pond, in intertidal dump sites near shrimp farms, and in shrimp pond effluents. Abandoned ponds may be rehabilitated for shrimp production or other sustainable uses such as salt making and integrated aquaculture, or restored to a productive mangrove system.

Mangrove-friendly aquaculture

Mangroves and aquaculture are not necessarily incompatible. For example, seaweeds, bivalves and fish (seabass, grouper) in cages can be grown in mangrove waterways. Such mangrove-friendly aquaculture technologies are amenable to small-scale, family-based operations and can be adopted in mangrove conservation and restoration sites. Brackish water culture ponds may not necessarily preclude the presence of mangroves. Dikes and tidal flats in ponds were planted with mangroves to provide firewood, fertilizers and protection from wave action. Present-day versions of integrated forestry-fisheries-aquaculture can be found in the traditional ponds in Hong Kong, mangrove-shrimp ponds in Vietnam, aquasilviculture in the Philippines, and silvofisheries in Indonesia. Alternatively, mangroves adjacent to intensive ponds can be used to process nutrients in pond effluents.

Disease control

The most realistic approach to combat diseases is combining good husbandry and good feed with the use of prophylactic agents, including immunostimulants and probiotics. The control of diseases (and pests) through the use of chemicals should be a last resort only after environmental conditions, nutrition and hygiene have been optimized. Chemicals used should be safe to the cultured crop, farm staff, environment and consumer. Farmers should avoid prophylactic treatment, apply effective and narrow spectrum antibacterials, adopt withdrawal periods and avoid discharge of effluents with toxic chemical levels into natural water bodies.

Low trophic level species, native species

There is a need to counter the market-driven trend towards carnivorous crustaceans and marine fish and focus on herbivorous species that do not require fishmeal-based pellets or raw (‘trash’) fish. Likewise, introduction of exotic species should be minimized and strictly follow established protocols.

Role of government, market mechanisms and self-regulation

Legislation is designed to prevent or reduce harm created by aquaculture by means of such instruments as: government authorizations (licenses, permits, certifications); environmental impact assessments and regulation in the form of standards on water quality, permissible emission levels, etc. However, the regulatory approach is fraught with problems because the targeted sectors, i.e., shrimp farmers, can be powerful and disregard or circumvent the laws. Moreover, there is little will or ability to enforce legislation, often because the delineation of the government agencies responsible for enforcement of specific laws, and the level of authority, whether local, state, provincial, regional or national, for enforcement remain vague. Economic incentives and disincentives in the form of taxes, penalties and credits for effluent disposal, groundwater abstraction, chemical use, etc., may be more effective than regulatory approaches in inducing behavioural changes towards the environment and generating revenues to finance environmental policy programs. Such fees should reflect the economic rent of the resource used, e.g., ground water and mangrove area converted to pond and encourage efficient pond utilization. Green taxes (based on the Polluter Pays principle) can mitigate the environmental and socioeconomic damage of shrimp farms by correcting water quality problems, financing alternative water supplies in salt-contaminated areas, rehabilitating mangroves and other damaged landscapes, and compensating local populations for the loss in livelihoods.

Ecolabelling in Shrimp Farming

Market mechanisms provide financial incentives for industry to modify its production processes and include consumer boycotts and eco-labelling. Eco-labelled shrimp/fish grown in ecologically and socially responsible farms can command premium prices from generally affluent and environmentally aware consumers. There should be joint certification of such products by government representatives and independent third parties, and regular monitoring. Shrimp from extensive Indonesian farms certified as organically grown are marketed by a Japanese company to consumers through a Swedish cooperative. Site visits to the farms in Java revealed non-compliance by the shrimp farms with standards set by the certifier (e.g., mangrove protection and non-use of chemicals by hatcheries), and release of partially incorrect information to consumers by the cooperative.

For aquaculture to fulfil the promises of food security and poverty alleviation, a paradigm shift is needed away from its sectoral promotion detached from traditional coastal activities to a more holistic approach requiring the participation of other stakeholders including fishers and local communities. Within the aquaculture sector itself, sustainability requires improvements in farm management, especially with regard to feed, water, effluents and diseases; focus on native and low trophic level species, and integration with agriculture and silviculture, in particular mangroves. Finally, responsible aquaculture can be promoted by government regulation, market mechanisms and self-regulation in the form of codes of conduct and best management practices.

Conclusion

Protection and restoration of mangrove forests is happening in many countries, including India, Brazil, Thailand, and Vietnam. Creation and implementation of laws and regulations is crucial to protect remaining forests. Assessments of mangrove degradation along the coastal lines are needed to determine what areas to protect and restore, and which to develop, though most governments now recognize that construction of shrimp farms should occur inland. Restoration, mitigation, and management need to be scientific and community based to ensure successful recovery and sustainability of forests. In addition, traditional coastal populations need to benefit from these efforts socio-economically by restoring human rights and quality of life. Services such as coastal protection, soil accretion, and carbon sequestration are very difficult to quantify monetarily; however, I believe their overall value far outweighs any benefits gained through farming of shrimp. Innovation and ingenuity can reduce impacts to mangrove forests by finding alternative ways to farm shrimp. Implementation of regulations and sustainable practices is needed to protect the forests that still remain. A global policy to protect traditional villages and communities from exploitation by large investors is also greatly needed.

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Artificial feeds for successful hatchery production of fish larvae

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Abstract

Successful aquaculture depends on the supply of quality seeds. Initial stage of rearing larvae is very critical. If the feed is not nutritionally balanced, larval survival will be affected. Live feeds are used in initial rearing, but they are not sustainable for mass rearing. Microparticulate feed can be ideal solutions to overcome these constraints and they can be used along with the live feeds in the larvae culture. The different micro particulate feeds are micro bound (MBD), micro coated and microencapsulated. Among these, the production of micro bound feed is comparatively easier than the others. A good quality microbound feed can be prepared as a dry feed using a suitable binder matrix. The binders used in the microbound feed are- sodium alginate, carrageenan, zein, gelatin etc. These binders reduce the leaching of nutrients, especially the water-soluble nutrients from it. Micro bound feed can be used along with live feeds in the larval rearing in a hatchery. Co-feeding of these two can be the best solution in the larvae culture. The microbound feed can be on-size or crumbled. The on-size MBD can be microextruder marumerization (MEM), and particle assisted rotational agglomeration (PARA). MEM is the most common type of MBD, which is adopted from the pharmaceutical industry. The cold extruded feed gets spheroid shape in the marumerizer, which helps in forming a smooth layer outside the MBD. Since these feed particles are not encapsulated, there is a chance of leaching water-soluble nutrients. It is most suitable for freshwater and marine fish larvae, but not suitable for the column-feeding fish larvae.

Keywords: Microbound diet, larvae, live feeds, binders

Introduction

Intensification of aquaculture needs a high quantum of fish seeds supply. However, lower larval survival at initial stage due to improper feed supply, is one of the major drawbacks for many years. Live feeds have been used in larval rearing since the beginning, but most of them are not nutritionally balanced, and they lack some essential nutrients like EPA (Eicosapentaenoic acid), DHA (Docosahexaenoic acid), vitamin C, taurine etc. Additionally, there is no certainty of their consistent supply, and microbial contamination is likely. A microparticulate feed used in larvae culture may be the best way to solve this problem. These feeds can be used along with live feeds during larval rearing. Although 100% replacement of live feeds may not be possible, co-feeding or mixed feeding can be done. Live feeds, and microparticulate feeds together can fulfil the nutritional requirement of larvae in the hatchery. There are different categories of microparticulate feeds which include microbound, microcoated and microencapsulate ones. The manufacture of microparticulate feed is much more complex and time-consuming than manufacturing pelleted feeds due to the extremely small feed particles. However, larvae can accept only small feed particles due to the relatively undeveloped digestive system of the larvae, need for high palatability, water stability, and nutrient stability. The size of larval feeds should be in the range of 0.2 to 0.6 mm. Some of the issues associated with the microparticulate feeds are high nutrient leaching, low water stability, low palatability, digestibility & retention of water-soluble nutrients.

Microbound diets (MBD)

The manufacturing process for MBDs is the simplest and most used method of preparation. This is the most common particle type used in feeding fish larvae. Dietary ingredients are bound together in a polymer matrix. These particles do not possess walls and, technically, should not be designated as microcapsules. This diet consists of a binding material such as agar, zein, gelatine, alginate, or carrageenan. Formulation of MBD particles typically requires activating or gelling a mixture of ingredients, followed by drying. The final dry mix is crushed and sieved to obtain the desired particle size. These particles do not possess walls, so there is potential for nutrient leaching, and they are susceptible to direct bacterial attack.

Preparation of an MBD diet bound with carrageenan: Powdered ingredients (10 g) → Water (35 ml) → Heat in a water bath at 80ºC → Mix well with a high-speed homogenizer→ K-Carrageenan (0.5 g) → Mix well with the homogenizer → Cool in a refrigerator at 4°C → Freeze-dry → Crush and sieve → K-Carrageenan microbinding diet (Kanazawa, 1986).

Benefits of microbound diets:

The majority of artificial diets now on the market are effective at supplying high-molecular-weight proteins, carbohydrates, and other nutrients that are not soluble in water. Benefits of MBDs are-

- Inexpensive to produce
- Easy to produce/Ease of preparation
- It can be produced within a narrow size range
- Binders can be nutritionally inert.
- Absence of capsule wall which allow leaching of nutrients that may promote ingestion
- More digestible because no capsule wall to break down before digestion of dietary ingredients
- MBD particles allow short to medium-term feed storage (Southgate and Partridge, 1998).

Types of microbound diets

Microbound particles can be characterized as crumbled and on-size feeds (or shaped particles) based on the manufacturing processes.

Crumbled feeds:

Crumbled feeds are produced by first making a pellet, flake, or a cake, crumbling, and then sieving to the appropriate size range. All the ingredients are ground, mixed with a binder, activated by temperature or chemicals, dried (drum drying or spray drying), ground, and sieved to the required size. The final product is usually uneven and rough-edged particles. (Kolkovski, 2001; Kolkovski *et al.*, 2009; Langdon and Barrows, 2011). This creates waste during crumbled feed production. Moreover, the resulting increase in surface area-to-volume ratios will adversely affect the leaching rates of water-soluble nutrients.

Types of crumbled feeds

1. **Steam-pelleted: It was** used effectively for many years in the salmonid and catfish industries, not effective for producing larval feeds.
2. **Extruded crumbles:** These are used to prevent leaching of water-soluble nutrients
3. **Crumbled flake feeds**: Flake feeds the most common feed fed to aquarium fish. Effective binders used for production includes agar, gelatin, carrageenan, and alginates. The most common production technique is the one using double-drum drier. This machine consists of two parallel drums rotating in opposite directions. A feed slurry coats the drums, and as the drums rotate, the slurry is spread to a uniform thickness. Steam is used as a heat source for the drum, which quickly dries the feed. The thickness of the flake can be adjusted by altering the distance between the drums. Drying conditions may influence the product's nutritional value; therefore, the feed is exposed to the heat for only a short time (~30 sec). Flake feeds come off the drum drier as sheets, which must be ground, and sometimes sifted to produce appropriately sized thin flakes. This process results in a particle with a high surface-area-to-volume ratio. Because of this high ratio, particles float on the surface for a long time before becoming saturated with water and sinking.
4. **Crumbled Cake Feeds:** Many binders can be used to produce crumbled cake feeds. Each binding system is activated differently. For example, zein is a protein found in corn and is soluble in alcohol but not water. Zein was used effectively in preparing diets for prawn

larvae. Egg albumin can also form a matrix but must be activated by heat. The cake can be dried by freeze-drying, oven-drying, or drum-drying. Nutritional quality is affected by the type of drying. Crumbled cake feeds are currently produced commercially and can be very effective for production of larval feeds.

On-size feeds/Shaped particles

Shaped particles are prepared in the desired particle sizes, and thus it does not require crumbling of feed to achieve the appropriate size. It eliminates under or oversized particles, therefore reducing the waste production. It also increases particle stability and has a suitable range of size. In addition to eliminating a production step, it also creates different physical shapes of on-size. There are three types of shaped particles, namely, (a) Microextruded marumerized (MEM) particles, (b) Particle-assisted rotational agglomerated (PARA) particles, and (c) Spray beads. The first two techniques have gained attention in the past few years, with commercially available diets produced using these methods.

Microextruded marumerization (MEM)

This technique can be used for larval feeds and has been used in the pharmaceutical industry for many years. This is a two-step process of cold extrusion followed by marumerization (spheronization). These cold extruders can produce noodles down to 1000 μm in diameter. Commercial manufacturing systems are currently being used to make, ornamental and salmonid feed.

Cold extrusion

Finely ground ingredients are required to produce all types of larval feeds, but it is particularly critical with the MEM process to prevent die blockage. It is generally recommended to have all ingredients smaller than 20% of the die opening. The best grinding method may include hammer mills, ball mills, pin mills, and homogenizers, but it depends on the ingredients' moisture, starch, and fat content. For high fat, low moisture ingredients, the air-swept pulveriser has been proven to be very effective on a large scale but costly in terms of energy demands.

Types of extruders capable of producing a small extrudate

1. Radial discharge extruders with increased die surface area since the die holes wrap around the screws, resulting in less pressure on the screen.
2. Twin-dome extruders also reduce pressure at the die screen and produce these tiny particles.

Marumerization/Spheronization

Once the wet mash is extruded into noodles, the second step begins. The noodles are placed into a spheronizer (originally termed a marumerizer), consisting of a cylindrical chamber with a high-speed rotating plate at the bottom. Plates are grooved and available with different grooves to break the noodles, reshaping and compacting the particles. The depth of the groove affects the amount of energy that is transferred to the feed during marumerization. A firm noodle will require a deeply grooved plate and a soft noodle will be processed most effectively with a shallowly grooved plate. The spheronizer is equipped with a variable speed motor to deliver a range of energies to the extrudates.

The marumerizer imparts two effects to the feed. (a) The first effect is to reshape the particle into a spheroid shape. Noodles are broken into particles with lengths equivalent to the diameter of the noodle. (b) The second effect is to impart surface densification to the particle.

Many types of binders can be used with MEM particles if they are moisture and pressure activated. No heat is added to the process, but some are generated at the extrusion screen due to friction. Binding systems based on gums have been used, but protein hydrolysates are also effective. Particles produced by MEM can be characterized as smooth and spheroid, with a high density. The smooth shape may decrease nutrient leaching by reducing the surface area-to-volume ratio. The high density of the feed results in a faster-sinking particle, which is a negative property for fish species that feed in the water column.

Particle-Assisted Rotational Agglomeration (PARA) Feeds

This is a single-step process capable of producing particles from 50–500 μm that are lower in density than particles produced by the MEM. This method differs from MEM because only a cylindrical shaper is used, and the process does not involve an extruder. Compared to MEM, the lower capital expenditure required and lower operating costs. The ingredients are mixed, slightly higher moisture levels are required. Feed formulation and moisture content are essential in this method. The wet mixture of ingredients is then added to the spheronizer with a charge of 3.0-mm inert particles (75% weight of beads/weight of wet mesh). The rotation of the spheronizer imparts energy to the inert particles, which in turn transfer energy to the mash, producing roughly spheroid particles in a wide size range. Particles and inert beads are discharged from the spheronizer and sieved through a 2.0-mm screen to remove the beads.

The PARA process produces a wide range of particle sizes and is less uniform in shape but manipulating moisture levels and spheronization time can alter the particle size distribution. The PARA process depends on adequate binding capacity from the diet formulation than the MEM method since high pressure is not used to agglomerate the particles. The same binders used with MEM particles are effective in PARA particles, with minor modifications. The PARA process is a low-pressure agglomeration method that results in the production of a low-density feed particle. The low-density results in a slower sinking rate of the particles than MEM particles, which can be beneficial for slow-feeding larvae of some species, such as halibut.

