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Aquaculture practices in rural ponds of southern West Bengal, India

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Abstract
Aquaculture in rural ponds of southern West Bengal, India had been examined to understand its practices, challenges, and potential for sustainable development. The study had synthesized findings from multiple peer-reviewed articles, government reports, and case studies focusing on pond-based aquaculture systems. Traditional carp polyculture, semi-intensive and intensive practices, integrated rice–fish and duck–fish farming, and sewage-fed aquaculture in peri-urban areas had been identified as the dominant systems. Rural pond aquaculture had been shown to play a vital role in livelihood generation, nutritional security, and income diversification for smallholder households. However, several constraints had been documented. These included poor seed and feed quality, frequent fish diseases, environmental contamination, and climate-induced risks such as cyclones and saline intrusion. Heavy metal accumulation in peri-urban systems such as the East Kolkata Wetlands had raised food safety concerns, while socio-economic barriers such as limited access to credit and gender disparities had restricted wider adoption of improved practices. Despite these constraints, innovative approaches such as the use of chironomid larvae as supplementary feed and the adoption of Better Management Practices (BMPs) had demonstrated promising results in improving fish health and productivity. The study had concluded that rural pond aquaculture in southern West Bengal had provided significant socio-economic benefits but had remained vulnerable to systemic, environmental, and institutional barriers. Strengthening aquaculture would require certified seed supply, improved feed practices, farmer training, gender-inclusive participation, and climate-resilient strategies. Sustainable development of pond aquaculture in the region had therefore depended on integrating traditional practices with modern innovations and institutional support.

Keywords: Aquaculture; rural ponds; southern west bengal; carp polyculture; integrated farming; livelihoods; fish health; climate change adaptation; better management practices (bmps); sustainable aquaculture

Introduction

Aquaculture had played a central role in food production and rural livelihoods in India. West Bengal, endowed with abundant ponds and wetlands, had emerged as one of the leading states in inland fish production (Abraham, Sil, & Vineetha, 2011). Small ponds, both natural and man-made, had served as the foundation of rural aquaculture practices, particularly in the southern districts such as Purulia, East Medinipur, West Medinipur, and South 24 Parganas. Traditional fish culture in these ponds had been dominated by Indian Major Carps (IMCs) such as *Catla catla, Labeo rohita*, and *Cirrhinus mrigala*, with supplementary species like silver carp and grass carp (Patra, Dubey, Roy, & Biswas, 2019). Aquaculture had been recognized as one of the fastest-growing sectors in food production, contributing significantly to global nutrition and rural livelihoods (FAO, 2020) [4]. In India, the expansion of freshwater aquaculture had been remarkable, with carp polyculture in ponds and tanks accounting for the majority of inland fish production (Ayyappan & Jena, 2003) [2]. Among the Indian states, West Bengal had been acknowledged as a pioneer, contributing over 30% of India's total fish seed production and maintaining a dominant role in freshwater aquaculture (Paul, 2022) [7].

Southern West Bengal, comprising districts such as South 24 Parganas, East Medinipur, West Medinipur, Howrah, and Hooghly, had been uniquely positioned for aquaculture due to its abundance of ponds, favourable climatic conditions, and cultural preference for fish consumption (Hoque *et al*., 2018) [5]. Rural ponds, both perennial and seasonal, had historically been utilized for multipurpose activities, including irrigation, bathing, livestock watering, and fish farming. Over time, these ponds had been transformed into productive aquaculture units, forming the backbone of rural livelihood systems (Sarkar *et al*., 2023b) [9, 10, 11].

The cultural significance of fish in Bengal had shaped aquaculture practices beyond economic terms. With more than 80% of the state's population consuming fish, rural ponds had provided a steady source of protein, thereby addressing nutritional security alongside income generation (Paul, 2022) [7]. Traditional knowledge and community-based management had shaped early aquaculture systems, particularly polyculture of Indian major carps (Rohu, Catla, Mrigal), often supplemented with exotic species such as silver carp and grass carp (Ayyappan & Jena, 2003) [2]. In peri-urban areas such as the East Kolkata Wetlands (EKW), rural ponds had been connected to sewage-fed aquaculture systems, which had sustained livelihoods while recycling urban wastewater, creating one of the world's most unique aquaculture models (Sarkar *et al*., 2023a) [9, 10, 11].

