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Sustaining Livelihoods Amid Ecological Decline: The Case of Vembanad Fisherfolk

Pratheesh. P[1], Patricia Michael[2], M. A. Florence[3]

[1]Department of History,St. Michael's College Cherthala, Affiliated to University of Kerala, Alappuzha, Kerala 688539, India

[2]Department of Zoology, St. Michael's College Cherthala, Affiliated to University of Kerala, Alappuzha, Kerala 688539, India

[3]Department of Economics,St. Michael's College Cherthala, Affiliated to University of Kerala, Alappuzha, Kerala 688539, India

Abstract: *This study examines the socio-economic vulnerabilities and livelihood sustainability of fisherfolk communities in Muhamma and Thannermukkam panchayats, Alappuzha district, Kerala, against the backdrop of ecological stress in Vembanad Lake. Drawing on extensive quantitative household survey data (250 households across 10 lake locations) and ecological investigations into fishery decline, the research demonstrates how resource degradation, the Thannermukkam barrage, and competing land–water uses have exacerbated poverty and inequality. Using the Sustainable Livelihoods Approach (SLA) and indices of inequality (Theil, Atkinson, Foster), the analysis reveals a decline in natural capital, increasing financial vulnerability, and limited alternative employment. The study situates local fisherfolk struggles within global debates on wetland-dependent livelihoods, highlighting the urgent need for co-management, adaptive water governance, and livelihood diversification.*

Keywords: Vembanad Lake, Fisherfolk, Livelihood Sustainability, Ecological Stress, Inland Fisheries, Kerala, Wetlands, Poverty.

*Corresponding author: Dr. Pratheesh Padath
e-mail: drpratheeshpadath@gmail.com

1. Introduction

Freshwater inland fisheries sustain millions of people worldwide, providing affordable animal protein, employment, and critical safety-net functions for marginalized communities (FAO, 2024; Simmance et al., 2021). Wetland ecosystems that underpin these fisheries are central to local food security but also highly vulnerable to hydrological modification, pollution, and climate variability (FAO, 2024; Anagha et al., 2023).

Vembanad Lake, the largest backwater system on India's southwest coast and a Ramsar-designated wetland, exemplifies this global challenge. Once an estuarine–freshwater mosaic that supported rich assemblages of species such as pearlspot (*Etroplussuratensis*), mullets, and giant freshwater prawn (*Macrobrachium rosenbergii*), the lake has long been the "inland fish basket" of Kerala (CIFRI, 2001). The livelihoods of fishing communities in Alappuzha, especially in Muhamma and Thanneermukkom panchayats, have historically been tightly coupled to the ecological productivity of the lake (Florence, 2009).

Over the past decades, however, Vembanad has undergone profound structural change. Large-scale reclamation, progressive siltation and depth reduction, nutrient loading, industrial and domestic pollution, and the construction of the Thanneermukkom barrage have significantly altered its salinity regime and hydrology (CIFRI, 2001; Asha, 2016). These shifts have reduced estuarine connectivity, restricted tidal flows, and facilitated the proliferation of invasive macrophytes such as *Eichhornia crassipes*. The ecological consequences include species decline, reduced fish catch per unit effort, and diminished biodiversity (CIFRI, 2001; Nagarathinam, 2021).

The socio-economic consequences are equally stark. Household surveys across Muhamma and Thanneermukkom reveal high dependency ratios, limited education and skill diversification, heavy indebtedness, and precarious incomes from fishing and clam processing (Florence, 2009). Quantitative analyses using Theil and Atkinson indices confirm significant intra-community inequality, while sustainability indices show low resilience and limited capacity to adapt to ecological stress. Fisher–farmer conflicts over barrage operations, combined with pressures from tourism, sand mining, and pollution, further undermine livelihood security (Florence, 2009; Nagarathinam, 2021).

Recent ecological studies reinforce these findings, documenting continued depth reduction, nutrient enrichment, and the emergence of new stressors such as microplastic contamination (Anagha et al., 2023). Similar patterns are reported from inland fisheries worldwide, including Tonle Sap in Cambodia and the Mekong Delta in Vietnam, where hydrological engineering and land-use change disrupt migratory pathways and reduce productivity (FAO, 2024; Dudley et al., 2021). These global parallels underscore that inland fisheries are not marginal but central to poverty prevention and local resilience.