Spray Beadlets

These are particles produced by spraying a slurry of material into a liquid that assists in forming particles. Binders such as alginate and gelatin can be used effectively. This process has a wide range of sizes, so particle sieving is often necessary to obtain appropriate size categories. Shaped microbound particles can also be formed by spraying a mixture of diet and binder into a gelling solution or drying chamber where particles are formed on contact; for example, alginate- and CMC-bound particles can be prepared by spraying a mixture of dietary components and binder into a solution of calcium salt the spray method results in lower-density particles with a slower sinking rate than MEM particles. A disadvantage of spraying dietary mixtures into an aqueous medium is that leaching of water-soluble dietary ingredients will likely occur, changing the dietary composition of the particles. The problem can be addressed by spraying a mixture of binder and diet into heated air to evaporate the solvent and deposit the binder material around the dietary particles

Binders used in microbound particles

Binding agents used to make microbound particles include hydrocolloids, such as alginate, carrageenan, carboxymethyl cellulose, starches, chitosan, gelatine, fish proteins, and zein. Some of these binders, such as wheat gluten or pre-gelatinized starches, can have a nutritional value for the animals. In contrast, others are inert raw materials used purely as gelling agents or thickeners in the diet (Melcion, 2001). One binder may not be optimal for all species. Partridge and Southgate (1999) reported that alginate- and zein-bound particles were poorly digested by barramundi (*Lates calcarifer*) larvae, and they recommended gelatin or carrageenan as binders instead. Carrageenan was not considered suitable as a binder for larvae due to poor digestibility (Gawlicka et al. 1996) and first-feeding walleye (*Stizostedion vitreum*) (Guthrie et al. 2000). Genodepa et al. (2007) used 14C-labeled MBD particles to determine the ingestion rate of diet particles prepared with zein, gelatin, agar, alginate, or carrageen as the binding agent. From a nutritional perspective, for mud crab larvae a protein binder (e.g., zein or gelatine) may be more appropriate than a polysaccharide binder (e.g., agar, alginate, or carrageen).

Table 1: Binders used in the preparation of MBD diets for altricial fish larvae (Langdon 2003)

Binder type	Species	Reference
Alginate	Dicentrarchus labrax Lates calcarifer Stizostedion vitreum Brachydanio rerio	Partridge and Southgate, 1999 ; Guthrie et al., 2000 Onal and Langdon, 2000
Agar	Lates calcarifer	Partridge and Southgate, 1999
Carboxymethyl cellulose	Stizostedion vitreum	Guthrie et al., 2000
Carrageenan	Plecoglossus altivelis Acipenser transmontanus Lates calcarifer Gadus morhua Stizostedion vitreum	Kanazawa et al., 1982 Gawlicka et al., 1996 Partridge and Southgate, 1999; Baskerville-Bridges & Kling, 2000; Guthrie et al., 2000
Fish meal	Dicentrarchus labrax	Cahu et al., 1999
Gelatin	Pleuronectes platessa Solea solea Sparus aurata Lates calcarifer	Kolkovski and Tandler, 2000; Partridge and Southgate, 1999
Starch	Gadus morhua, Pleuronectes platessa Stizostedion vitreum Hippoglossus hippoglossus	Guthrie et al., 2000 Hamre et al. 2001; Naess et al. 2001

Zein	Pagrus major Plecoglossus altivelis Pagrus major Paralichthys olivaceus Dicentrarchus labrax Lates calcarifer Stizostedion vitreum	Kanazawa et al., 1982 ; Kanazawa et al., 1989; Partridge and Southgate, 1999 ; Guthrie et al., 2000

Considerations in the development of formulated larval feeds

1. Microdiet characteristics
2. Nutrient leaching
3. Particle size
4. Buoyancy/ Sinking rate
5. Larval characteristics
6. Ingestion rate of the diet
7. Larval development
8. Ontogeny of digestive systems and digestive enzymes
9. Digestibility
10. Nutritional requirements
11. Microdiet formulation and nutrition experiments
12. Weaning and co-feeding methods

Microbound diets in advancing larval rearing:

Despite poor retention of water-soluble nutrients by microbound particles, researchers have reported success on weaning larvae with microbound diets after as initial period of feeding on live feeds or a combination of live feeds and microbound diets (Kolkovski et al. 1997; Cahu et al. 1999; Lazo et al. 2000; Hamre et al. 2001). In contrast to marine fish, larvae of several freshwater fish species have been successfully reared entirely on microbound diets such as larvae of goldfish, Carassius auratus; (Szlaminska et al. 1993), pike perch (Sander lucioperca (Ostaszewska et al. 2005), and zebrafish Danio rerio; (Carvalho et al. 2004). Several hatcheries and laboratories around the world have reported successful use of MBD (Liao et al., 1988; Kanazawa, 1990b); however, as these particles show relatively poor stability in water, there are potential problems relating to water quality

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and bacterial proliferation, as well as nutrient deficiency resulting from leaching (Amjad et al., 1992).

Table 2. Formulated microbound diets previously tested as live feed replacements for various crustacean species

Species	**Survival**	**Reference**
P. monodon	85%	Galgani and Aquacop (1988)
P. monodon	52% Nauplii to Mysis	Paibulkichakul et al. (1998)
P. japonicus	90% to PL1	Kanazawa et al. (1982)
P. japonicas	80% to PL	Kanazawa et al. (1986)
P. japonicus	75% to PL1	Kanazawa (1990b)
P. indicus	62% to M1	Galgani and Aquacop (1988)
P. indicus	100% PL20–PL50	Immanuel et al. (2003)
M. rosenbergii	77.3% from Z5 to PL1	Kovalenko et al. (2002)
Homarus Gammarus	Non beyond stage III	Kurmaly et al. (1990)
Scylla serrata (MBD+Artemia)	66% from ZIII–ZIV	Holme et al. (2006b)
S. serrata	90% from ML to C1	Genodepa et al. (2004a)

Conclusion

In practice, high concentrations of water-soluble nutrients added to microbound diets likely compensate for rapid leakage rates as long as larvae ingest feed particles soon after the particles are added to the culture medium. Larvae may also acquire leached nutrients by drinking the culture medium. Frequent exchanges of culture medium can remove leached nutrients and reduce the potential for developing high bacterial concentrations. The economic cost of wasted leached nutrients may be acceptable given the small amounts of feed required for larval production; however, the costs of poor larval performance due to inadequate delivery of essential nutrients may pose a serious problem for commercial fish hatcheries.

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Biofloc Technology: A Novel Approch for Enhanced Fish Production

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Abstract

Aquaculture, is the cultivation of economically important aquatic organisms under a set of controlled conditions. It is mainly the farming of aquatic organisms, which includes fishes, molluscs, crustaceans and aquatic plants. The farming also implies some form of intervention in rearing process to enhance production such as regular stocking, feeding and protection from predators. Among different cultivable aquatic organisms, fishes are being cultured because of easy selection of fishes with desirable characteristics, high quality of protein and easy maintenance than any other aquatic organism. The culturing and production of fishes is more profitable. With almost 7.98 billion population on earth, there is always an increase in demand for aquatic food and hence, expansion and intensification of aquaculture production are highly required. Presently, in India, the rate of commercial fish farming is rapidly increasing because the fishes and their products has huge demand. The common fishes that are used for fish culture in India are Carp (Silver, Grass and common), Tilapia, Koi, Pomfret, etc. Though fish culture is highly profitable, there are some inevitable problems faced by the aquafarmers during culture period. The factors that affect the culture includes content of oxygen, salinity, pH, toxic nitrogenous waste molecules, water availability, turbidity, solubility of CO_2 in water, etc. To meet this demand, various strategies have been developed through different techniques, one of which is Biofloc Technology. This chapter provides the principle and applications of biofloc technology in enhancement of the fish production through sustainable ecofriendly aquaculture.

Key Words: biofloc, aquatic organism, aquaculture

Introduction:

Aquaculture is an important source of food, nutrition, income and livelihoods for several hundred millions of people around the world. Fish is a source of animal protein, which contains all essential amino acids, vitamins, minerals and omega-3 fatty acids and has good benefits for human health. Production can be enhanced through sustainable intensification by the adoption of advanced culture systems and technologies as shown in Figure.1. One of such advanced technologies is biofloc technology (BFT). It is also called as aerobic microbial floc (AMF), a minimal or zero water exchange technology, which allows the animals to stock at higher densities. It is an innovative farming technology which potentially exploits the capacity of the natural microbial food web, a remedy for water quality and also helps in disease management in aquaculture by boosting the innate immunity of the fish (Ahmad *et al.*, 2017). BFT encourage the proliferation of heterotrophic bacterial biomass to assimilate inorganic nitrogenous waste, thus resulting in maintenance of the water quality at acceptable level and usage of floc as a feed source. This process maintains or greatly improves the quality of pond water. Improvement in water quality significantly reduces the usage of large volume of additional water in the pond. Biofloc Technology is considered as “Blue Revolution” in aquaculture. It is an eco-friendly process. In 1990’s the biofloc technology was developed, which helped the fish and shrimp farmers in conserving feed inputs and utilization of wastewater during culture. The scientific and practical concepts of biofloc technology (BFT) evolved concurrently and independently at about same time, by Steve Hopkins and co-workers in Israel (Avimelech, 1993). This technique is based on *in situ* microorganism production which plays the major roles such as maintenance of water quality (by up taking the nitrogen compounds), increasing nutrition, and also providing competition with pathogens.

The Biofloc technology (BFT) is mainly based on the manipulation of microbial community through the addition of a carbon source that promotes the development of heterotrophic bacteria. These bacteria use the organic carbon and the inorganic nitrogen present in the water to produce their biomass by removing toxic ammonia from the culture system. The heterotrophic bacteria that is produced through bioflocs (Halet *et. al.*, 2007) produces some natural substances (Dinh *et al.*, 2010; Iyapparaj *et al.*, 2013) which suppress the growth of other pathogenic species like *Vibrio harveyi* (Defoirdt *et al.*, 2007). This system facilitates the production of aquatic animals at high stocking densities in a sustainable and bio-secure fashion. In some cases, the protein content of feed can be reduced due to partial protein supplementation by the microbial community. Thus this sustainable approach helps in maintaining water quality, there by generating *in situ* microbial protein and providing nutrition to fishes in the form of Biofloc. This increases the feasibility of the culture by reducing feed conversion ratio and also by decreasing feed cost. This farming system makes use of aggregated single – cell microbial protein or heterotopic organisms colonized through manipulation of C: N ratio in the culture systems (Panigrahi *et al.*, 2019). Capacity of the biofloc system is to control the water quality in culture system and the nutritional properties of the flocs are influenced by the type of carbon source used to produce the flocs. Some of the carbon sources are tapioca flour, wheat flour, molasses, and sugar. C: N ratio has to be maintained in the ratio between 10:1 and 20:1 for the biofloc to operate effectively. Under optimum C: N ratio, inorganic nitrogen is immobilized into bacterial cell. Not all species can adapt Biofloc technology, characteristics such as tolerance to high density, intermediate level of dissolved oxygen (3-6 mg/l) and nitrogen.

The technology in which the aggregates of microorganisms i.e., biofloc inoculum is used for the purpose of improving water availability, quality, prevention against disease and waste treatment is Biofloc technology. The basis of Biofloc technology are the bioflocs that are used, which is nothing but conglomerates of microbes, algae, protozoa and others together with detritus, dead organic particles. Bioflocs are porous, light and usually have a diameter of 0.1 to few milli meters (Avnimelech *et al.,* 2009). The main need of biofloc technology is that it helps in minimizing the water usage during fish or shrimp farming. When the water is not much turbid, it means that the water is free from disease causing microbes and also has better oxygen availability for the culturing organisms. Using this biofloc technology the farmers are able to remove nitrogen in case of high Biological Oxygen Demand and also can remove the presence of organic matter in the water. It also helps in reducing unwanted expenses (like nitrate reduction treatment, etc) during fish or shrimp culture since it already helps in maintain the water quality parameters. If the aquaculture farmers gain the knowledge of this biofloc technology they will be benefited in many ways such as zero water exchange, maintenance of water quality parameters and also disease-free culture. Since there is no water exchange, this biofloc helps in turning wastes into fish feeds thus by reducing the water pollution. If the biofloc technology continues and becomes common in future, there will be more producion without any wastage and also eco-friendly aquafarms will be seen everywhere.

Biofloc and its principle:

Biofloc is considered as "Blue revolution" in the aquaculture industries as it continuously recycles and reuse the culture medium. Zero water exchange or minimal water exchange can be achieved using Biofloc technology. It is an environmentally friendly aquaculture technique based on *in situ* microorganism production. It is a group of biotic and abiotic components such as bacteria, diatoms, zooplankton, protozoa, macro algae, feces, uneaten feed and exoskeleton of dead organisms which are suspended in the water. In general, it is the macro- aggregation of bacteria, algae, detritus and other decomposed components. According to National Agricultural Library (NAL), Biofloc technology is defined as the use of aggregates of bacteria, algae or protozoa held together in a matrix along with particulate organic matter for the purpose of improving water quality, waste treatment and disease prevention in intensive aquaculture systems (Abdel Fattah M. El-Sayed, 2020). Biofloc is made up of wide range of microorganisms, including bacteria, micro algae, yeast, rotifers, protozoa, nematodes and copepods (Monroy & Dosta, 2013). These microorganisms are the basis of aquatic food chain and are of ecological and nutritional importance in aquaculture systems (Muller-Feuga, 2000). The main principle of this technique is the practice of nutrient recycling (Ray *et al*., 2011). Based on this principle of waste nutrients recycling, particular nitrogen, into microbial biomass can be used *in situ* by the cultured animals or be harvested and processed into feed ingredients (Avnimelech, 2009; Kuhn *et al.*, 2010). Its origin depends on the maintenance of the carbon/nitrogen supplementation to pond water (Avnimelech *et al.*, 1994). The biofloc consist of a heterogenous mixture of hetrotropic bacteria, algae, colloids, organic polymers and dead cells with associated protozoa and zooplankton. A ratio of carbon/nitrogen is managed to stimulate the growth of heterotrophic bacteria to produce microbial biomass (Avnimelech, 1999). This use of carbon/nitrogen for production of heterotrophic bacteria helps to feed the culture animal. Supplemented carbon will help in holding the excreted ammonia and by proper maintenance of the carbon/nitrogen ratio in the pond culture helps convert the ammonia in the water into bacterial biomass (Schneider *et al.*, 2006). High C: N ration is maintained by adding carbohydrate source and the production of high single celled protein helps in maintaining water quality. In the high maintenance of C-N ratio heterotrophic microbial growth occurs which assimilates the nitrogenous waste that can be exploited by the culture animals as feed and also works as bioreactor controlling of water quality. Microbial substrate of heterotrophs are ten times greater than that of autotrophic nitrifying bacteria which helps in the immobilization of toxic nitrogen species more rapidly. This heterotrophic microorganism plays a key role in escalating culture feasibility by reducing the nitrogen metabolites and by producing microbial protein. It also helps in maintaining water quality by taking up the excess nitrogen compounds in the water and generates microbial protein (Das & Mandal, 2018).

Figure 1. Biofloc based fish farming

Growth enhancement:

In an intensive aquaculture technique, there are factors that affects the growth performance of the culture animal. Factors such as feeding rate, stocking density and water quality (Akalu, 2021). However, biofloc helps in maintaining these factors in a balance and helps to enhance growth in the culture animal. Nutrition is one of the most important factors that influence growth performance in fish and it is sometimes it is influenced by factors like behavior of fish, stocking density and water quality.

Feed:

Feed is an important factor in intensive rearing of fishes. Growth of the culture animal strongly depends in the quality of the feed. Feed rate and feeding frequency can influence the production of the culture animal. The feed should contain nutrients and energy sources which are essential for maintaining normal growth and health. In the biofloc technique the remaining feed and the biological waste in the water is converted into feed which can be consumed by the culture animal. By converting the waste biological product into feed, it minimizes the cost of feed. The combination of microorganisms fungi, algae forms a biofloc which absorbs waste and enhances water quality. Biofloc shows an adequate protein, lipid, carbohydrate and ash content for use as an aquaculture feed (Crab *et al*., 2010). Biofloc also consists of many bioactive compounds such essential fatty acids, carotenoids, free amino acid and chlorophyll (Ju *et al*., 2008), trace minerals (Tacon *et al*., 2002) and vitamin C (Crab *et al*., 2012). These bioactive compounds show a positive effect on culture animals. These compounds also enhance antioxidant status, growth, reproduction and immune response. The efficiency of protein utilization is twofold higher in biofloc technology system when compared to conventional pond making (Avnimelech, 2009). Ponds which use biofloc technology have relatively low FCR. The culture animal grows well and is found to have full digestive tract all day long due to constant feeding on the Biofloc suspensions. The protein utilization is high in the biofloc technique as it produces microbial protein that are consumed by the fish this is achieved by adding carbonaceous substrates which causes microbes to harvest the excreted nitrogen. Biofloc is protein rich live feed (Khanjani *et* al 2022). It has a good nutritional value, the dry protein content ranges from 25-50%, fat 0.5-15%. It has a similar effect to probiotics (Halim *et al*., 2019). The high-yield from biofloc fish farming proves to be beneficial when compared to conventional open pond fish farming and the value of feed efficiency is better in the biofloc technology. The biofloc in the tank acts as a food source for the culture animal so less commercial feed would be required in biofloc system (Hari *et al*., 2004; Avnimelech, 2007).