Despite these advantages, aquaculture practices in rural ponds of southern West Bengal had been constrained by technical, socio-economic, and environmental challenges. Poor seed quality, inadequate feed, and limited scientific management had restricted productivity (Sarkar *et al*., 2023c) [9, 10, 11]. Frequent disease outbreaks, including ulcers, dropsy, and epizootic ulcerative syndrome (EUS), had reduced yields by nearly 26% in carp culture systems (Sahoo *et al*., 2020) [8]. Moreover, rural ponds in southern West Bengal had been highly exposed to climate variability, with cyclones, salinity intrusion, and erratic rainfall altering pond ecology and fish survival (Sarkar *et al*., 2024) [9, 10, 11]. Environmental issues such as heavy metal accumulation in sediments and fish tissues in sewage-fed systems like the

EKW had further posed risks to both aquaculture sustainability and public health (Sarkar *et al*., 2023a) [9, 10, 11]. The integration of traditional practices with scientific innovations had been increasingly emphasized as a solution. Indigenous methods such as the application of neem leaves, turmeric, and bamboo beating for oxygenation had been combined with Better Management Practices (BMPs), including liming, seed treatment, and pond drying (Hoque *et al*., 2018) [5]. At the same time, experimental approaches such as the use of chironomid larvae as a supplementary feed had demonstrated nutritional benefits for cultured species (Mandal *et al*., 2022) [6].

In this context, rural pond aquaculture in southern West Bengal had reflected both opportunities and vulnerabilities. On one hand, it had provided livelihood security, nutrition, and employment to smallholder households; on the other, it had faced production losses, climate threats, and ecological risks. The present study had therefore aimed to synthesize existing evidence on aquaculture practices in the rural ponds of southern West Bengal, highlighting systems in use, socio-economic contributions, constraints, and emerging adaptive practices. This integrated analysis had been intended to inform strategies for achieving sustainable, climate-resilient, and health-conscious aquaculture in the region.

Study Area

The study area had included southern districts of West Bengal, notably Purulia, East Medinipur, West Medinipur, North 24 Parganas, and South 24 Parganas. These districts had been characterized by diverse physiographic and climatic conditions. For instance, Purulia had represented a drought-prone, undulating plateau with seasonal water scarcity, where ponds had often dried within 6–9 months (Patra *et al*., 2019). In contrast, coastal districts such as South 24 Parganas and East Medinipur had included brackish water environments where ponds had been integrated with saline farming systems (Babu & Mishra, 2001).

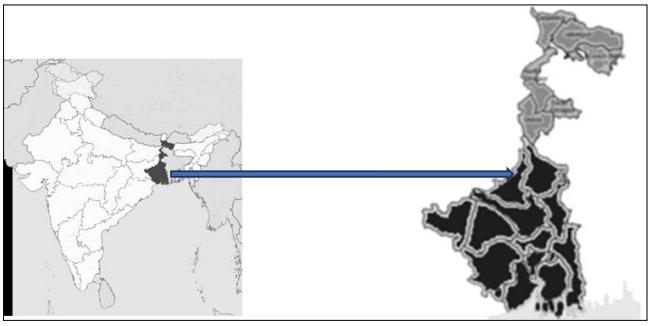

Fig 1: Southern West Bengal, India

Ponds in the region had varied in size from small homestead *pukurs* (<0.2 ha) to large multi-use water bodies (>1 ha). Both community-owned and privately-owned ponds had existed, with government programs like MGNREGA contributing to excavation and renovation. Climatic conditions had been favourable for aquaculture, with high rainfall in the monsoon season but considerable variability across districts, influencing water retention in ponds.

Aquaculture Practices in Rural Ponds

Aquaculture systems in rural ponds of southern West Bengal had evolved from traditional low-input carp culture to more diversified systems, including semi-intensive practices, integrated aquaculture, and sewage-fed fisheries. These systems had reflected a combination of indigenous knowledge, socio-economic constraints, and adaptive innovations shaped by environmental conditions.