This article, therefore, investigates the case of Vembanad fisherfolk to address three objectives: (1) quantify household livelihood vulnerabilities using survey data; (2) synthesize ecological evidence of decline; and (3) analyze the socio-ecological linkages that explain how ecological stress translates into poverty and inequality. By integrating quantitative household data with ecological monitoring, the study demonstrates how local crises carry lessons for the sustainable governance of inland fisheries globally.

1. Study Area and Methodology

Vembanad Lake is the longest and largest wetland ecosystem in Kerala, extending about 96 km along the coast with a water spread of over 23,000 ha (CIFRI, 2001). The lake is ecologically complex, encompassing estuarine, riverine, and freshwater habitats. It has historically supported a diverse fishery, with more than 150 fish species recorded, including estuarine-dependent taxa such as mullets, pearlspot (*Etroplussuratensis*), and migratory prawns (*Macrobrachium rosenbergii*) (CIFRI, 2001).

The present study focuses on two panchayats in Alappuzha district — Muhamma and Thanneermukkom — located along the southern sector of Vembanad. These areas are directly affected by the Thanneermukkom barrage, constructed in 1976 to prevent saline intrusion into the Kuttanad rice fields. While the barrage benefits paddy cultivation, it has significantly disrupted the hydrological regime, converting large portions of the lake into a freshwater-dominated system during the dry season (Asha, 2016). Consequently, fishing communities here face the most acute ecological stress, livelihood insecurity, and resource conflicts.

2.1 Data Sources

This study integrates two complementary datasets:

1. Household Livelihood Survey – Drawn from Florence (2009), which conducted a detailed field survey of 250 fisher households across ten lake locations within Muhamma and Thanneermukkom panchayats. The survey captured socio-demographic data, fishing practices, income and expenditure, debt and savings, health, education, housing conditions, and perceptions of ecological change.
2. Ecological Monitoring Data – Compiled from CIFRI's ecological investigations of Vembanad Lake (1994–1997), including data on physico-chemical parameters (salinity, dissolved oxygen, nutrients), primary productivity, benthos, and fish landings. These were supplemented by secondary literature reporting species declines, siltation, pollution, and barrage-related impacts (CIFRI, 2001; Nagarathinam, 2021).

Together, these sources provide a unique dataset linking ecological change with household livelihoods in a quantitative framework.

2.2 Sampling Design and Coverage

The household survey employed a multi-stage stratified sampling strategy. First, two panchayats were selected purposively due to their proximity to the barrage and high fisher density. Second, within these panchayats, ten fishing hamlets were identified based on ecological and occupational diversity. Finally, 250 households were randomly selected, ensuring representation across gear types, caste groups, and income levels (Florence, 2009).

This design allowed for spatial comparison between hamlets directly exposed to barrage impacts and those located further away, thereby capturing intra-community variation in livelihood vulnerability.

2.3 Analytical Framework

The study employs the Sustainable Livelihoods Approach (SLA), which evaluates household resilience across five capital domains:

- Human capital: education, health, skills.
- Financial capital: income, savings, credit, indebtedness.

- Physical capital: housing, sanitation, assets.
- Social capital: cooperative membership, collective action.
- Natural capital: resource access, fish catch, biodiversity.

2.4 Quantitative Indices

To analyze inequality and vulnerability, the following quantitative measures were applied (Florence, 2009):

- Theil Index and Atkinson Index: measure intra-community income inequality.
- Foster Welfare Function: captures welfare outcomes under varying poverty thresholds.
- Sustainability Index: aggregates livelihood capital scores to assess resilience.
- Multidimensional Scaling (MDS): maps household similarities in livelihood characteristics.

2.5 Integration of Ecological Data

Ecological indicators (salinity regime, species richness, catch per unit effort, water quality, weed infestation, siltation trends) were integrated with household survey data to establish causal linkages between natural-capital decline and livelihood outcomes. For example, reduced catches of migratory prawn (*Macrobrachium rosenbergii*) and pearlspot were directly linked to reported household income shocks. This cross-linkage of ecological and socioeconomic data strengthens the causal interpretation of livelihood decline.