Water quality:

Aquaculture is now becoming one of the major food production industries that provides food that are rich in proteins. With the increase in global population, the demand for the aquaculture products has been increased (Bossier & Ekasari 2017). One of the major limitations in the aquaculture industries is the maintenance of the water quality. The organic materials such as remaining feed and feces are toxic to the culture animal (Avnimelech, 2007). The success of an aquaculture pond and the quality of the aquaculture products depends on the reducing the production of waste water products. The increase in concentration of inorganic compounds affects the temperature, pH and dissolved oxygen in the culture tank. It is important to maintain the water quality in an optimum condition for the fishes to grow healthy. Many methods such as biofiltration, closed recirculating system and exchange of water are used in maintaining water quality but these methods are expensive and economically not feasible and also may lead to water scarcity. Biofloc is one of the alternative methods to control and maintain water quality in the culture pond. With the use of biofloc minimum exchange or zero exchange of water can be possible. Thus, it is considered as “Blue Revolution”. Since with biofloc technology zero water exchange can be achieved with less amount of water change or no water change, less water pollution is seen (Emernciano *et al*., 2013). The zero-water change or the minimal water change prevents disease outbreak in the culture pond. It also protects pathogen entry and improves bio security in the farm (Burford *et al*., 2013). It is economical for the farmers and prevents any harmful microbe’s entry through water exchange. Along with the fish’s biological waste the remaining feed which is rich in protein contains 65% of nitrogen which can cause disease susceptibility (Francis – Floyd *et al*., 2009). The zero or the minimal exchange of the water exchange depends on the dynamic interaction among bacteria, microalgae, fungi, protozoans, nematodes, rotifers etc. The Biofloc consist of heterotrophic bacteria which use organic and inorganic materials of the water and helps in maintaining the water quality. It also helps in suppressing nitrogenous wastes such as ammonia and nitrogen and prevents growth of any harmful bacteria in the water. This heterotrophic bacteria also helps in maintaining the biological oxygen demand of the culture system (Avnimelech, 1994). With the help of biofloc, nutrients can be continuously recycled and reduced in the culture medium. In Biofloc the heterotrophic bacteria convert the nitrogenous wastes into bacterial biomass. This natural role in recycling plays and important role in production of nutrients and maintaining water quality. The sustainable approach for the high production of fish/shrimp in a small area can be achieved using biofloc, as only minimum or zero exchange of water is required.

Disease free fish production:

Biofloc plays an important role in maintaining the microbes that are present in the culture. The consumption of fish has increased with the increase in the human population growth. But it is not sure that all the fishes that are consumed from local markets are disease free. During culture the fishes are lost because of the harmful microbes that are present in the pond. Thus, farmers are losing many fishes that lead to a huge loss during harvest. Not only for zero water exchange but also for disease free culture biofloc helps in many ways. The contents in biofloc enhance many beneficial microbes to grow and also suppress the harmful microbe's growth. The less Oxygen availability, increased level of ammonia, nitrogen increases the chance of diseases in fishes through pathogens. Bioflocs will provide more oxygen availability thus pathogen's growth will be reduced. These microbes are useful in conversion of ammonia cycle, for example *Pseudomonas* fixes the nitrogen that is readily available in biofloc, and these will reduce the mortality of fishes. Thus, microbes help in minimal-exchange production system. Biofloc technology mainly helps in securing the fishes from diseases in rearing ponds that is caused by pathogens from inlet water (Hargreaves, 2013). It was reported that Jaggery based biofloc technology enhanced the immunity of Nile tilapia against pathogenic *Aeromonas hydrophila* infection through up regulation of various immune cells, immune related genes and enzymes and antioxidant capacity. Thus this proves that Jaggery- based BFT was capable of enhancing the survival rate of Nile tilapia and also growth performances of the same (Elaiyaraja *et al.*, 2020). Also biofloc technology results in lower suspended solids, higher biomass production thus there will be less chances of pathogen invasion in the culture. In normal culture there will be regular exchange of water; this might invade new disease-causing pathogen into the culture. In biofloc this problem won't occur since it is zero water exchange technology and also the enhancement of useful microbes will suppress the activity of pathogens in culture. Usually in normal cultures, when its intensive method, the farmers will use recirculating aquaculture system (RAS) to avoid the invasion of the pathogens. However, considering an operating and implementation cost of all structure is high, BFT was more effective in terms of cost–benefit than RAS (Luo *et al.*, 2014).

Growth performance:

During a culture period, the main expectation of the farmer is the good growth of fish. If the fishes do not attain the expected size during harvest, this will lead to huge loss. Thus during fish production the farmer expects a healthy and good sized harvest. Biofloc provides good growth performance in fishes. The growth in fishes may become slow because of stress, less oxygen availability, fewer intakes of food, more turbid water or even due to some diseases. Biofloc enhances the water quality in the ponds thus the fishes do not undergo stress. Since the biofloc is zero water exchange method the wastes can be converted into food for fishes that provides essential nutrients for the normal growth of fishes. Biofloc contains high level of protein 38-50%, fiber 6%, and ash 12%, 19 kJ/g energy. Polyunsaturated and monounsaturated fatty acids also seen in biofloc in the amount of 27-28% and 28-29% respectively (Kola *et al*., 2018). These contents help higher growth performance in fishes during rearing as shown in Figure.2. These contents in biofloc maximize not only the growth but also the survival rate. The food convertion ratio will be higher in biofloc treated tanks than normal culture tanks. Thus during harvest the weight of the biofloc treated fish will be more. Biofloc is a sustainable and natural process that reduces the usage of antibiotics and enhances the flesh quality by providing natural growth. When a normal cultured fish and biofloc reared fish with same harvest period was compared, the growth of biofloc reared fish was greater than normally cultured fish. Not only fats, protein and carbohydrates but also the environmental condition is needed for good growth of fish. The Biofloc doesn't help in growth directly but makes the other growth factors to be maintained at normal levels. Biofloc mainly contains the *Bacillus sp.* This species helps in maintaining the water quality parameters in the culture, thus providing a stress-free environment to fishes for its growth.

Stocking densities:

In an intensive culture the stocking densities will be more. Depending on the stocking density the growth, feed utilization and yield of the culture animal can be affected. In high stocking densities the culture animal may experience stress that may limit growth and become harmful for the culture animal. Proper examination is needed for good growth and survival rate as stocking density directly influence survival, growth, water quality and feeding. Since the stocking density is more the competition for food between the fishes will be higher. The maintenance of Oxygen availability in the water must be checked regularly because of high stocking density. In the biofloc technology helps the maintenance of water quality as the biofloc water is rich in heterotrophic bacteria which helps in maintaining the biological oxygen demand in the culture (Burford *et al*., 2004). When there are more fishes, the more waste will be excreted which may cause increase in concentration of ammonia and nitrogen (Brune *et al*., 2003) which is highly toxic for aquatic organisms (Stickney, 2005). In a normal pond culture, the waste removal and water exchange process will be more. But in biofloc since it converts wastes into nutrients there will be no need for any exchange of water and it also helps in maintaining the total ammonia and nitrogen concentrations. In higher stocking densities there maybe competition among the animals for the food. Due to these few fishes may not get the required amount of nutrition they need which may affect the growth of the fish (Mirdha *et al*., 2014). But using the biofloc technique the fishes can get the required amount of nutrition as the components in the biofloc can be used as feed. It also increases the chances of the survivability of the organisms that are cultured. The ammonia and nitrogen concentration are controlled by biofloc as the ammonia and nitrogen conversion ratio is faster in biofloc technique. In high stocking densities the accumulation of waste metabolites may lead to the mortality of the fish. But using the biofloc technology the mortality rate of the culture organism is reduced and the survival rate is increased.

Figure. 2 Growth performance in Fish cultured under biofloc system

Conclusion:

Aquaculture is one of the promising methods of farming, in which the farmers can get more production and profit at same time. It offers many environmental benefits, when compared to other form of livestock farming. By fish farming, because of regular water exchange, the nearby land and water bodies are polluted by the pesticides, feed-derived wastes, some chemicals and also the excretory wastes of cultivable organisms. To overcome these problems Recirculating Aquaculture System came into role. But these techniques are quite expensive, which all the farmers could not afford. It only circulates the water within it but, it is not confirmed that the water quality is maintained and enhancement of microbes is done. On the other hand, the wastes are not utilized properly rather they are cleaned. Biofloc technology is low cost compared to other techniques and mainly it is eco- friendly way of farming. Farmers can adapt to this technology since it is easily adaptable method. The use of biofloc inoculum is not necessarily to be purchased always, farmers can also prepare it by using all the natural resources that are available. Microbial flocs form these bioflocs, since they are rich in nutrient level, they provide proteins, fatty acids and ammino acids for the rearing organisms (Burford *et al*., 2004). Using biofloc the usage of water can be minimized so that there will be no pollution in the surrounding area. Not only biofloc helps in maintaining water quality production, control of disease, increased survival rate, it helps in recycling of waste into essential nutrients for the fishes. Fishes gain more growth and weight through biofloc treated culture than normal culture. The survival rate is more when the culture is treated with biofloc than normal culture, thus the farmer can get more count of fishes with less or no loss of fishes during harvest. The weight per fish will be more in biofloc treated cultures. Thus, the farmer can gain more profit with minimal investment through this technique. The biofloc technology thus considered as “Blue revolution” since it helps to control pollution, minimizes the usage of water, easily adaptable and also it provides more profit to the farmers. Since the demand for fish food has been increasing nowadays, the production of more and healthier fishes must be enhanced without any loss.

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Role of Women in the Fisheries Sector: Scope and Opportunities

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Abstract

Women in India's fisheries sector play an integral yet under acknowledged role across all stages of the value chain from aquaculture and inland fisheries to post-harvest processing and marketing. While their contributions are critical to sustaining the sector and supporting community livelihoods, they are often marginalized due to socio-cultural constraints, lack of access to institutional support, and gender-insensitive policies. This chapter provides a comprehensive review of the current status, scope, and emerging opportunities for women in India's fisheries sector. Drawing on case studies, government data, and community-level insights, it highlights the need for gender-responsive development strategies to empower women as leaders, innovators, and stakeholders in sustainable fisheries management.

Keywords: fisheries, gender, aquaculture, economy, livelihood security

1. Introduction

India is one of the leading fish-producing nations globally, with the fisheries and aquaculture sector emerging as a powerful engine of growth, employment, and nutrition security. According to the Department of Fisheries (2023), the fisheries sector contributes over 1.24% to India's Gross Value Added (GVA) and around 7.28% to agricultural GVA. It employs more than 28 million people, of which a significant portion comprises women, especially in small-scale and artisanal fisheries. Despite their contributions, the role of women in fisheries has often remained invisible in policy, planning, and investment (Department of Fisheries, 2023). From preparing nets to sorting, drying, and selling fish, women's work in this sector is extensive but under-documented. The Food and Agriculture Organization (FAO, 2022) highlights that women represent 47% of the global fisheries workforce, mainly in post-harvest activities, and in India, this figure is even higher in certain coastal states like Kerala, Tamil Nadu, and Odisha.

In the Indian context, women are involved in almost every segment of the fisheries value chain including pre-harvest (fish feed, pond preparation), harvest (inland and coastal), and post-harvest (processing, marketing, export). Their participation is vital for ensuring household food security, community resilience, and sustainable resource management (Salagrama, 2020).

However, gender disparities persist due to limited access to:

- Financial capital and credit
- Training and technology
- Formal recognition as workers or entrepreneurs
- Social security and welfare schemes (FAO, 2022; Kumar et al., 2021).

With the advent of flagship programs such as the Pradhan Mantri Matsya Sampada Yojana (PMMSY) and institutional support from the National Fisheries Development Board (NFDB), the government of India has taken significant steps toward empowering women in the sector (NFDB, 2023; MoFAH&D, 2022). Yet, a coordinated and gender-sensitive approach is needed to address persistent gaps (World Bank, 2020).

Table 1: Women's Roles in Fisheries Sector (India) (Source, Department of Fisheries (2023); ICAR-CIFE Reports (2022)

Activity Segment	**Common Roles Performed by Women**	**States with High Participation**
Pre-harvest	Pond cleaning, feed preparation, hatchery support	West Bengal, Andhra Pradesh, Assam
Harvest (inland/coastal)	Fishing in backwaters, harvesting shellfish/crabs	Kerala, Bihar, Manipur, Odisha
Post-harvest	Drying, sorting, fermenting, packaging, value-adding	Gujarat, Tamil Nadu, Maharashtra
Marketing/Retail	Street vending, cold chain sales, cooperative retail	Kerala, Odisha, Tamil Nadu, Karnataka

2. Contributions of Women in the Indian Fisheries Value Chain

Women's involvement in the fisheries value chain in India is extensive and varied, encompassing multiple stages from pre-harvest activities to post-harvest processing and marketing. Despite the fact that women's roles are crucial for ensuring the economic viability of the sector, their contributions remain largely unrecognized in official data and policy frameworks (Salagrama, 2020; FAO, 2022). This section outlines women's contributions at every stage of the fisheries value chain, with specific reference to government initiatives that have helped empower women in the sector (Department of Fisheries, 2023).

2.1 Pre-Harvest and Input Management

Pre-harvest activities in the fisheries sector primarily involve the preparation of water bodies, feed production, and maintenance of brood stock. In India, women's role in aquaculture is particularly significant in pond management, seed production, and hatchery operations (FAO, 2022). They are involved in the preparation of ponds and tanks for fish farming, ensuring proper water quality, and selecting appropriate fish species for cultivation. They also play a crucial role in feeding fish, managing water exchange systems, and monitoring the growth of fish (Salagrama, 2020).

Key Activities:

- **Pond Maintenance and Cleaning**: Women in West Bengal, Andhra Pradesh, and Tamil Nadu play a vital role in cleaning and preparing ponds, often using traditional knowledge of local fish species and pond ecosystems (ICSF, 2021).
- **Feed Preparation**: In Karnataka and Assam, women are responsible for preparing and distributing fish feed, which may include mixing organic materials such as rice bran, mustard oil cake, and fish meal (Kumar et al., 2019).
- **Hatchery Operations**: Women in Odisha and Assam are involved in maintaining hatcheries and ensuring the healthy production of fish fingerlings. They also participate in the collection and storage of brood stock to ensure quality seed production (NFDB, 2021).

Figure 1: Women in Pre-Harvest Aquaculture Activities

2.2 Harvest Activities and Inland Capture Fisheries

Although open-sea fishing is predominantly a male-dominated domain due to physical demands and cultural norms, women actively participate in inland capture fisheries. In regions like Kerala, Bihar, and Manipur, women are involved in collecting small fish, mollusks, prawns, and crabs in wetlands, backwaters, and estuaries (Salagrama, 2020; WorldFish, 2018). Women from indigenous and tribal communities in states like Jharkhand, Chhattisgarh, and Madhya Pradesh engage in seasonal fishing activities in small reservoirs, seasonal tanks, and community-managed water bodies (Pandey & Sharma, 2019).

Key Activities:

- **Mussel and Crab Collection**: In coastal states like Kerala, Maharashtra, and Goa, women collect mussels, clams, crabs, and other shellfish, which form an important part of the local seafood diet and markets (FAO, 2022).
- **Small-scale Fishing in Wetlands**: In states like Bihar and Assam, women are involved in small-scale fishing, often in collaboration with their families and communities, using traditional methods such as hand nets and traps (Kumar et al., 2019).

Table 2: Women's Involvement in Inland Capture Fisheries by State

State	Primary Activities	Species Harvested
Kerala	Mussel collection, small-scale fishing	Mussels, crabs, prawns
Bihar	Inland fishing, crab collection	Fish, crabs, shrimp

State	Primary Activities	Species Harvested
Assam	Fishing in seasonal tanks, pond-based harvesting	Fish, frogs, prawns
Odisha	Collecting shellfish in estuaries and mangroves	Shellfish, shrimp

2.3 Post-Harvest Processing and Value Addition

Post-harvest processing is perhaps the most significant area of women's contribution in the fisheries sector. Women dominate activities such as fish drying, salting, fermentation, and smoking in coastal and inland fisheries (ICSF, 2021), and their work significantly adds value to fish products, extending shelf life, and expanding market access. In Tamil Nadu, Gujarat, and Maharashtra, women are involved in drying and preserving fish, a critical activity for meeting domestic and international demand (Salagrama, 2020; FAO, 2022).