1. Traditional Carp Polyculture

Carp polyculture had been the dominant system in rural ponds. Farmers had stocked Indian major carps (*Catla catla*, *Labeo rohita*, *Cirrhinus mrigala*) in mixed ratios, often supplemented with exotic species such as silver carp, grass carp, and common carp (Ayyappan & Jena, 2003 [2]; Sarkar *et al*., 2023c) [9, 10, 11]. The system had been preferred because it maximized resource utilization, with surface feeders (Catla), column feeders (Rohu), and bottom feeders (Mrigal) occupying different pond niches.

Traditional farmers had relied on organic inputs such as cow dung, mustard oil cake, and rice bran, avoiding costly commercial feeds. This system had been highly suitable for small and marginal farmers due to its low capital requirement and adaptability (Paul, 2022) [7]. However, seed quality and poor feeding practices had constrained yields.

2. Semi-Intensive and Intensive Systems

With increasing demand for fish, many farmers had shifted toward semi-intensive aquaculture, characterized by higher stocking densities, supplemental feeding, and periodic fertilization. Some large farmers and entrepreneurs had even adopted intensive culture systems, using commercial feed and aeration devices (Hoque *et al*., 2018) [5].

While these systems had increased productivity, they had also introduced challenges, including high input costs, water quality deterioration, and disease outbreaks. Intensive systems had particularly been vulnerable to fin rot, ulcers, and EUS due to higher fish densities (Sahoo *et al*., 2020) [8].

3. Sewage-Fed Aquaculture (East Kolkata Wetlands)

The East Kolkata Wetlands (EKW) had represented a unique example of rural-urban aquaculture linkage. For decades, untreated sewage from Kolkata had been used to fertilize ponds, supporting large-scale carp culture (Sarkar *et al*., 2023a) [9, 10, 11]. This model had provided low-cost fish production and sustained thousands of livelihoods.

However, studies had revealed heavy metal contamination (Cd, Cr, Pb, Cu) in sediments and fish tissues, with concentrations often exceeding WHO/FAO permissible limits (Sarkar *et al*., 2023a) [9, 10, 11]. While EKW aquaculture had been socially and economically beneficial, it had also posed food safety risks that required careful monitoring.

4. Integrated Aquaculture Systems

Integrated aquaculture practices had been widely observed in rural West Bengal, combining fish culture with agriculture and livestock. Common models included:

- **Rice–fish systems:** Fish stocked in paddy fields during the monsoon, reducing pests and fertilizing crops (Sarkar *et al*., 2024) [12].
- **Duck–fish systems:** Ducks provided natural fertilization through droppings while feeding on aquatic weeds.
- **Vegetable–fish systems:** Vegetables grown on pond dykes provided household food and income while recycling pond nutrients.

These integrated systems had increased resource efficiency, household nutrition, and income diversification, especially for marginal farmers (Hoque *et al*., 2018) [5].

5. Emerging Innovations

Recent experiments had tested alternative feed sources, such as *Chironomus striatipennis* larvae, which had been shown to enhance protein content and fatty acid quality of cultured fish compared to commercial feeds (Mandal *et al*., 2022) [6]. Farmers had also increasingly adopted Better Management Practices (BMPs), including pond drying, liming, seed treatment, and use of improved feed formulations (Sahoo *et al*., 2020) [8]. These practices had been essential for moving toward sustainable pond aquaculture.

Table 1: Aquaculture systems in rural ponds of southern West Bengal

System	Main Features	Advantages	Constraints
Traditional Carp Polyculture	Stocking IMCs (Rohu, Catla, Mrigal) + exotic carps; organic feed (rice bran, oil cake).	Low cost, suited for small farmers.	Poor seed quality, low productivity.
Semi-Intensive Systems	Higher stocking density, supplemental feed, fertilization.	Higher yields, faster growth.	High input costs, disease outbreaks.
Intensive Systems	Commercial feed, aeration, high fish density.	Maximized production per unit area.	Expensive, prone to fish health issues.
Sewage-Fed Aquaculture (EKW)	Use of untreated wastewater in ponds; carp polyculture.	Low-cost production, livelihood support.	Heavy metal contamination, food safety risk.
Integrated Systems	Fish + rice/duck/vegetables in combined systems.	Nutrient recycling, income diversification.	Labour-intensive, management complexity.
Innovations (Feeds/BMPs)	Chironomid larvae feed; liming, pond drying, net disinfection.	Improved fish growth, better health outcomes.	Limited adoption, training required.