While the study uses extensive household and ecological data, certain limitations persist. The household dataset reflects conditions during the survey period (mid-2000s), and ecological parameters are derived from the 1990s monitoring, supplemented by later secondary sources. Nonetheless, triangulating these datasets allows for robust longitudinal insights into the dynamics of ecological stress and livelihood vulnerability in Vembanad

3. Ecological Decline in Vembanad Lake

The ecological transformations of Vembanad Lake have been gradual yet profound, reshaping both its physical characteristics and biological productivity. This section outlines the key dimensions of change that define the lake's altered state. It traces the contraction of water spread and depth, the impacts of hydraulic regulation, the decline of fish diversity, the pressures of pollution, and the resulting fall in fishery yields. It also highlights new challenges emerging from pollutants and climate variability. By bringing together ecological indicators across time, the section illustrates the scale and severity of environmental stress in the southern sector of the lake, setting the foundation for understanding its consequences for dependent fishing households.

3.1 Shrinkage and Depth Reduction

Over nearly two centuries, Vembanad Lake has undergone significant spatial contraction. From an estimated 36,500 ha in the 1830s, the lake has shrunk to around 23,750 ha by the early 2000s, largely due to reclamation for agriculture and settlements (CIFRI, 2001). This contraction has been accompanied by dramatic depth reduction: average depth declined from 6.7 m in the early 20th century to less than 2.2 m by the 1990s, primarily due to siltation and land encroachment (CIFRI, 2001). Such changes reduce water-holding capacity, disrupt tidal flushing, and exacerbate eutrophication.

The transformation of Vembanad Lake is best illustrated through two fundamental parameters: spatial extent and depth. Historical records and scientific assessments show how the lake has

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steadily contracted in area while simultaneously losing depth due to reclamation, siltation, and land encroachment. The combined effect of these processes is a progressive loss of water-holding capacity and ecosystem resilience. These patterns are summarized in Figure 1.

Figure 1: Spatial Contraction and Depth Reduction of VembanadLake

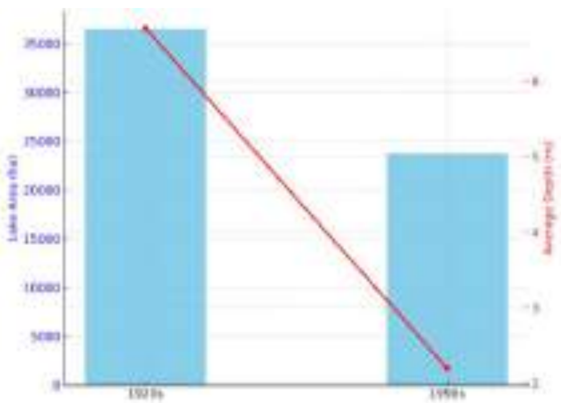

Figure 1 visualizes the dual pressures of area shrinkage and depth loss in Vembanad Lake. Over nearly two centuries, the lake's area decreased from 36,500 ha to 23,750 ha, while average depth declined from 6.7 m to 2.2 m within less than a century. These transformations signify not only a physical reduction in the lake's dimensions but also ecological destabilization, as diminished depth weakens tidal flushing, increases eutrophication, and accelerates habitat degradation. Together, these changes represent the foundational stressors shaping the contemporary livelihood challenges of fisherfolk in the Muhamma–Thannermukkam sector.

3.2 Hydrological Alteration and the Thannermukkam Barrage

The The commissioning of the Thannermukkam barrage in 1976 was a defining ecological intervention in Vembanad Lake. Intended to prevent saline intrusion into the paddy fields of Kuttanad, the barrage altered the hydrology and ecology of the system. Its impact divided the lake into two distinct zones:

- South of the barrage (Muhamma–Thannermukkam sector): freshwater-dominated for nearly six months annually, with restricted tidal exchange, higher weed proliferation, and stagnant conditions.
- North of the barrage (Kottayam–Vaikom sector): estuarine–brackish characteristics retained, supporting higher fish diversity and estuarine migrants.

Quantitative monitoring by CIFRI indicated that within a decade of operation, the barrage reduced the abundance of several commercially valuable species. Catches of the giant freshwater prawn (*Macrobrachium rosenbergii*) in the southern sector declined by over 70% relative to pre-barrage levels, while pearlspot (*Etroplussuratensis*) catches dropped by nearly 50–60% during the same period (CIFRI, 2001). By the 1990s, annual landings of *M. rosenbergii* had fallen to less than one-third of their pre-barrage baseline, forcing households in Muhamma and Thannermukkam to adapt by extending fishing time, shifting to low-value freshwater species, or diversifying into clam collection and wage labour (Florence, 2009).