Key Activities:

- **Fish Drying and Smoking**: In **Kerala**, **Maharashtra**, and **Tamil Nadu**, women take part in drying fish on racks or smoking them over wood-fired stoves to enhance the flavor and preservation of the fish (WorldFish, 2018)
- **Fish Pickles and Canning**: Women in Gujarat and West Bengal are increasingly involved in creating value-added products such as fish pickles, fish cutlets, and canned fish, catering to urban and export markets (NFDB, 2021).
- **Packaging and Storage**: With the rise of cold storage facilities and fish processing units under government initiatives like the PMMSY, women have taken on roles in managing hygienic packaging, sorting, and labeling of fish products for retail and export markets (Department of Fisheries, 2023).

Figure 2: Women Processing Fish for Value Addition

2.4 Fish Marketing and Retail

Women are often the primary fish vendors in both urban and rural markets. In cities like Chennai, Mumbai, and Kolkata, women fish vendors are a common sight in fish markets, where they procure fish directly from fishers, clean, and sell it to local consumers (Salagrama, 2020). In Odisha, Andhra Pradesh, and Kerala, women work through Self-Help Groups (SHGs) and Fisheries Federations (FFPOs) to collectively purchase, store, and market fish, gaining better access to markets and improved bargaining power (NFDB, 2021; FAO, 2022).

Key Activities:

- **Fish Vending**: Women operate fish stalls in local markets, managing day-to-day sales, customer relations, and pricing, which gives them independence and a reliable income (ICSF, 2021).
- **Cold Chain Development**: With increasing demand for fresh fish, women's cooperatives have collaborated with PMMSY to set up cold chain logistics, ensuring that fish products remain fresh during transportation and storage (Department of Fisheries, 2023).
- **Digital Platforms**: Digital literacy has enabled women to sell fish through online platforms, expanding their reach to urban markets and even international buyers. In Kochi and Chennai, women have begun using mobile-based fish vending apps to increase efficiency (WorldFish, 2018).

Table 2: Women's Role in Fish Marketing and Retail

Activity	Role Performed by Women	State of Activity
Local Fish Vending	Selling fish in street markets, small shops	Kerala, Tamil Nadu, Odisha
Cold Chain Logistics	Managing refrigerated transport and storage	Andhra Pradesh, Gujarat
Digital Selling	Selling through mobile apps, e-commerce platforms	Chennai, Kochi

3. Government Initiatives and NFDB's Role in Women's Empowerment

The Indian government has recognized the need for gender equality and women empowerment within the fisheries sector. This recognition is reflected through multiple schemes and programs aimed at improving access to resources, enhancing skills, and facilitating economic inclusion of women in the fisheries value chain (MoFAHD, 2020; NFDB, 2023). Below are some of the most significant initiatives:

3.1 Pradhan Mantri Matsya Sampada Yojana (PMMSY)

Launched in 2020, the Pradhan Mantri Matsya Sampada Yojana (PMMSY) is a flagship initiative of the Ministry of Fisheries, Animal Husbandry, and Dairying (MoFAHD) aimed at enhancing the productivity and sustainability of India's fisheries sector (MoFAHD, 2020). A key component of PMMSY is its focus on empowering women and marginalized groups in both marine and inland fisheries.

Key Features of PMMSY Benefiting Women:

- **Financial Assistance for Women Entrepreneurs**: The scheme offers financial support for establishing women-led fish processing units and fish retail outlets, with a strong emphasis on SHGs and cooperative models (PMMSY Guidelines, 2020).
- **Cold Chain and Packaging Support**: Women fish vendors benefit from cold chain infrastructure set up under PMMSY, enabling hygienic storage and improved market access (NFDB, 2021).
- **Capacity Building and Skill Development**: PMMSY includes extensive training for women in fish handling, processing, and logistics, often in collaboration with institutions like the NFDB (NFDB, 2022).

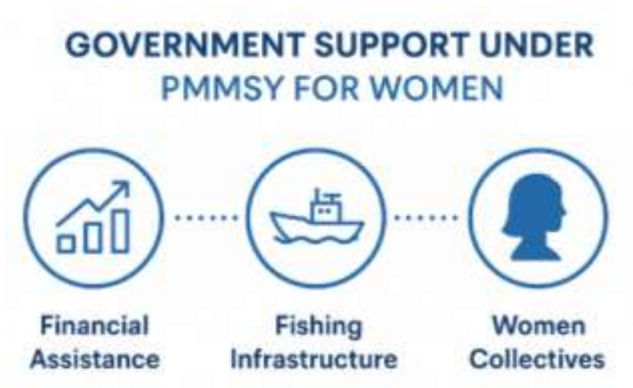

Figure 3: Government Support under PMMSY for Women

3.2 National Rural Livelihoods Mission (NRLM)

The National Rural Livelihoods Mission (NRLM), under the Ministry of Rural Development, promotes self-employment and women's empowerment in rural sectors. Through the Mahila Kisan Sashaktikaran Pariyojana (MKSP), NRLM provides focused interventions for women engaged in agriculture and fisheries (MoRD, 2018).

Key Features of MKSP for Women in Fisheries:

- **Fisherwomen Empowerment**: MKSP strengthens women's collectives in aquaculture, with training in hatchery operations, fish farming, and value-added processing (NRLM Annual Report, 2022).
- **Financial Assistance and Micro-Credit**: Women involved in aquaculture are provided with micro-financing and credit access for setting up fish farming units. This has made it easier

for women to engage in the more capital-intensive aspects of the sector, such as establishing ponds, hatcheries, and processing units. SHGs receive access to micro-credit for fish pond construction, hatcheries, and retail units (World Bank, 2020).

- **Community-Based Models**: MKSP has supported the creation of women-led collectives and Self-Help Groups (SHGs) focused on the fisheries sector.Women's SHGs are supported to manage collective fisheries ventures, enhancing market access and operational efficiency (MoRD, 2021).

Table 3: Women's Role in Fish Marketing and Retail

Activity	Role Performed by Women	State of Activity
Local Fish Vending	Selling fish in street markets, small shops	Kerala, Tamil Nadu, Odisha
Cold Chain Logistics	Managing refrigerated transport and storage	Andhra Pradesh, Gujarat
Digital Selling	Selling through mobile apps, e-commerce platforms	Chennai, Kochi

3.3 National Fisheries Development Board (NFDB)

The National Fisheries Development Board (NFDB), an autonomous body under the Ministry of Fisheries, plays a pivotal role in promoting sustainable fisheries and aquaculture in India. NFDB's contribution to the empowerment of women in the fisheries sector is significant, particularly through training, capacity building, and financial support for women-led fishery cooperatives and self-help groups. NFDB is instrumental in promoting women's participation through financial aid, skill development, and infrastructure support (NFDB Annual Report, 2023).

Key Initiatives by NFDB for Women:

- **Capacity Building Programs**: The NFDB runs training programs for women in various aspects of the fisheries sector, including hatchery management, fish processing, and marketing techniques. As of 2023, over 15,000 women in states like Tamil Nadu, Odisha, and Assam have been trained in aquaculture and fish processing skills (NFDB, 2023).

- **Financial Support for Women Entrepreneurs**: NFDB has supported women-led fish farming ventures through loans, subsidies, and financial schemes aimed at promoting sustainable aquaculture (NFDB, 2022). Women-run cooperatives in West Bengal and Kerala have benefitted from NFDB-backed schemes, improving their productivity and economic status.
- **Women's Fish Processing Units**: NFDB has helped establish modern, women-managed fish processing centers under PMMSY, producing export-oriented products like frozen fish and ready-to-cook snacks (MoFAHD, 2023). These units focus on producing value-added fish products such as frozen fish, fish snacks, and ready-to-cook fish products, expanding the market for women entrepreneurs.

Figure 4: NFDB's Capacity Building Programs for Women

3.4 Other Government Schemes

There are several other state-specific and national government schemes aimed at uplifting women in the fisheries sector. These include:

- **Fisheries and Aquaculture Infrastructure Development Fund (FIDF)**: Offers low-interest loans for building fisheries infrastructure, often accessed by women SHGs and cooperatives (MoFAHD, 2019).

- **Pradhan Mantri Awas Yojana (PMAY)**: Supports housing for fisher families, improving living conditions, especially for women-headed households (MoHUA, 2020).
- **Rashtriya Krishi Vikas Yojana (RKVY)**: Promotes innovation and infrastructure in fisheries, creating opportunities for women-led enterprises to access markets and technology (DAC&FW, 2021).

4. Key Barriers to Women's Advancement in Fisheries

Despite significant advancements in policy and government support, women in the fisheries sector continue to face numerous barriers that limit their potential (Salagrama, 2020; FAO, 2022). These barriers range from societal expectations to financial constraints, and they prevent women from fully benefiting from opportunities in the fisheries industry. Below are the primary challenges that need to be addressed to create an equitable and inclusive fisheries sector.

4.1 Socio-Cultural Constraints and Gender Norms

India's fishing communities, like many rural areas, are influenced by traditional patriarchal norms that assign gender-specific roles. Women are often restricted to post-harvest jobs such as processing and marketing, which are informal, underpaid, and undervalued (WorldFish, 2018). In many coastal and inland regions, women's roles are largely confined to low-paying, informal jobs like post-harvest processing, marketing, and supporting male family members in fishing operations. Despite their significant contributions, their roles are often ignored in development and governance structures.

Key Issues:

- **Limited Decision-Making Power**: Women's voices are often marginalized in decision-making processes related to fisheries management, resource allocation, and community-level planning. This lack of representation means that policies and development strategies do not always address women's specific needs and aspirations. According to Harper et al. (2017), this lack of representation results in policies that overlook women's priorities and working conditions.
- **Social Stigma and Stereotyping**: Working in fisheries, especially in the harvest phase, is often viewed as "men's work." This perception discourages women from entering or

continuing in the sector (FAO, 2022). Salagrama, 2020 said the presence of traditional norms and stereotypes often limits women's participation in decision-making forums, where men dominate.

4.2 Limited Access to Resources and Technology

One of the most significant barriers women face is their limited access to critical resources such as land, capital, and technology. In the fisheries sector, where capital investment is necessary for aquaculture and fisheries infrastructure, women often find it difficult to access these resources due to lack of ownership and financial inclusion.

Key Issues:

- **Ownership of Land and Ponds**: In many regions, women do not have formal ownership rights over land or aquaculture ponds. This limits their ability to invest in and scale up fish farming activities. A study by the National Bank for Agriculture and Rural Development (NABARD, 2021) indicates that only 13% of women in fisheries-owning households have land in their name, severely limiting their eligibility for institutional credit.
- **Access to Credit**: Despite schemes like PMMSY and NRLM, many women in rural areas still struggle to access micro-financing or institutional credit. According to the Department of Fisheries (2023), fewer than 20% of female fish farmers have availed institutional loans, largely due to lack of collateral and financial literacy.

Figure 5: Gender Gaps in Access to Credit in the Fisheries Sector

4.3 Lack of Market Access and Digital Literacy

Women in the fisheries sector face significant challenges in accessing markets for their products. In many cases, market networks are dominated by men, and women have limited control over pricing, distribution, and sales strategies.

Key Issues:

- **Market Linkages**: Women often sell their products at local markets with limited access to larger regional or national markets. This affects their profit margins and limits their economic growth. Women vendors, particularly those in remote coastal or inland areas, are dependent on middlemen, which can reduce their income (WorldFish, 2018).
- **Digital Divide**: With the rise of e-commerce platforms and mobile technology, women fish traders face digital literacy challenges. Limited access to mobile phones, internet, and training restricts women from leveraging e-commerce platforms and digital payment tools (FAO, 2022; PMMSY Guidelines, 2020).

Table 4: Barriers to Market Access for Women in Fisheries

Barrier	Impact	Potential Solution
Lack of Cold Chain Infrastructure	Reduced shelf life of fish; loss of income	Support for cold chain logistics through PMMSY
Limited Market Access	Lower profits, dependence on middlemen	Establishment of SHGs for collective marketing
Digital Literacy	Exclusion from online markets, digital payments	Digital literacy training programs for women fish vendors

4.4 Gender-Based Violence and Discrimination

Gender-based violence and discrimination remain significant barriers to women's advancement in fisheries. Women working in fisheries face harassment, both in the workplace and in public spaces, which create critical barrier for women in the fisheries sector (Salagrama, 2020).

Key Issues:

- **Violence in the Workplace**: According to Harper et al. (2017), In the fishing industry, women, particularly in rural areas, often face harassment from male counterparts, such as verbal abuse and physical intimidation. This is particularly common in fish markets, where women face discriminatory behavior.
- **Violence in Family Settings**: Women's work in fisheries is often undervalued by male family members, leading to domestic violence and economic exploitation. Women's earnings from fisheries are often controlled by male relatives, preventing them from achieving economic independence (FAO, 2022). The WorldFish, 2018 reported, Gender-based violence in fishing communities continues to restrict women's access to the full range of economic opportunities available in the sector.

4.5 Lack of Infrastructure and Training

Government and institutional training programs do exist, but participation by women remains low due to accessibility and awareness issues (NFDB Annual Report, 2023).

Key Issues:

- **Limited Access to Training**: Women in rural areas are often unaware of government schemes or face difficulty in attending training sessions due to family responsibilities, cultural norms, or lack of mobility (MoFAHD, 2023). This limits their ability to develop new skills in areas such as advanced aquaculture techniques, business management, or cold chain logistics.
- **Poor Infrastructure**: In many fishing communities, the lack of proper infrastructure—such as storage facilities, processing units, and transportation—further hinders women's progress (NFDB, 2023). Even in coastal areas, where women dominate post-harvest processing, unsanitary conditions and lack of modern equipment can lead to poor-quality products, which limits their marketability.

5. Emerging Opportunities for Women's Empowerment in Fisheries

The fisheries sector, while presenting challenges for women, also offers vast opportunities for empowerment. With growing recognition of gender equality in development policies, there is a notable push to create a more inclusive fisheries sector**.** Several emerging opportunities offer pathways for women to thrive in the sector, ranging from skills development programs **to** digital inclusion and entrepreneurship support (FAO, 2021).

5.1 Government Schemes and Initiatives for Women in Fisheries

Over the years, the Indian government has implemented various schemes aimed at empowering women in the fisheries sector. These programs focus on capacity building**,** infrastructure support**,** and financial inclusion (MoFAHD, 2022).

I. **Pradhan Mantri Matsya Sampada Yojana (PMMSY)**

The PMMSY, launched in 2020, is one of the flagship schemes aimed at boosting the sustainable development of fisheries in India. The scheme promotes inclusive growth, and a specific focus is placed on providing benefits to women involved in fisheries (MoFAHD, 2020). This scheme facilitates training and infrastructure support, especially for Self-Help Groups (SHGs) and women entrepreneurs in the fisheries value chain.

Key Components of PMMSY:

- **Support for Women Entrepreneurs**: PMMSY promotes entrepreneurial opportunities for women in the fisheries sector by supporting cold storage units**,** processing facilities**,** and marketing networks (NFDB, 2023)**.**
- **Training and Capacity Building**: Under this scheme, women are provided training in modern aquaculture practices**,** fish processing**,** and cold chain management**.** For example, in the Kochi and Bhubaneswar regions**,** women SHGs have benefited from such training, leading to improved processing techniques and better market access (Das et al., 2022).

II. **National Rural Livelihoods Mission (NRLM)**

The NRLM is another key initiative designed to improve the livelihoods of rural women, including those involved in fisheries. Under the Mahila Kisan Sashaktikaran Pariyojana (MKSP) component, women in aquaculture and fish farming receive technical training**,** financial assistance**,** and access to market linkages (Ministry of Rural Development, 2021). NRLM has focused on forming women-led producer groups and Self-Help Groups (SHGs), which act as support systems for women in fisheries.

III. Matsya Vikash Yojana (MVY) (State-level Initiative)

Various state governments also support women's involvement in fisheries through localized schemes. For instance, Matsya Vikash Yojana in Odisha supports women in fish seed production**,** processing**,** and fishing. Women SHGs have been able to access financial assistance and technical support for capacity building (Govt. of Odisha, 2022).