Socio-Economic Dimensions of Pond Aquaculture

Aquaculture in rural ponds of southern West Bengal had extended beyond food production, playing a crucial role in livelihood generation, income diversification, and nutritional security for rural households. Its socio-economic impact had been particularly visible among small and marginal farmers, who formed the majority of fish producers in the region (Paul, 2022) [7].

1. Livelihood and Employment

Pond aquaculture had generated both direct employment (in fish farming, seed production, harvesting, and marketing) and indirect employment (in net making, feed supply, and transport services). Sarkar *et al*. (2023b) [9, 10, 11] reported that rural aquaculture households had enjoyed higher income stability compared to non-aquaculture households, with small ponds being used as supplementary income sources by many farming families. Women and youth had increasingly been engaged in feeding, harvesting, and post-harvest activities, although their access to credit and training opportunities had remained limited.

In rural areas such as South 24 Parganas and East Medinipur, aquaculture had acted as a buffer against agrarian distress, providing year-round livelihood opportunities, unlike seasonal agriculture (Sarkar *et al*., 2023c) [9, 10, 11].

2. Income Contributions

Fish farming in rural ponds had contributed a significant share of household income. Households practicing aquaculture had reported 20–30% higher annual incomes compared to households without aquaculture (Sarkar *et al*., 2023b) [9, 10, 11]. Seasonal harvesting, particularly during festivals, marriage seasons, and local markets, had enabled farmers to secure premium prices for species like Rohu and Catla (Paul, 2022) [7].

However, profits had varied widely depending on pond size, input use, and management practices. Farmers dependent on low-quality seed and feed had often faced production losses, reducing net profits (Sahoo *et al*., 2020) [8].

3. Nutrition and Food Security

Aquaculture had significantly contributed to food and nutritional security in rural Bengal. Fish, often termed the "staple protein of Bengal," had provided essential micronutrients such as omega-3 fatty acids, calcium, and vitamins. Households with access to aquaculture ponds had reported greater fish consumption per capita compared to households without ponds (Sarkar *et al*., 2023b) [9, 10, 11].

However, environmental concerns such as heavy metal contamination in sewage-fed aquaculture had raised questions about long-term food safety, especially for urban consumers of East Kolkata Wetland fish (Sarkar *et al*., 2023a) [9, 10, 11].

4. Gender and Social Inclusion

Women had participated actively in aquaculture-related tasks such as feeding, netting, pond cleaning, and dyke vegetable farming, yet they often lacked decision-making power and ownership rights over ponds (Hoque *et al*., 2018) [5]. Empowering women through self-help groups (SHGs) and training programs had been identified as a potential pathway to expand aquaculture's socio-economic impact.

Challenges and Constraints in Rural Pond Aquaculture

Although rural ponds in southern West Bengal had supported diverse aquaculture practices, their productivity and sustainability had been hindered by a range of technical, environmental, and socio-economic constraints. These challenges had limited the potential of aquaculture to meet rising fish demand in the state.

1. Seed and Feed Quality Issues

Poor availability of quality fish seed had been repeatedly identified as a major barrier. Many hatcheries had supplied low-quality or diseased seed, resulting in poor survival rates (Sarkar *et al*., 2023c) [9, 10, 11]. Farmers had also struggled with high feed costs, as commercial fish feeds were often unaffordable for small-scale farmers. As a result, many households had continued to rely on traditional feeds such as rice bran and oil cakes, which had not always supported optimal growth (Paul, 2022) [7].

2. Disease Outbreaks and Fish Health

Fish diseases had posed serious risks to rural pond aquaculture. Sahoo *et al*. (2020) [8] found that the occurrence of diseases such as epizootic ulcerative syndrome (EUS), fin rot, and dropsy had led to production losses of nearly 26% across surveyed farms.

Key factors increasing disease risks included:

- High stocking densities in semi-intensive systems.
- Poor pond hygiene and black pond bottoms.
- Use of untreated sewage in peri-urban ponds.
- Mortality of fish seed during transport.

Farmers had often applied traditional remedies such as turmeric, neem, and bamboo beating for oxygenation, but these had not always been effective against viral or bacterial infections (Hoque *et al*., 2018) [5].

3. Climate Change and Environmental Vulnerability

Southern West Bengal, particularly South 24 Parganas and East Medinipur, had been highly vulnerable to climate-induced risks such as cyclones, floods, saline water intrusion, and erratic rainfall. Sarkar *et al*. (2024) [12] reported that climate variability had reduced pond water retention, disrupted fish breeding cycles, and increased mortality during extreme events. Farmers had responded with adaptive measures such as pond lining, seasonal water storage, and mixed-species culture, but many lacked resources to fully implement these practices.

4. Pollution and Food Safety Concerns

In peri-urban aquaculture systems such as the East Kolkata Wetlands (EKW), the use of untreated sewage had raised significant environmental and public health concerns. Sarkar *et al*. (2023a) [9, 10, 11] showed that fish species cultured in EKW ponds had accumulated heavy metals such as cadmium (Cd), chromium (Cr), lead (Pb), and copper (Cu), in some cases exceeding WHO/FAO safety limits. While EKW aquaculture had provided affordable fish protein to urban and rural consumers, it had also posed long-term health risks if left unmanaged.

5. Institutional and Socio-Economic Constraints

Many smallholder farmers had faced challenges related to:

- Pond ownership disputes among family members.
- Limited access to credit and subsidies, making it difficult to invest in improved practices.
- Lack of training and extension services to adopt better management practices (Sarkar *et al*., 2023c) [9, 10, 11].
- Theft and poaching of fish, which had discouraged investments in aquaculture.

These socio-economic issues had reduced profitability and discouraged expansion, even when technical solutions were available.

Table 2: Key challenges in rural pond aquaculture of southern West Bengal

Challenge	Details	Impact on Aquaculture	Source
Poor seed and feed quality	Low survival of hatchery seed; high commercial feed cost; reliance on traditional feed.	Reduced growth rates, economic losses.	Sarkar *et al*., 2023c; Paul, 2022 [7]
Disease outbreaks	EUS, fin rot, dropsy linked to poor hygiene and high stocking density.	~26% yield loss reported in carp ponds.	Sahoo *et al*., 2020 [8]
Climate variability	Cyclones, floods, saline intrusion, erratic rainfall in South 24 Parganas & East Medinipur.	Reduced pond retention, breeding disruption.	Sarkar *et al*., 2024[12]
Pollution (EKW ponds)	Sewage-fed ponds contaminated with Cd, Pb, Cr, Cu.	Food safety risks, environmental degradation.	Sarkar *et al*., 2023a [9, 10, 11]
Institutional/social barriers	Credit shortage, pond disputes, poor training, and theft.	Low adoption of BMPs, limited expansion.	Sarkar *et al*., 2023c [9, 10, 11]

Input Management

1. Pond Preparation and Water Management

Farmers had practiced pond preparation by deweeding, liming, and manuring. In coastal saline zones, excavation of farm ponds had been encouraged to enable pisciculture along with multi-cropping, increasing cropping intensity and income (Babu & Mishra, 2001). In water-scarce areas like Kharagpur, bentonite-lined ponds had conserved water, supporting irrigation and fish culture simultaneously (Bhandari & Mailapalli, 2023).

2. Seed Procurement

Seed procurement had been a critical issue. While some farmers had purchased fingerlings from hatcheries, others had relied on local markets, where seed quality had often been poor. In Purulia, over 50% of farmers had reported poor seed quality as a major constraint (Patra *et al*., 2019).