5.2 Technological Advancements and Digital Inclusion

In recent years, technology has emerged as a key enabler for women's empowerment in the fisheries sector. Digital tools are increasingly helping women expand their businesses, improve productivity, and access new markets (FAO, 2021).

I. Digital Platforms for Market Linkages

In the fisheries sector, digital platforms and e-commerce solutions are opening new doors for women entrepreneurs. Women in coastal states, such as Kerala and West Bengal, are using digital platforms to sell their fish and seafood products directly to consumers, bypassing traditional middlemen (Bene et al., 2021). This helps women achieve better profit margins and market outreach.

II. Technology in Aquaculture and Fish Farming

Women involved in aquaculture can now take advantage of mobile applications and online resources for better pond management**,** water quality monitoring, and feed optimization. Platforms like Fisheries India provide real-time data and training modules that assist women farmers in making data-driven decisions regarding their farming operations (ICAR-CIFE, 2022).

Figure 6: Digital Tools Empowering Women in Fisheries

5.3 Financial Inclusion and Micro-Credit Schemes

One of the persistent barriers faced by women in fisheries is lack of financial inclusion. However, the government has recognized the need to promote access to credit and financial products for women in rural areas (NABARD, 2022).

I. **Micro-Credit and Financial Support**

Under schemes like Pradhan Mantri Jan Dhan Yojana and MUDRA (Micro Units Development and Refinance Agency) Scheme, women entrepreneurs in fisheries are being provided with micro-loans**,** insurance coverage, and financial literacy programs (MoF, 2023). These schemes help women acquire the financial capital necessary for setting up small-scale fish farming operations or fish processing units**.**

II. **Women-Centered Financial Products**

Various financial institutions are offering women-centered loans for fish-related businesses. For example, the NABARD (National Bank for Agriculture and Rural Development) provides low-interest loans to women-led SHGs in fisheries, enabling them to access modern technologies and scale their businesses (NABARD, 2022).

5.4 Skills Development and Capacity Building

A critical area of focus is skills development. Women in the fisheries sector often lack access to advanced technical training, which is essential for their growth as entrepreneurs and leaders in the industry. However, new government initiatives are focusing on closing this gap (NFDB, 2023).

I. **Skills Development Programs**

Training programs such as those offered under the PMMSY and NRLM focus on enhancing women's technical, financial, and business management skills. These programs cover a wide range of areas including:

- Aquaculture and Fish Farming Techniques
- Post-Harvest Processing and Value Addition
- Cold Chain Management and Storage
- Entrepreneurship and Business Management (Das et al., 2022)

Women also benefit from sector-specific training in areas like shrimp farming and marine fisheries management, which are increasingly being incorporated into vocational education programs in states like West Bengal and Andhra Pradesh (ICAR-CIFE, 2022).

Figure 7: Skills Development Programs Benefiting Women in Fisheries

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6. Policy and Research Recommendations

To ensure that women in the fisheries sector can fully capitalize on the emerging opportunities, it is essential to implement inclusive policies and focus on targeted research. The government, non-governmental organizations (NGOs), industry stakeholders, and research institutions all have a role to play in enabling women's full participation in the fisheries sector. This section outlines key policy recommendations and identifies critical research gaps that need to be addressed.

6.1 Policy Recommendations

6.1.1 Gender Mainstreaming in Fisheries Policy

Gender mainstreaming should be an integral part of national and state-level fisheries policies. This involves incorporating a gender perspective in the design, implementation, and evaluation of all fisheries development programs (FAO, 2021; Harper et al., 2020). Gender-responsive policies can help ensure that women receive equal access to resources**,** training, and financial support. Key actions include:

- **Gender-Specific Targets**: Policies should set specific targets for women's participation in fisheries programs, ensuring that a significant percentage of resources are allocated for women's training, entrepreneurship, and empowerment (Ministry of Fisheries, 2022).
- **Gender-Sensitive Data Collection**: Reliable gender-disaggregated data is crucial for understanding the specific needs and challenges faced by women in the sector. Government agencies should implement systems for collecting and analyzing data on women's involvement in fisheries to ensure evidence-based decision-making (Williams, 2008; FAO, 2021).

6.1.2 Strengthening Women's Access to Financial Resources

Women in fisheries face significant barriers when it comes to accessing financial services and credit facilities**.** There is a need for gender-sensitive financial products **t**hat take into account the unique challenges women face in accessing capital (NABARD, 2022; UN Women, 2021).

- **Microfinance Initiatives**: The government should expand the reach of micro-credit **schemes** for women in fisheries, providing easier access to loans**,** grants, and insurance. Microfinance institutions can be instrumental in promoting entrepreneurship and business development among women (IFAD, 2020).

- **Inclusive Financial Institutions**: Commercial banks and financial institutions must develop financial products specifically designed for women entrepreneurs in the fisheries sector. These products should offer low-interest rates, flexible repayment terms, and access to collateral-free loans for women-led businesses (MoF, 2023; Singh & Sharma, 2021).

6.1.3 Promoting Women's Leadership and Decision-Making in Fisheries Management

Women should be included in decision-making processes at all levels of fisheries management. Leadership programs and capacity-building initiatives should be implemented to enable women to take on leadership roles within fishery cooperatives, government bodies, and industry associations (Weeratunge et al., 2010). The government should:

- **Increase Women's Representation**: Efforts should be made to increase the representation of women in fisheries policy making, especially in cooperative societies, fisheries management committees, and National Fisheries Development Board (NFDB) programs (NFDB, 2023).
- **Leadership Training**: Implement training programs focused on leadership development for women in the fisheries sector. These programs should cover management skills, negotiation techniques, business development, and conflict resolution (ICAR-CIFE, 2022; FAO, 2021).

6.1.4 Infrastructure Support for Women Entrepreneurs

The lack of adequate **infrastructure** and **market access** limits the opportunities available to women entrepreneurs in the fisheries sector (Harper et al., 2020). To address these barriers, the government should invest in:

- **Women-Centered Infrastructure**: Establish cold storage facilities, processing units, and **fishing markets** that are tailored to the needs of women entrepreneurs. These facilities should be equipped with modern technologies that enhance productivity and ensure hygiene standards (Ministry of Fisheries, 2020).
- **Market Access and Linkages**: Women entrepreneurs should be given access to both local and international markets. Government programs should facilitate linkages between women-

led businesses and marketplaces, and support the use of e-commerce platforms (Das et al., 2022; Bene et al., 2021).

6.1.5 Enhancing Access to Technology and Innovation

Women's access to modern technologies is often limited by factors such as illiteracy, lack of training, and social norms (FAO, 2021). To close this gap, the government should:

- **Digital Literacy Programs**: Establish digital literacy programs specifically for women in rural areas to help them adopt modern farming techniques, market platforms, and fish processing innovations. These programs should focus on teaching skills like mobile app usage, online marketing, and data management (ICAR-CIFE, 2022; UN Women, 2021).
- **Promote Innovation**: Encourage women-led innovations in the fisheries sector by creating research and development hubs that focus on gender-inclusive technologies. This includes technologies for sustainable aquaculture, processing, and supply chain management (Weeratunge et al., 2010; Harper et al., 2020).

6.2 Research Recommendations

6.2.1 Research on Gender and Fisheries Value Chains

To fully understand women's role and challenges in the fisheries sector, research must be conducted on the gender dynamics within the fisheries value chains (FAO, 2021; Williams, 2008). Key areas for research include:

- **Women's Role in Aquaculture**: Detailed studies should be conducted on the contributions of women in aquaculture systems, particularly in breeding, seed production, and fish farming management (Singh & Sharma, 2021).
- **Impact of Gender-Inclusive Policies**: Research should evaluate the impact of gender-specific policies and programs (e.g., PMMSY) on women's economic empowerment in the fisheries sector (NFDB, 2023; Ministry of Fisheries, 2022).

6.2.2 Impact of Climate Change on Women in Fisheries

Climate change has a disproportionate effect on women in fisheries, especially those dependent on coastal and inland fisheries (FAO, 2021; Weeratunge et al., 2010). Research must focus on the specific vulnerabilities of women in these areas, including:

- **Impact on Livelihoods**: How climate change and environmental degradation (e.g., loss of fish stocks, changes in water salinity) affect women's livelihoods and food security (Harper et al., 2020).
- **Adaptation Strategies**: Identifying and promoting adaptation strategies that women can implement to mitigate the effects of climate change on their fishing practices (Bene et al., 2021).

6.2.3 Research on Financial Inclusion and Women's Entrepreneurship

There is a need for research into how financial institutions can better serve women in fisheries (NABARD, 2022). This includes:

- **Access to Credit**: Research into barriers that prevent women from accessing financial services and understanding the role of microfinance in empowering women in fisheries (IFAD, 2020; Singh & Sharma, 2021).
- **Entrepreneurship Models**: Study successful entrepreneurship models for women in the fisheries sector and the factors that contribute to their sustainability and growth (Das et al., 2022; FAO, 2021).

7. Emerging Opportunities for Women in Fisheries

The government initiatives, such as the Pradhan Mantri Matsya Sampada Yojana (PMMSY)**,** National Rural Livelihood Mission (NRLM)**,** and Women Fish Vendors Scheme (WFVS)**,** present significant opportunities for women in the fisheries sector (MoFAHD, 2022; NFDB, 2023). By addressing barriers related to financial access, technology, and skill development, these initiatives create a more inclusive and empowering environment for women (FAO, 2021).

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7.1 Role of Technology in Empowering Women

Technology has the potential to significantly transform the lives of women in fisheries by improving productivity, market access, and processing capabilities (Harper et al., 2020). Mobile platforms, digital marketing, and cold storage units are just some examples of technological advancements that can help women overcome traditional barriers and access new market opportunities (Weeratunge et al., 2010; UN Women, 2021). Digital tools such as mobile apps for fish market price updates, training modules for aquaculture, and e-commerce platforms have enabled women to connect directly with consumers and reduce dependency on intermediaries (Das et al., 2022).

7.2 The Need for Gender-Sensitive Policies

While significant strides have been made, gender disparities continue to persist in the fisheries sector. Therefore, the government must take a more active and systematic approach to gender mainstreaming (FAO, 2021; Williams, 2008). This can be achieved through:

- **Policy Advocacy**: Increased advocacy to raise awareness about the importance of gender equality and women's empowerment within the fisheries sector (Harper et al., 2020).
- **Training Programs**: More targeted training programs for women in entrepreneurship**,** fisheries management, and technology adoption should be promoted at the state and district levels (ICAR-CIFE, 2022; NABARD, 2022).
- **Support for Women Entrepreneurs**: Encouragement of women-led cooperatives and fisheries federations will give women access to larger, more organized supply chains and higher market share (NFDB, 2023; Singh & Sharma, 2021).

7.3 Barriers Faced by Women in the Sector

Women face several barriers to their full participation in the fisheries sector. These include:

- **Cultural Norms**: In many fishing communities, patriarchal systems prevent women from taking leadership roles in decision-making processes, limiting their ability to own assets, participate in policy discussions, and access market linkages (Weeratunge et al., 2010; Williams, 2008).
- **Lack of Financial Access**: Women face challenges in accessing credit and financial services due to gender biases in formal financial institutions. This restricts their capacity to invest in

business expansion or acquire the necessary technologies for efficient operations (IFAD, 2020; NABARD, 2022).

- **Limited Access to Resources**: Women have limited access to resources like land, fisheries equipment, technologies, and training. Gender-insensitive policies have resulted in inequitable access to these resources, further perpetuating the gender gap (FAO, 2021; UN Women, 2021).

8. Conclusion

The fisheries sector is a crucial component of the Indian economy, supporting millions of livelihoods across the country. While the role of women in this sector is critical, their contributions often go unnoticed and are underappreciated due to a lack of gender-sensitive policies, cultural barriers, and limited access to resources. In India, women play a significant role in various stages of the fisheries value chain, including aquaculture, processing, marketing, and value-added products. However, they continue to face challenges such as unequal access to financial services, training, technologies, and decision-making processes. Women's involvement in fisheries is not only a critical factor for economic growth but also for food security, nutrition, and sustainable livelihoods. As India continues to move forward with the goal of promoting the Blue Economy, it is vital that women are empowered as key contributors to the sector's success. In light of the ongoing efforts to address gender disparities, a comprehensive, gender-inclusive approach is necessary to ensure women's economic and social empowerment within the fisheries sector.

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Biofloc technology: A novel approach for enhanced fish production

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Abstract

The major contributor to aquaculture growth is farming sector which can be projected to contribute to the food security through available cheap protein. The capture fishery already stagnated and revival indicates a very slow pace, culture intensification is necessary to cater the demand. But the intensification in farming sector as per the demand will lead to more effluent discharge. Various farming practices like integrated farming, integrated multitrophic aquaculture, aquaponics and recirculatory aquaculture systems are considered as environmentally sustainable farming practices. Eventhough, intensive practices like recirculatory aquaculture system is environment friendly, it requires huge financial investment. Moreover, intensification in aquaculture will have to resort to heavy investment in feed. The major sustainability concepts in intensive aquaculture include attaining food security through higher production, cost effective feeding, and effluent management. So there is huge scope for a technology which will be environmentally sustainable and economically viable.

Key words: aquaculture, biofloc, food security, probiotics

Introduction

Biofloc technology is gaining popularity because of scarce resources (land and water) and effluent generation from conventional practices. BFT reduces the water exchange rates considerably thus prevents severe outbreaks of infectious diseases led to more stringent biosecurity measures (Avnimelech, 2009). So the technical knowhow on the technology and its implementation protocols need to be transferred to the grass root level. Possible monitoring tools are the concentration of total suspended solids or bioflocs, and the settle ability. The system is based on the knowledge of conventional domestic wastewater treatment systems and is applied in aquaculture environments.

Microbial biomass is grown on fish excreta resulting in a removal of these unwanted components from the water.

What is Biofloc?

Microbial flocs formed within the system, consists of mixture of the microbial organisms (both filamentous and flocculating bacteria), polymers, dead organisms and excretory waste aggregates which are formed under controlled conditions conducive for flocculation. The extra cellular polymeric substances were reported to be forming a matrix which in turn binds the floc components together. The major category of microbes flocculating in the system is heterotrophic bacteria and their flocculation can be altered by various means including addition of various carbon sources. The flocculated conditions of heterotrophic microbes can be beneficial to evade predation by protozoans and other grazers.

The flocculated particles or the flocs clump and are held together in a loose matrix of mucus that is secreted by bacteria, bound by filamentous microorganisms, or held by electrostatic attraction. Typical flocs are irregular by shape, have a broad distribution of particle size, and the flocs aggregate together and can remain in suspension on provisions of sufficient aeration. Bioflocs are generally microscopic in size, mostly around 50-200 microns and easily settles in calm water.

How biofloc can be formed?

The external carbon source added to the culture environment will be assimilated by the microorganisms along with the nitrogenous matter present in the water through feed and fecal matter to form microbial protein. Carbohydrate addition to the system should be calculated in terms of feeding rate and protein content of the feed. Indiscriminate addition of carbon will lead to solid accumulation and which in turn will lead to gill clogging. More oxygen will be needed to support the respiratory demands of a greater bacterial load, and additional energy is needed to keep solids in suspension. Since the biofloc unit is based on intensive farming mode, the lack of aeration as per the demand may lead to the crashing of the system. The management should ensure adequate aeration points in the system to cover the entire area and not leaving any area without aeration. But if there is a cessation of carbon source addition, then the heterotrophic pathway which is much required for biofloc unit will be transformed to nitrification pathway.

The biofloc unit initially will have higher Total Ammonia Nitrogen (TAN) and will gradually stabilize with the addition of calculated amount of carbon source to the system. The reduction in

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nitrogenous compounds like Ammonia -N, Nitrite –N, and Nitrate -N could be attributed to the addition of carbonaceous substrates that lead to an increased microbial biomass, which immobilized TAN for the synthesis of new bacterial cells. Hence the heterotrophic bacteria population utilizes the ammonium in addition to the organic nitrogenous wastes to synthesize new cells equivalent to single cell microbial protein.

For optimum growth of heterotrophic bacterial population for ammonia control, there is a need to maintain a C:N ratio of the culture unit above 12:1. The balancing of C: N ratio of the biofloc unit is by the lowering of protein in feed supplemented. Ammonia production in the system can be controlled by balanced C:N ratio, promoting nitrification and by providing aeration. The C: N ratio in the system can be maintained by adding inputs with high C: N ratio, otherwise can also be achieved by lowering feed protein content. For rapid alteration of C: N ratio simple sugar can be added especially during the start up. But the practically used carbon sources for cost effectiveness include molasses, grain pellets, sugar cane bagasse, jaggery etc. It can also be in the form of rice bran, rice flour, wheat flour, tapioca flour, sorghum flour, cassava flour and cornflour, In addition any low cost and available carbon sources including distillery wastes or spent wash also can be used after ensuring the pathogenic microbial strength.

Figure 1. Imhoff cone with floc

There are two types of biofloc production in practice, In-situ and ex-situ. In the in-situ biofloc unit, the carbon sources will be supplemented to the culture system itself to maintain C:N ratio by calculating the nitrogen produced on a daily basis. In well managed system, heterotrophic bacterial population will be produced which in turn will serve as the feed for the cultured organism. Ex-situ floc will be produced with the help of a biofloc reactor where the C:N ratio will be manipulated and the floc production will be controlled externally and the floc will be added to the culture system at regular intervals. In this system, the floc quality can be controlled manually and the dried floc will be used as alternative protein source in the diet of the organism. It will be helping the farming community to resort to cost effective feeding. Moreover, the farm effluent can be diverted and can also be used for biofloc production and the floc can be added to the culture unit. Culturists can manipulate the energy, lipid, mineral and protein content of bioflocs by adjusting how they operate the biological reactors.

Figure 2. In-situ biofloc system

Why biofloc technology to be adopted?

Bioflocs are found to be nutritionally rich and is a good source of microbial protein which can serve as an alternative source of protein for cultured organisms. The fish meal is the costliest and scarce ingredient for any fish or shrimp feed. Therefore there was constant research on finding out the alternative ingredients which can partially or fully replace the fish meal and fish oil. Many plant based ingredients were proved to be better alternative sources for fish meal and fish oil. Bioflocs which have been reported to contain adequate protein, lipid, carbohydrate and ash content can be a cheaper and ecofriendly ingredient in farmed organism's diet. The adoption of biofloc technology can reduce the dependence on fish meal by 5-10% in a 35% crude protein diet.

Bioflocs has been recently projected as a possible novel strategy for disease management with the "natural probiotic effect" in contrast to conventional approaches such as antibiotic, antifungal, external probiotic and prebiotic application (Emerenciano *et al.*, 2013). A wide range of microorganisms has been used in shrimp and fish aquaculture as probiotics to enhance the beneficial microbiota in the gut tract or water, which in consequence improves the nutritional value of feed by enzymatic contribution to digestion. The presence of microbial biomass in culture system had been reported to improve the health status of the cultured organism which may be due to the competitive inhibition and displacement of pathogens.

The nitrogenous compounds generated from the unconsumed food and excreta from the cultured organisms and the decomposition of various organic matters in the system are converted into proteinaceous natural feed for those same culture organisms. Hence the system can be maintained as minimal or zero water exchange-based units which in turn can control the pollution load from intensive aquaculture system. The technology offers sustainable intensification in aquaculture.

Figure 2. Ex-situ biofloc system

Preparation of ponds and tanks under biofloc system

The use of nucleation sites such as soil or biofloc-rich water as inocculum from a prior production cycle to accelerate the formation of bioflocs in new culture system. Avnimelech (1999) reported using of 20g pond bottom-clay soil, 10 mg Ammonium Sulphate (NH_4SO_2) and 200 mg glucose (carbon sources) shaken for 12 h with 1000 ml tap-water for the initial production of bioflocs. According to Crab et al. (2012), a certain start-up period is needed to obtain a well-functioning biofloc system in aquaculture ponds with respect to controlling water quality depending on the nitrogen and organic load of the system. The development process may vary from 7-8 weeks in outdoor ponds to 5 weeks in super-intensive systems. In general a proper biofloc tank will take its maturation time of 4-5 weeks.

Pond should be lined with polyethylene lining and ponds should have sludge drainage pipes installed at the bottom to drain the sludge when the suspended solids concentration exceeds 400ml/L. Stocking density of different species: Tilapia 35-45 kg/m^3, Shrimp 15-25 kg/m^3, Carps 40 kg/m^3. The aeration facility has to be arranged for sufficient suspension of the flocs. The aeration can be provided using aeration tubes which can be arranged in the bottom to provide proper air flow uniformly in the system. The cascade type of splashing aerators and air diffusers can be arranged at suitable positions to ensure the uniform distribution. Nowadays, indoor tank system is gaining popularity of which the size varies from 5 m^3 to 75 m^3 depending upon the availability of space and skilled expertise to manage the system. The commonly used sizes of tanks vary from 10-15 m^3.

Figure 3. Biofloc System

Advantages of Biofloc Systems

- Water conservation: Water use is greatly reduced, recycled, and available for multiple crops (Tacon et al., 2002).
- Stable water quality: Lower diel fluctuations in certain water quality properties, especially dissolved oxygen and pH.
- Reduced fertilizer use: Many nutrients are recycled within the culture tank, greatly reducing the need for inputs of chemical fertilizers.
- Small footprint: Occupies much less area than ponds per unit shrimp produced.
- Year-round production: Can operate throughout the year, despite local climate.
- Faster growth: Supports faster shrimp growth rates (Otoshi et al., 2001) because of greater control over feeding and temperature.
- Lower susceptibility to disease: Shrimp are less susceptible to pathogens common in traditional systems (Taw, 2015) because of improved biosecurity.
- More efficient use of protein in feed: Efficiency is 45%, compared to 25% in conventional ponds (McIntosh, 2001) because waste nutrients are recycled into bacterial protein in floc that is consumed by shrimp.
- Lower feed requirements: FCRs of 1.0–1.3 reduce production expenses by 15%–20% (Avnimelech, 2009).
- Higher yields: Production is 5%–10% greater than that from traditional ponds (Avnimelech, 2009).
- Sustainability: Less impact on the environment than open pond culture.

Disadvantages of Biofloc Systems

- High capital investment per unit area: Compared to conventional ponds, capital investment is greater, but much less land is needed for commercial levels of production.
- Liner expense: Membrane liners are expensive and need constant maintenance.
- High energy input: Higher energy expenses for aeration and pumping are incurred to operate biofloc facilities (Avnimelech, 2009).
- Power failure is critical: More than an hour without power can result in crop loss.
- Operating complexity: Management is more complicated than in traditional aquaculture thus requiring a more technically trained staff and higher labour costs.
- Toxins: Without adequate remediation, undesirable substances—nitrate, phosphate, and heavy metals—accumulate in reused culture water.
- Disease risk: Disease, mainly Vibrio, has afflicted some closed systems. Despite the ever-present threat of disease common to all aquaculture systems, Horowitz and Horowitz (2002) found that limited-exchange systems reduce the threat and spread of pathogens.

Challenges

Advances in biofloc systems have been impressive, but current knowledge certainly is not complete. For example, the failure of some indoor biofloc projects can be traced to the complex interrelationships that characterize the diverse and difficult-to-control microbial biofloc community. This assemblage can be unstable in relatively small tanks stocked at high densities and driven by the large input of feed required for good shrimp growth. If the microbial community of the biofloc system is not balanced properly, harmful chemicals can accumulate, particularly ammonia, nitrite, and nitrate. Water quality changes are exacerbated when water is reused over multiple crop cycles. Trouble shooting the problems in water quality, disease management, culture systems maintenance.

It's being observed that many young professionals are starting new small scale Aquaculture projects in the name of Bio floc and RAS systems, even though it’s good to see building up interest in IT, and non-fisheries start-ups to enter into Fish/shrimp culture, it’s been observed that many of them are dependent on YouTube and Facebook videos and also the self-claimed technicians in YouTube many of whom doesn't even understand aquaculture. Finally the projects are lacking any suitable business goals/views and will become just a projects for photos and add up-to one more YouTube video but unable to achieve any results. There are lot of famous pseudo consultants on

YouTube who are just exploiting and misguiding people for consultancy charges and Commissions. They are mushrooming and minting money with their training programs.

Recommendations:

For sustainable aquaculture to develop by means of Biofloc Technology, a dedicated aquaculture policy which promotes innovation and technology, and diversification of aquaculture activities in Biofloc Technology can be fostered by the government.

- Recommendations for the optimum stocking density of the different culture systems using biofloc technology in the nursery and grow-out culture of Penaeus vannamei and GIFT Tilapia by the regulating authority.
- Dissemination of Standard Operating Procedures for the Biofloc driven culture can be released by the appellate governing bodies
- A multi-institutional approach for the exploration of the feasibility of microbial composition of biofloc to develop several 'Turn Key' projects would ease the farmers for adoption.
- Development of "one-stop-shop' licensing " to certify the farms as well as the trainers working on this technology
- All Biofloc products has to be recognized with the regulatory bodies and necessary approval for the commercial application
- BFT pilot developers must maintain close contact with regulators and input into the necessary reforms for establishing legislation in these areas –establishing a continual science into policy process is key.

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Role of ICT and Social Media for fisheries extension

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Abstract

Information and Communication Technology (ICT) and social media are transformative tools in fisheries extension, revolutionizing the dissemination of information, capacity building, and overall management of the sector. This document explores their multifaceted roles, including enhancing information dissemination, capacity building, data collection and management, market linkages, community building, advocacy, and disaster management. ICT and social media platforms have emerged as powerful tools for facilitating communication, knowledge sharing, and networking among fisherfolk, extension agents, researchers, policymakers, and other stakeholders. By leveraging ICT tools such as mobile apps, websites, and online forums, fisheries extension agents can disseminate timely information on weather conditions, market trends, fishing techniques, regulations, and best practices. Social media platforms enable the creation of virtual communities where fisherfolk can exchange experiences, seek advice, and access training materials. Through practical examples and addressing challenges such as digital literacy and infrastructure, this paper underscores the potential of ICT and social media to significantly contribute to the sustainability and prosperity of the fisheries sector.

Keywords: Information and Communication Technology, Social Media, e-Extension, Digital Inclusion

1. Introduction

The fisheries sector plays a crucial role in ensuring global food security, providing livelihoods for millions, and significantly contributing to the global economy (FAO, 2020). Over the years, traditional fisheries extension methods have faced challenges in effectively reaching remote fishing communities, limiting access to timely information and support (Ramachandran & Ganesh Kumar, 2018; World Bank, 2018). However, the advent of Information and Communication Technology

(ICT) and social media has transformed the way fisheries extension services operate, bridging the communication gap and introducing innovative solutions to enhance knowledge dissemination and stakeholder engagement (FAO, 2021; ICAR-CIFE, 2023). ICT tools such as mobile-based advisory services, Geographic Information Systems (GIS), websites, and online forums have enabled extension agents to connect with fishers, providing them with real-time updates on best practices, weather conditions, and market trends (INCOIS, 2023; FAO, 2020; CMFRI, 2020).

These digital platforms have made fisheries extension services more accessible, allowing fishers to receive timely advice, improve productivity, and adopt sustainable fishing practices that contribute to long-term resource conservation (FAO, 2021). Social media platforms, including WhatsApp, Facebook, and YouTube, have emerged as vital tools for knowledge-sharing, networking, and policy awareness in the fisheries sector (Ahmed, Thompson, & Glaser, 2020; Sugathan, 2020). These platforms facilitate real-time communication, enabling fishers to interact with experts, seek guidance, and share their experiences with peers (FAO, 2021; Kumar & Radhakrishnan, 2021). The ability to create virtual communities on social media has empowered fisherfolk to access training materials, stay updated on regulatory policies, and exchange insights on best fishing practices (FAO, 2021; Aquatic Commons, 2023). Additionally, social media has enhanced market access by connecting fishers with buyers and suppliers, reducing the dependence on intermediaries and ensuring better financial returns (eFishery, 2022; World Bank, 2022). By fostering interactive learning and participatory extension approaches, social media helps strengthen community engagement, ultimately leading to improved decision-making and resource management (Ahmed et al., 2020). However, while the benefits of social media in fisheries extension are undeniable, challenges such as misinformation, digital literacy gaps, and connectivity issues must be addressed to optimize its full potential (FAO, 2019; OECD, 2021; National Digital Communications Policy, 2018).

The integration of ICT and social media into fisheries extension has opened new avenues for empowering fishers with scientific knowledge, market intelligence, and climate resilience strategies. These digital innovations not only enhance the efficiency of extension services but also contribute to the overall sustainability of fisheries management (FAO, 2021; World Bank, 2020). As technology continues to evolve, investing in capacity-building initiatives, improving digital infrastructure, and addressing security concerns will be crucial in maximizing the impact of these tools (USAID, 2021; FAO, 2022). The future of fisheries extension lies in leveraging digital solutions to create an inclusive, knowledge- driven ecosystem that supports the long-term growth and resilience of the sector (FAO, 2023; ICAR-CIFE, 2022). This paper aims to explore the transformative role of ICT and social media in fisheries extension, analyzing their opportunities, challenges, and broader implications for sustainable fisheries development.

1. Enhancing Information Dissemination

Information and Communication Technology (ICT) enables the rapid and extensive dissemination of vital information, such as updates on weather conditions, market prices, and best practices in fishing and aquaculture (FAO, 2020; World Bank, 2020). ICT and social media have transformed the landscape of fisheries extension services, particularly in enhancing the dissemination of relevant and timely information to stakeholders across the value chain (Ahmed et al., 2020; FAO, 2021). Traditional extension methods—though effective—often face limitations in coverage, speed, and accessibility (Ramachandran & Ganesh Kumar, 2018; ICAR-CIFE, 2022). The integration of ICT and social media tools offers scalable, cost-effective, and interactive platforms for engaging fishers, farmers, and other stakeholders in real time (FAO, 2021; Kumar & Radhakrishnan, 2021).

a) Timely Dissemination of Technical Knowledge

ICT platforms provide real-time information essential for decision-making in fisheries operations. Mobile applications and SMS services broadcast weather alerts, ensuring the safety of fishers (INCOIS, 2023; Ministry of Earth Sciences, 2021).

ICT tools such as mobile apps, SMS services, interactive voice response systems (IVRS), and web portals facilitate the real-time sharing of scientific knowledge and best practices related to aquaculture, marine fisheries, disease management, and environmental monitoring (FAO, 2020; ICAR-CIFE, 2023). For example, mobile-based advisory services help fish farmers receive customized information on water quality management, feed practices, and health protocols, which are critical for improving productivity and reducing losses (eFishery, 2023; FAO, 2020).

b) Wider Outreach through Social Media Platforms

Social media platforms like Facebook, WhatsApp, YouTube, and X (formerly Twitter) allow extension personnel and institutions to reach a large audience within seconds (Ahmed et al., 2020; Sugathan, 2020). Video tutorials, live sessions, and infographics in regional languages make complex information easy to understand and implement (FAO, 2021). For instance, YouTube videos on fish breeding or disease control methods can visually guide farmers, even in remote areas (Kumar & Radhakrishnan, 2021).

c) Participatory and Feedback-Oriented Communication

Unlike traditional one-way communication methods, ICT and social media promote interactive engagement. Fishers can ask questions, share experiences, and provide feedback directly to extension experts or peer groups, creating a collaborative learning environment (FAO, 2021; World Bank, 2022). WhatsApp groups or Telegram channels formed by fisheries departments or cooperatives often serve as support communities for daily troubleshooting and updates (GIZ, 2023; ICAR-CIFE, 2021).

d) Real-time Alerts and Market Information

ICT platforms also enable the dissemination of alerts related to weather forecasts, fishing bans, disease outbreaks, and market prices (INCOIS, 2023; FAO, 2021). Apps like mKRISHI® Fisheries and Fisher Friend Mobile Application (FFMA) provide market intelligence and safety alerts, helping fishers make informed decisions regarding harvesting and trading (CMFRI, 2020; ICAR-CIFE, 2022).

e) Empowerment and Inclusivity

ICT promotes inclusivity by bridging the information gap among gender groups, small-scale farmers, and tribal communities (FAO, 2020; World Bank, 2020). Tailored content in vernacular languages ensures accessibility and enhances the decision-making capacity of diverse user groups, thereby supporting sustainable livelihood development (FAO, 2021; ICAR-CIFE, 2023).

f) Accessibility

ICT ensures that remote and underserved communities can access important information through internet-based platforms, radio broadcasts, and mobile networks, bridging the information gap (National Digital Communications Policy, 2018; NDMA, 2021; FAO, 2022).