3. Feed Practices and Yields

Feed practices had varied across districts. While Purulia farmers had often relied on natural productivity, North 24 Parganas farmers had used supplementary feeds, and East Medinipur had witnessed partial use of commercial pelleted feeds. These differences had reflected in yield variations across districts (Table 2).

Table 2: Stocking Density, Feed Practices, and Yield

District	Stocking Density (per ha)	Feed Practices	Average Yield (kg/ha/year)
Purulia	5,000	Natural productivity, no feed	1,200
North 24 Parganas	15,000	Rice bran + mustard cake (60:40)	4,000
South 24 Parganas	10,000	Mixed traditional and supplementary feeding	2,500
East Medinipur	12,000	Supplementary + partial commercial feed	3,000

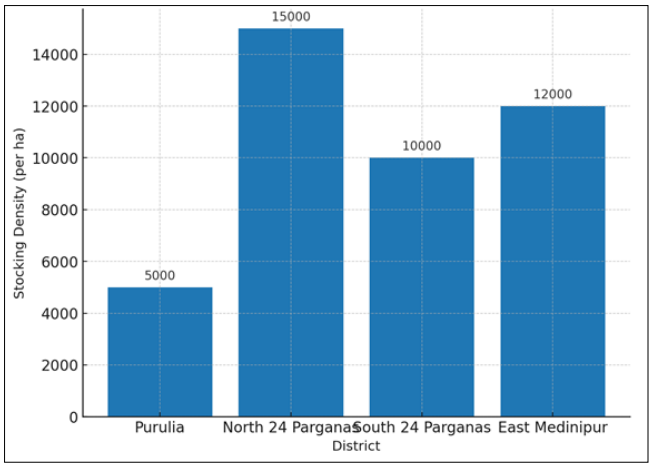

Fig 1: Stocking Density across Districts in Southern West Bengal

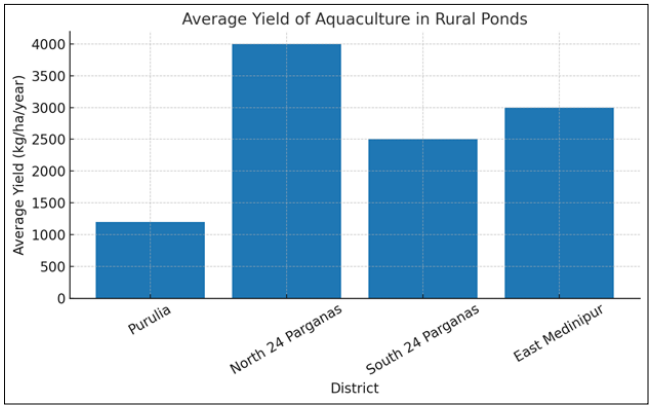

Fig 2: Average Yield of Aquaculture in Rural Ponds

Challenges and Constraints

Aquaculture development had been constrained by several factors. Water scarcity had been the most critical, reported by 78% of farmers in Purulia. High input costs had been reported by 85%, poor seed quality by 53%, lack of technical support by 65%, and theft by 39% (Patra *et al*., 2019). Disease outbreaks had also posed significant risks, though less frequently (25%).

Table 3: Challenges Reported by Farmers

Challenge	Percentage of Farmers Reporting (%)
Water Scarcity	78
High Input Costs	85
Poor Seed Quality	53
Lack of Technical Support	65
Disease Outbreaks	25
Theft/Poaching	39

Opportunities and Innovations

Despite constraints, opportunities had existed for aquaculture development. Adoption of BMPs such as liming, acclimatization of seed, and proper stocking densities had been reported at moderate levels, with potential for wider adoption (Saha *et al*., 2021). Integrated farming systems, such as rice-fish and duck-fish, had offered sustainable options by enhancing nutrient recycling (LEISA India, 2023). Bentonite-lined ponds had demonstrated effective water conservation and productivity in Kharagpur (Bhandari & Mailapalli, 2023).

Institutional innovations, particularly FFPCs, had helped smallholders by pooling resources and accessing inputs collectively. These models had shown potential to address inefficiencies and enhance resilience (Saha *et al*., 2021).