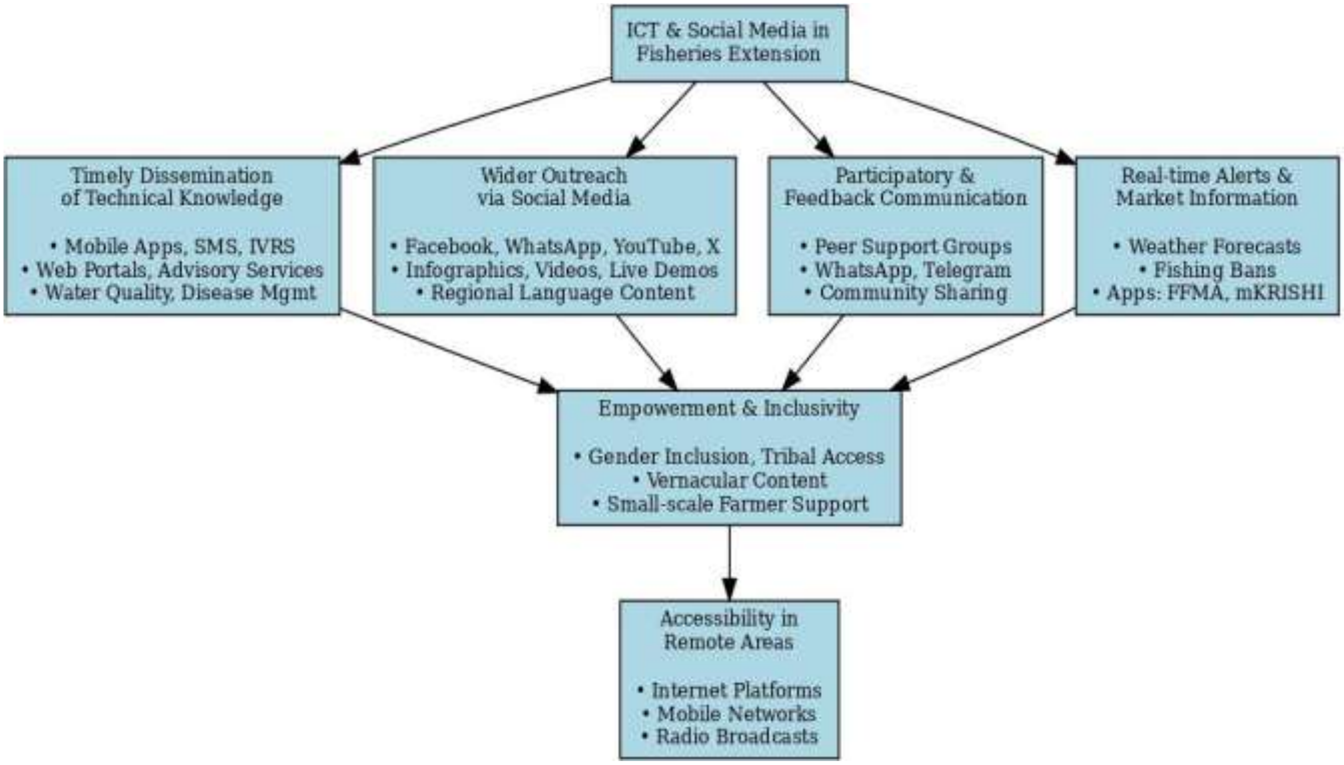

Fig.1: ICT & Social Media in Fisheries Extension

2. Capacity Building and Education

Information and Communication Technology (ICT) and social media have transformed the fisheries sector by enhancing communication, knowledge dissemination, training, and stakeholder engagement (FAO, 2021; Kumar & Radhakrishnan, 2021). These digital tools bridge the gap between research, policy, and practice by enabling real-time communication, access to updated information, and interactive platforms for capacity building (Ahmed et al., 2020; World Bank, 2020). They play a pivotal role in fisheries extension by promoting sustainable practices, increasing productivity, and ensuring inclusive growth. Education and training are fundamental to equipping fishers with the skills and knowledge necessary for adopting modern and sustainable fisheries practices (ICAR-CIFE, 2022).

ICT-based tools help overcome geographical barriers by delivering educational content in local languages through digital platforms and internet services (FAO, 2020; Sugathan, 2020). Extension workers and institutions can use mobile apps, SMS alerts, and voice-based services to provide timely information on weather forecasts, disease outbreaks, seed availability, and market trends (INCOIS, 2023; eFishery, 2023). Moreover, video tutorials and interactive media foster practical learning and ensure better retention of information among fishers with varying literacy levels (FAO, 2021; ICAR-CIFE, 2023).

a) Online Training Programs

ICT enables the organization of online training programs such as webinars, Massive Open Online Courses (MOOCs), and e-learning modules (ICAR-CIFE, 2021; FAO, 2021). These platforms ensure widespread dissemination of knowledge on key topics like sustainable aquaculture, pond management, climate-smart practices, fish disease control, and nutrition management (World Bank, 2022). Organizations like ICAR-CIFE, NFDB, and other national and international agencies regularly conduct online training that includes assessments and certification, which enhances the credibility and career prospects of fish farmers and extension workers (ICAR-CIFE, 2022; GIZ, 2023). Live sessions also allow interactive participation, where fishers can directly ask questions to experts. Recorded sessions are archived for later access, allowing users to learn at their convenience (Kumar & Radhakrishnan, 2021).

b) Digital Libraries

Digital libraries serve as repositories of vast and varied information essential for continuous professional development. They provide open access to research journals, policy briefs, technical manuals, project reports, and instructional videos (FAO, 2020; ICAR-CIFE, 2023). Resources such as the Indian Fisheries Knowledge Repository and the Aquatic Commons offer valuable literature that supports evidence-based decision-making in fisheries (FAO, 2022). Mobile-friendly platforms and offline- access features further expand their utility among rural and remote users (National Digital Communications Policy, 2018). In addition, digital platforms enable collaborative research and peer learning through discussion forums and knowledge-sharing networks among fishers, researchers, and policymakers (Ahmed et al., 2020).

c) Role of Social Media

Social media platforms such as Facebook, WhatsApp, YouTube, and Telegram have emerged as powerful tools for fisheries extension (Sugathan, 2020; Kumar & Radhakrishnan, 2021). They provide a space for instant communication, community engagement, success story sharing, and dissemination of alerts and advisories (FAO, 2021; World Bank, 2022). Fisheries departments, institutions, and NGOs are using these platforms to form online communities where fishers can ask questions, receive expert guidance, and exchange best practices (GIZ, 2023). Video-sharing platforms especially help demonstrate practical techniques like fish breeding, pond preparation, feed formulation, and disease diagnosis (ICAR-CIFE, 2022). Additionally, social media analytics help stakeholders track outreach and engagement, ensuring targeted delivery of extension messages and improving program effectiveness (FAO, 2022).

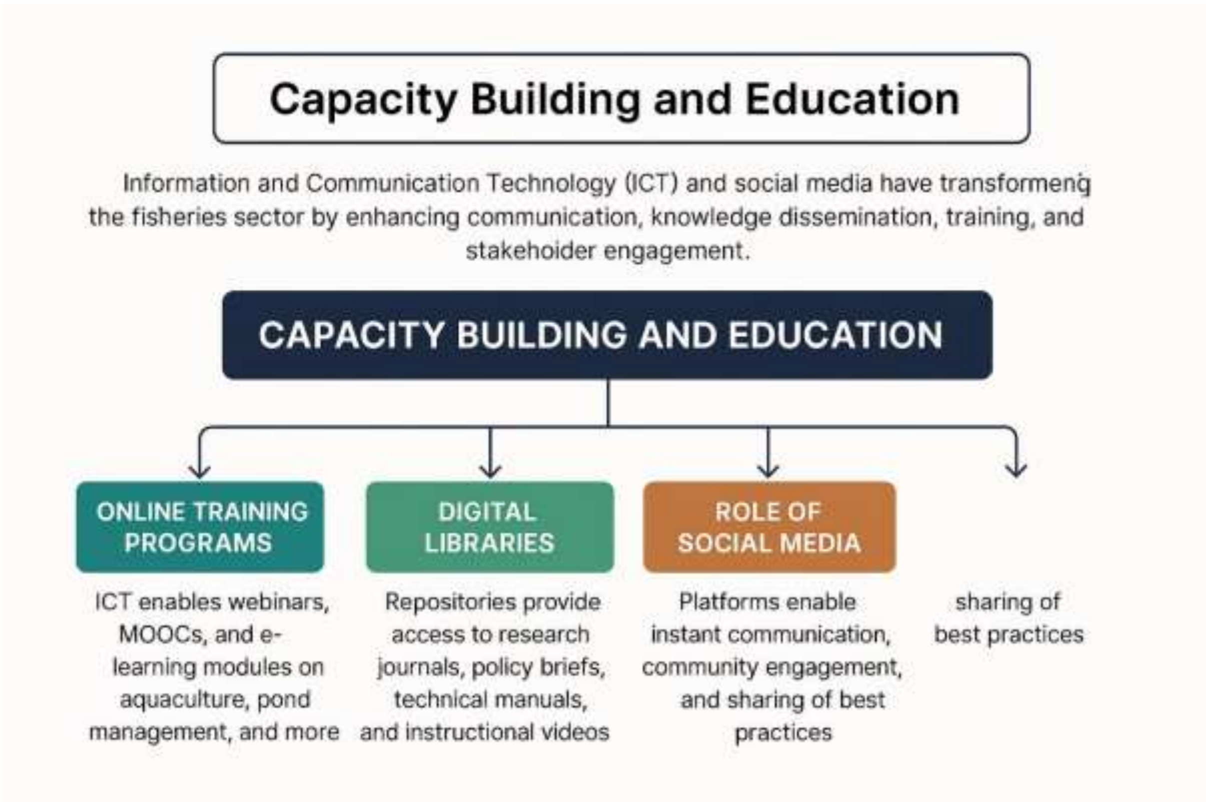

Fig.2: Capacity Building and Education

3. Data Collection and Management

Effective fisheries management heavily relies on accurate, timely, and comprehensive data. Information and Communication Technology (ICT) tools have significantly enhanced the ability of fisheries departments, researchers, and policymakers to gather, store, analyze, and disseminate crucial data (FAO, 2020; World Bank, 2018). These tools not only streamline traditional data collection methods but also introduce innovative approaches that contribute to sustainable fisheries and aquaculture development (OECD, 2021; ICAR-CIFE, 2023).

a) Real-time Data Collection

ICT-enabled tools such as Global Positioning System (GPS), Remote Sensing, Automatic Identification Systems (AIS), Internet of Things (IoT) sensors, and satellite imaging offer real-time insights into various aquatic parameters (INCOIS, 2023; Ministry of Earth Sciences, 2021). These include:

• Fish stock abundance and movement patterns.

• Water quality indicators such as temperature, dissolved oxygen, turbidity, pH, and salinity.

• Climatic and oceanographic conditions like wave height, wind speed, and ocean currents.

These data help in tracking environmental changes and predicting potential threats like harmful algal blooms, disease outbreaks, or illegal fishing activities (FAO, 2020; World Bank, 2020). Additionally, mobile-based applications allow fishers to upload catch data instantly, improving data reliability and aiding in the creation of digital logbooks (Ahmed et al., 2020; FAO, 2021).

b) Data Analysis

Once collected, data needs to be translated into meaningful insights. ICT tools provide advanced analytical capabilities through software and cloud-based platforms that process large volumes of data (Big Data) quickly and accurately. These systems help:

• Model fish population dynamics for stock assessments.

• Identify fishing trends and seasonal patterns.

• Forecast catch potential using artificial intelligence (AI) and machine learning (ML) algorithms.

• Assess the socio-economic impact of fisheries policies and extension activities.

For example, Decision Support Systems (DSS) help extension officers recommend best practices and optimize resource use. Dashboards and visual analytics also allow for real-time monitoring and adaptive management (World Bank, 2022; ICAR-CIFE, 2023).

c) Benefits of ICT-based Data Management in Fisheries

• Improved traceability and transparency across the fisheries value chain, crucial for exports and certification (FAO, 2021; eFishery Global, 2022).

• Better policy planning through evidence-based decisions.

• Reduced overfishing through quota monitoring (FAO, 2020). .

• Strengthened early warning systems for natural disasters or fish disease outbreaks (NDMA, 2021; INCOIS, 2023).

• Efficient implementation of fisheries regulations and MCS (Monitoring, Control & Surveillance) (World Bank, 2020).

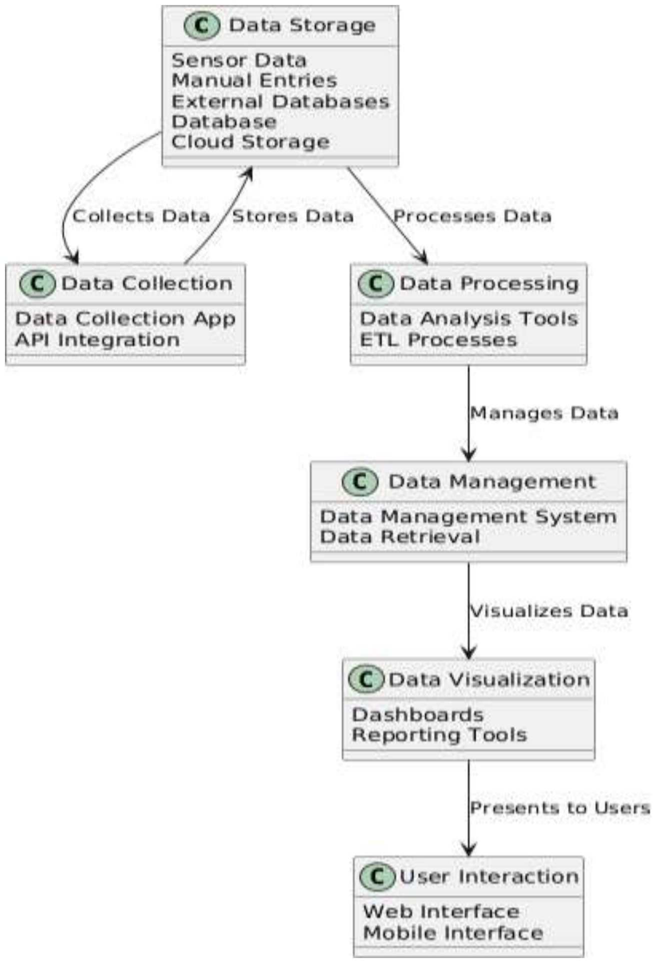

Fig.3: Data Collection and Management

4. Market Linkages

In the fisheries sector, market linkages are vital for enhancing the income of fishers and ensuring fair trade. Information and Communication Technology (ICT) and social media are playing a transformative role in improving market access, transparency, and efficiency. By connecting fishers directly with consumers, wholesalers, and retailers, ICT tools reduce the role of middlemen, ensure better price realization, and promote informed decision-making (FAO, 2021; World Bank, 2020).

a) Online Marketplaces

Several digital platforms have emerged globally and nationally to facilitate direct trading and reduce transaction costs. These platforms act as virtual markets where fishers can:

• List their products with quantity, species, and expected price.

• Connect with bulk buyers, retailers, and consumers in real-time.

• Track orders, delivery schedules, and payment status digitally (USAID, 2018; ICAR-CIFE, 2023).

• mFish (a public-private initiative supported by USAID and telecom companies) helps small-scale fishers access market demand data, price trends, and buyer information through mobile phones (USAID, 2018).

• eFishery (Indonesia) not only provides smart feeding solutions but also links fish farmers to B2B buyers, financial services, and feed suppliers via its digital platform (eFishery Global, 2022).

• In India, apps like AquaKart, FishBazaar, and e-Matsya offer end-to-end solutions from pond to market (Meena et al., 2021).

These platforms create a digital ecosystem where producers, processors, and marketers collaborate seamlessly.

b) Price Information

Price transparency is key to empowering fishers. ICT enables fishers to receive daily or real- time updates on market prices through:

• Mobile apps, such as mKRISHI®, IFFCO Kisan, and Fish Market Watch.

• SMS services delivered in local languages.

• Community radio and IVRS (Interactive Voice Response Systems) for areas with limited smartphone usage (FAO, 2020; ICAR-CIFE, 2023).

These services:

• Help fishers identify high-demand locations and species.

• Allow harvest planning based on expected returns.

• Prevent exploitation by middlemen or local buyers.