Discussion

The review of aquaculture practices in rural ponds of southern West Bengal had revealed a system characterized by both resilience and vulnerability. On the one hand, aquaculture had provided crucial support for livelihood security, food production, and employment in one of India's most fish-dependent regions. On the other hand, persistent challenges such as disease outbreaks, poor seed quality, environmental contamination, and climate stressors had undermined its sustainability.

Similar to national trends, pond-based aquaculture in West Bengal had been dominated by Indian major carp polyculture supplemented by exotic carps (Ayyappan & Jena, 2003) [2]. This system had allowed resource-efficient production, yet productivity had remained lower than its potential due to management inefficiencies (Sarkar *et al*., 2023c) [9, 10, 11]. Internationally, countries such as Bangladesh and Vietnam had successfully scaled pond aquaculture through adoption of scientific seed quality management and farmer training programs (Belton & Azad, 2012) [3], suggesting that West Bengal could benefit from similar interventions.

Socio-economic findings had indicated that aquaculture households in southern West Bengal had reported higher incomes and nutritional security compared to non-aquaculture households (Sarkar *et al*., 2023b) [9, 10, 11]. This finding aligned with studies from other South Asian contexts, where pond aquaculture had been shown to significantly reduce poverty and improve dietary diversity (Ahmed & Garnett, 2011) [1]. However, gender disparities had remained evident, with women contributing substantially to pond management but lacking access to decision-making and credit (Hoque *et al*., 2018) [5]. Such exclusion had mirrored global aquaculture systems, where women's roles had often been undervalued despite their critical participation in small-scale aquaculture (FAO, 2020) [4].

The environmental and health challenges identified in peri-urban systems such as the East Kolkata Wetlands (EKW) had also reflected a wider global concern. Heavy metal accumulation in EKW aquaculture ponds (Sarkar *et al*., 2023a) [9, 10, 11] had posed food safety risks comparable to issues reported in wastewater-fed aquaculture in parts of China and Southeast Asia (Zhou *et al*., 2019) [13]. These findings underscored the urgent need for regular monitoring, strict waste treatment, and improved biosecurity measures to ensure consumer safety.

Climate variability had emerged as a critical challenge, particularly in South 24 Parganas and East Medinipur, where cyclones, saline intrusion, and erratic rainfall had disrupted pond ecology and fish productivity (Sarkar *et al*., 2024) [12]. These vulnerabilities were consistent with global observations that aquaculture in coastal and deltaic regions had been disproportionately impacted by climate change (IPCC, 2019). Adaptive measures such as mixed-species culture, pond lining, and rice–fish integration had demonstrated some success, but limited financial and institutional support had constrained wider adoption.

Finally, innovations such as the introduction of chironomid larvae as alternative feed (Mandal *et al*., 2022) [6] and promotion of Better Management Practices (BMPs) (Sahoo *et al*., 2020) [8] had highlighted pathways toward sustainable intensification of aquaculture. These findings suggested that aquaculture in rural ponds of southern West Bengal could achieve both higher productivity and environmental sustainability, provided that systemic barriers such as credit access, seed quality, and extension services were effectively addressed.

Conclusion and Recommendations

Aquaculture in rural ponds of southern West Bengal had represented a vital livelihood strategy, contributing to nutrition, income generation, and employment in one of India's most fish-dependent states. Traditional carp polyculture, semi-intensive farming, integrated aquaculture, and sewage-fed systems had demonstrated the diversity of practices in the region. Despite their socio-economic significance, these systems had been constrained by poor seed and feed quality, recurrent fish diseases, environmental pollution, and climate variability.

The review had shown that disease outbreaks alone had reduced carp yields by nearly one-fourth of expected production (Sahoo *et al*., 2020) [8], while environmental contamination in the East Kolkata Wetlands had posed food safety risks (Sarkar *et al*., 2023a). Climate hazards such as cyclones and saline intrusion had further amplified vulnerabilities in districts like South 24 Parganas (Sarkar *et al*., 2024). These findings highlighted that aquaculture in southern West Bengal had required not only technical improvements but also systemic institutional support.

Recommendations for strengthening pond aquaculture included:

Seed and Feed Quality Enhancement: Establishment of certified hatcheries, quality testing centers, and promotion of cost-effective supplementary feeds (e.g., chironomid larvae) (Mandal *et al*., 2022) [6].

Adoption of Better Management Practices (BMPs): Regular pond drying, liming, seed disinfection, and improved net hygiene to reduce disease incidence (Sahoo *et al*., 2020) [8].

Climate-Resilient Strategies: Promotion of rice–fish systems, mixed-species stocking, pond lining, and community-based water storage in vulnerable coastal areas (Sarkar *et al*., 2024) [12].

Women and Youth Empowerment: Training and credit support through self-help groups (SHGs) to enhance inclusivity and expand aquaculture participation (Hoque *et al*., 2018) [5].

Environmental Monitoring and Regulation: Regular surveillance of heavy metals in sewage-fed aquaculture, coupled with stricter waste management in peri-urban ponds (Sarkar *et al*., 2023a) [9, 10, 11].

In conclusion, rural pond aquaculture in southern West Bengal had been a sector of both promise and challenge. It had provided livelihoods and nutrition but had remained highly vulnerable to systemic, environmental, and institutional barriers. A combination of scientific innovation, climate adaptation, and inclusive policy support had been essential to transform pond aquaculture into a sustainable driver of rural development in the region.

References

1. Ahmed N, Garnett ST. Integrated rice–fish farming in Bangladesh: Meeting the challenges of food security. Food Security,2011:3(1):81–92. https://doi.org/10.1007/s12571-010-0095-8
2. Ayyappan S, Jena JK. Sustainable freshwater aquaculture in India. Aquaculture Asia,2003:8(1):14–19.
3. Belton B, Azad A. The characteristics and status of pond aquaculture in Bangladesh. Aquaculture, 2012, 358–359, 196–204. https://doi.org/10.1016/j.aquaculture.2012.07.002
4. FAO The State of World Fisheries and Aquaculture 2020: Sustainability in action. Rome: Food and Agriculture Organization of the United Nations, 2020.
5. Hoque MM, Paul BN, Mandal SC. Managing water quality and fish health in aquaculture: Farmer's traditional practices in West Bengal. MOJ Ecology & Environmental Sciences,2018:3(4):238–244. https://doi.org/10.15406/mojes.2018.03.00111
6. Mandal B, Ghosh K, Chattopadhyay DN. Ex-situ evaluation of chironomid larvae as a potential supplementary food in aquaculture. Aquaculture International,2022:30(2):345–356. https://doi.org/10.1007/s10499-022-01377-9
7. Paul A. A study on the prospects of fish farming in West Bengal. Journal of Rural Development Studies,2022:14(2):55–70.
8. Sahoo PK, Mohanty J, Samal S. Association of risk factors and management issues on the occurrence of diseases in carp aquaculture in West Bengal, India. Fisheries and Aquatic Sciences,2020:23(1):1–12. https://doi.org/10.1186/s12595-020-00325-7
9. Sarkar S, Banerjee R, Bera B. Heavy metal contamination in sediments and fish of East Kolkata Wetlands: Implications for food safety. Environmental Monitoring and Assessment,2023:195:772. https://doi.org/10.1007/s10661-023-10772-8
10. Sarkar S, Das A, Chakraborty P. Aquaculture and livelihood security: A case study from West Bengal, India. Aquaculture International,2023:31(3):567–582. https://doi.org/10.1007/s10499-023-01257-7
11. Sarkar S, Mondal P, Mukherjee A. Status and constraints of aquaculture in West Bengal, India. Aquaculture International,2023:31(5):923–941. https://doi.org/10.1007/s10499-023-00477-2
12. Sarkar S, Roy P, Chatterjee S. Climate change and aquaculture adaptation in West Bengal, India. Aquaculture International,2024:32(1):112–127. https://doi.org/10.1007/s10499-024-01811-x
13. Zhou Q, Zhang J, Fu J, Shi J, Jiang G. Biomonitoring: An appealing tool for assessment of metal pollution in aquatic ecosystems. Science of the Total Environment,2019:407(23)4276–4294. https://doi.org/10.1016/j.scitotenv.2008.07.007