In some cases, market intelligence tools integrate weather forecasts, fuel costs, and logistics data, enabling fishers to calculate cost–benefit ratios and plan operations more effectively (Ramachandran & Ganesh Kumar, 2018).

c) Benefits of ICT-based Market Linkages in Fisheries:

• Fair pricing and better income for fishers.

• Reduced exploitation by intermediaries.

• Increased transparency in trade practices.

• Improved logistics and planning.

• Greater inclusivity, particularly for women and youth, by enabling participation through mobile and web-based access to market information (FAO, 2021; Ahmed et al., 2020).

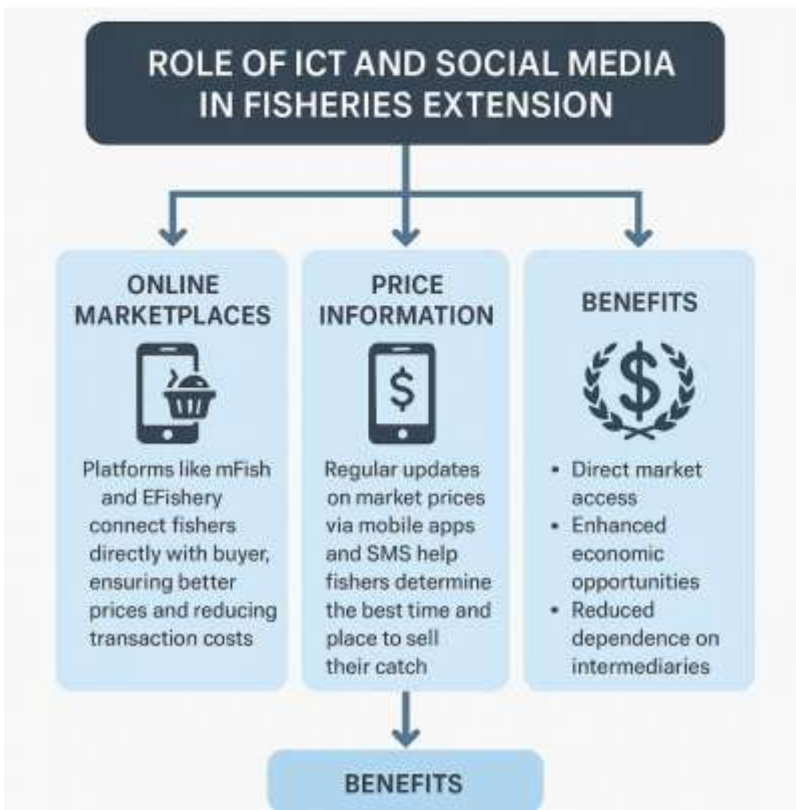

Fig. 4: Role of ICT and Social Media in Fisheries Extension

5. Community Building and Networking

Community building and networking are essential for the exchange of knowledge, support, and resources among fishers, researchers, and aquaculture professionals. ICT and social media have transformed how fishers interact, providing them with platforms to share experiences, discuss challenges, and collaborate with experts worldwide (FAO, 2020; Ahmed et al., 2020).. These tools facilitate both informal peer- to-peer learning and professional networking, strengthening the fisheries industry.

a) Social Media Groups

Social media platforms such as Facebook, WhatsApp, Telegram, and Twitter serve as virtual spaces where fishers can create or join groups to share knowledge, receive expert guidance, and stay updated on industry developments. These platforms enable real-time discussions on:

• Share real-time experiences and best practices in aquaculture and fisheries.

• Seek and offer guidance on disease prevention, pond and gear management.

• Stay informed on government policies, subsidies, and training programs.

• Monitor market price trends, weather forecasts, and fishing ban notifications.

These interactive forums enable decentralized communication and empower grassroots participation. Extension agencies and NGOs increasingly use these platforms to deliver training, issue alerts, and collect feedback directly from the community (ICAR-CIFE, 2023; Meena et al., 2021).

Example:

• The FAO Fisheries and Aquaculture group on Facebook shares real-time insights on sustainable practices.

• WhatsApp groups in coastal regions have been used to provide instant alerts on fishing bans, weather changes, and regulatory updates (Ramachandran & Ganesh Kumar, 2018).

b) Professional Networks

Professional networking platforms such as LinkedIn, ResearchGate, and Aquaculture- specific forums help fishers and aquaculture professionals establish meaningful connections with experts, policymakers, and industry leaders. These platforms facilitate:

• Professional visibility and employment opportunities in the blue economy.

• Collaboration on interdisciplinary research, policy design, and innovation.

• Dissemination of peer-reviewed articles, white papers, and policy briefs.

• Access to grants and funding opportunities for climate-resilient and inclusive aquaculture initiatives (World Bank, 2020; Ahmed et al., 2020).

Example:

• LinkedIn groups for fisheries and aquaculture professionals allow industry experts to share trends, research findings, and funding opportunities.

• ResearchGate connects fishery scientists and researchers globally, enabling collaboration on studies related to marine ecosystems and sustainable fishing practices.

Fig.5: Community Building and Networking

6. Advocacy and Awareness

Information and Communication Technology (ICT) and social media have emerged as crucial tools for advocacy and awareness in the fisheries sector. These platforms enable stakeholders to amplify voices, spread critical information, and foster informed public discourse on

By leveraging social networks, fishers, NGOs, researchers, and policymakers can promote sustainable practices, raise environmental consciousness, and influence decisions that impact the livelihoods of fishing communities (Ahmed et al., 2020; FAO, 2020).

a) Campaigns

Social media platforms such as Facebook, Twitter, Instagram, and YouTube serve as effective channels for launching digital advocacy campaigns. These campaigns focus on raising awareness about:

• Overfishing

• Marine pollution

• Plastic waste in aquatic ecosystems

• Sustainable harvesting methods

• Climate change and its impact on aquatic biodiversity

Through hashtags, viral videos, and infographics, these campaigns often reach national and global audiences, increasing visibility of issues that otherwise remain localized. Social media enables participatory advocacy by encouraging users to like, share, and comment, thus promoting community-driven activism (Meena et al., 2021).

Example: Campaigns such as #StopOverfishing, #SaveOurSeas, and #BlueEconomyNow have been widely used to engage youth, policymakers, and civil society to support environmentally responsible practices in fisheries (Ramachandran & Ganesh Kumar, 2018).

d) Policy Influence

Social media and ICT tools are also becoming instruments for influencing fisheries policies. Through platforms such as LinkedIn, blogs, WhatsApp groups, and community forums, fishers and stakeholders can:

• Share on-ground realities directly with decision-makers

• Present data-driven stories highlighting the socio-economic and environmental challenges they face

• Mobilize online petitions and signature drives to demand reforms or support

These digital expressions create a bottom-up flow of information, supporting participatory governance and ensuring that community perspectives are reflected in policy decisions (ICAR-CIFE, 2023).

Example: During the COVID-19 pandemic, many fishing cooperatives in South and Southeast Asia used online channels to advocate for inclusion in government relief packages, leading to timely support interventions (World Bank, 2020).

Key Advantages

• Enhances public engagement in fisheries governance

• Drives awareness on sustainability and conservation

• Empowers marginalized voices to participate in advocacy

• Encourages transparent and inclusive policymaking

7. Early Warning Systems and Disaster Management

ICT and social media have revolutionized early warning systems (EWS) and disaster management in the fisheries sector. Timely and accurate dissemination of alerts helps in saving lives, reducing economic losses, and preserving the marine ecosystem. ICT ensures that critical information reaches fishing communities, even in remote coastal regions, thus enhancing their resilience and preparedness (INCOIS, 2021; FAO, 2020).

Weather Alerts

One of the most vital contributions of ICT is the real-time transmission of weather-related information through:

• Mobile applications (e.g., IMD-Mausam, Kisan Suvidha)

• SMS and voice alerts via telecom networks

• Radio and satellite communication

• GIS-enabled dashboards and visualizations

These tools provide fishers with advance warnings about cyclones, high tides, wind speeds, and storm surges, helping them avoid going to sea during dangerous conditions and safeguarding both lives and assets (ICAR-CIFE, 2023).

Example: The Indian National Centre for Ocean Information Services (INCOIS) provides Ocean State Forecasts and Potential Fishing Zone (PFZ) advisories through ICT tools and apps that have significantly reduced loss of life among coastal communities (INCOIS, 2021).

8. Disaster Response

During and after natural calamities (cyclones, floods, tsunamis), ICT and social media platforms become central to:

- Coordinating rescue operations
- Mapping affected areas using drones and satellites
- Crowdsourcing real-time updates from ground-level users
- Directing relief materials and emergency supplies efficiently
- Connecting affected fishers with disaster compensation or insurance schemes

Platforms like Twitter, WhatsApp, and Facebook are being used by authorities and local NGOs to mobilize response teams, locate missing persons, and share helpline numbers in real- time (Meena et al., 2021).

Example: During Cyclone Fani (2019) and Cyclone Yaas (2021), the Odisha and West Bengal fisheries departments used ICT-based tools and WhatsApp broadcast groups to warn thousands of fishers, achieving near-zero casualties in coastal belts (World Bank, 2020).

9. Practical Examples

The practical implementation of ICT and social media tools in fisheries extension demonstrates how technology can transform traditional fisheries into data-driven, sustainable, and profitable sectors. These examples highlight the potential for scaling such tools nationally with support from ministries and stakeholders (FAO, 2020; ICAR-CIFE, 2023).

a) Fishery Management Information System (FMIS)

The FMIS is a centralized digital platform that provides real-time, geo-tagged information

on

- Fishery resources (marine and inland)

• Fishing zones and conservation areas

• Licensing and regulatory compliance

• Catch data, species composition, and seasonal availability

Impact:

• Enhances transparency in fishery governance

• Supports sustainable exploitation of fish stocks

• Helps fisheries officers and policymakers with decision-making based on reliable data (MoFPI, 2022).

Ministry Use Case: FMIS can serve as a central repository for data across all states and UTs, enabling integrated national planning and monitoring.

b) mFish Mobile App

Developed through global public-private partnerships, mFish offers fishers:

• Weather forecasts, potential fishing zones (PFZs)

• Market pricing data and connections to buyers

• Guidelines on sustainable fishing practices and regulatory advisories Impact:

• Reduces risk by offering early warnings and safety protocols

• Improves income by giving access to market trends and direct buyers

• Promotes eco-friendly harvesting and responsible fishing (USAID, 2021)

Ministry Use Case: mFish-type platforms can be replicated at the state level and translated into local languages for maximum penetration among small-scale fishers.

c) eFishery (Indonesia-Origin Model, now adapted in parts of India)

eFishery is an IoT-based smart aquaculture solution that uses automated feeding devices to:

• Optimize feeding based on fish behavior and pond conditions

• Reduce overfeeding and feed costs (which account for up to 70% of input costs)

• Provide mobile-based monitoring and farm analytics Impact:

• Increases production efficiency and reduces wastage

• Enables remote monitoring and precision aquaculture

• Encourages youth involvement through tech-based entrepreneurship (World Bank, 2020)

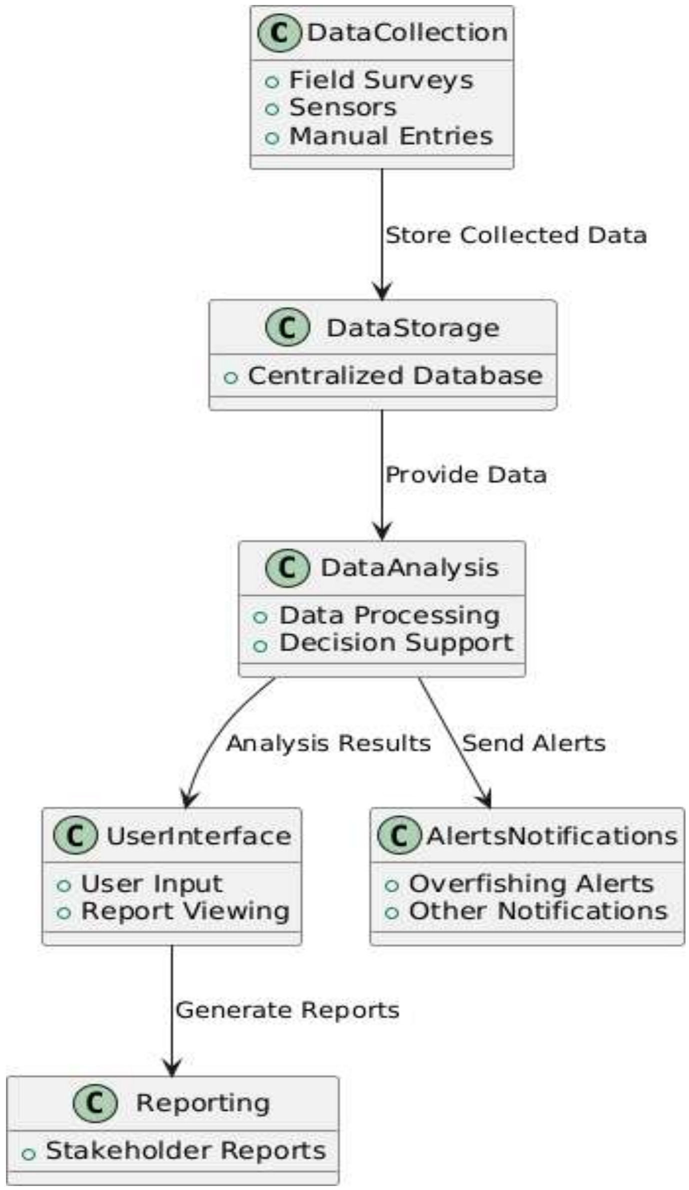

Fig.5: System Architecture Diagram

10. Challenges and Considerations

Despite the transformative potential of ICT and social media in fisheries extension, several barriers must be addressed to ensure equitable and effective adoption. Recognizing and resolving these challenges is key for policymakers and implementing agencies to achieve long- term success and digital inclusiveness in the sector (FAO, 2020; ICAR-CIFE, 2023).

a) Digital Literacy

Many fishers, particularly in rural and remote coastal/inland regions, lack the basic skills to navigate mobile applications, digital tools, or social media platforms.

Impact:

• Limits the ability to benefit from weather alerts, market information, and digital advisory services

• Leads to underutilization of government-supported ICT platforms (MoFPI, 2022)

Way Forward:

• Integrate digital literacy modules in fisheries training programs under PMMSY and other schemes

• Involve NGOs, SHGs, and Krishi Vigyan Kendras (KVKs) in local language-based training delivery

• Provide interactive voice response systems (IVRS) for illiterate fishers (USAID, 2021)

b) Infrastructure Gaps

Lack of reliable internet connectivity, electricity, and mobile device accessibility in coastal and inland fishing villages hampers ICT adoption.

Impact:

• Fishers face delays or total inaccessibility to real-time weather, disaster alerts, and market data

• Exacerbates rural-urban and gender digital divides (World Bank, 2020)

Way Forward:

• Improve rural digital infrastructure under the BharatNet and Digital India programs

• Promote low-cost smart devices and offline-compatible applications

• Establish Digital Fishery Resource Centres in rural clusters (FAO, 2020)

c) Content Relevance and Localization

Generic or non-localized content limits the practical usefulness of ICT interventions in fisheries.

Impact:

• Fishers receive irrelevant or difficult-to-interpret technical information

• Risk of misinformation or lack of trust in digital sources

Way Forward:

• Co-develop content with input from local fishers, scientists, and extension workers

• Ensure multilingual content, visual infographics, and context-specific advisories

• Incorporate feedback loops to assess the effectiveness of information delivered (ICAR-CIFE, 2023)

11. Conclusion

ICT and social media are revolutionizing fisheries extension by improving information dissemination, capacity building, data management, market access, community building, advocacy, and disaster management. To fully realize their potential, efforts must focus on addressing challenges such as digital literacy and infrastructure. With continued advancements and strategic implementation, ICT and social media can significantly contribute to the sustainability and prosperity of the fisheries sector. By leveraging the power of these technologies, fisheries extension services can become more efficient, inclusive, and impactful, ensuring the long-term viability of this crucial industry.

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AQUAENTREPRENEURSHIP FOR THE SUSTAINABLE FISHERIES SECTOR GROWTH

This is e-book is will be highly useful to Fisheries Professionals across the country and Extension workers who are working at the grassroot level. This book covered the topics like scope and opportunities and in fisheries sector, Biofloc, Women Agripreneurs in AC&ABC, Application of ICT in fisheries sector. In addition, the authors address the key information in FPOs regulatory principles, managemental skills.

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