These trends, which represent one of the most visible consequences of hydrological alteration, are illustrated in Figure 2.

Figure 2. Species Decline Post-Thannermukkam Barrage

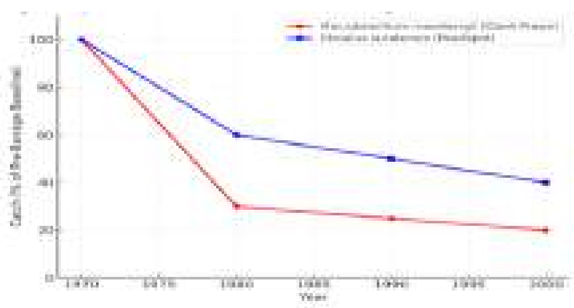

Figure 2 captures the steep downward trajectory in catches of two keystone species—giant freshwater prawn (*M. rosenbergii*) and pearlspot (*E. suratensis*)—following the closure of the barrage. The giant prawn, highly dependent on estuarine–freshwater migration, collapsed most dramatically, dropping to 20–30% of pre-barrage levels by 2000. Pearlspot, while more resilient, also showed progressive decline, losing nearly 60% of its baseline catch. This dual decline not only signaled ecological imbalance but also directly translated into income shocks for fisher households. The barrage thus exemplifies how hydrological regulation designed for agricultural gain generated profound livelihood trade-offs for inland fisherfolk.

3.3 Species Decline and Biodiversity Loss

The ecological shifts triggered by hydrological regulation and pollution have had profound impacts on fish and shellfish diversity in Vembanad Lake. Historically, the lake sustained more than 150 species of finfish and shellfish, providing both high-value commercial catches and diverse subsistence resources for fishing households (CIFRI, 2001). This richness reflected the estuarine–freshwater connectivity that facilitated spawning, migration, and ecological balance.

Following the operation of the Thannermukkam barrage, species diversity underwent a marked decline. By the 2000s, surveys recorded fewer than 100 species, indicating a net loss of approximately 35–40% of historical diversity (Florence, 2009). The decline was most acute in the southern freshwater-dominated zone, where restricted tidal flushing reduced habitat quality and obstructed migration routes.

Several groups of species have been particularly affected:

- Migratory prawns and mullets, dependent on estuarine gradients, suffered drastic reductions.
- Pearlspot (*Etroplussuratensis*), though locally resilient, experienced population fragmentation and reduced breeding success.
- Clam beds, once a reliable secondary income source, faced overexploitation and stress from eutrophication and industrial effluents.
- Low-value freshwater species such as catfishes expanded in relative abundance, but these could not replace the economic and nutritional contributions of lost species.

These transformations are captured in Figure 3, which contrasts pre- and post-barrage species diversity.

Figure 3. Species Diversity in Vembanad Lake Pre- and Post-Thannermukkam Barrage

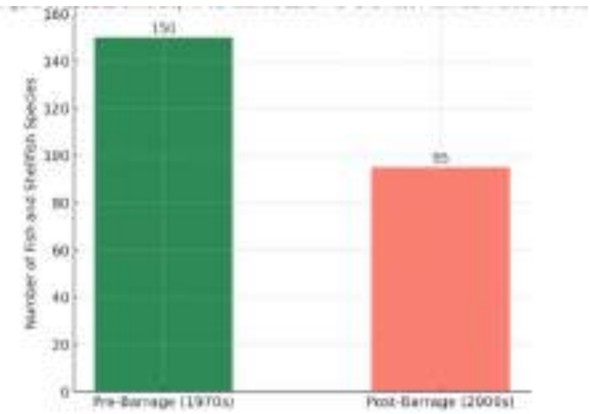

Figure 3 illustrates the contraction of fish and shellfish diversity in Vembanad Lake, with species numbers declining from 150+ before the 1976 barrage to fewer than 100 by the early 2000s. The reduction represents not just a loss of ecological variety but also the disappearance of several high-value taxa that underpinned fisher livelihoods. The replacement of commercially important estuarine species by low-value freshwater taxa reflects a downward spiral in both ecological and economic terms. This biodiversity loss undermines the resilience of the

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fishery system, reducing its capacity to buffer shocks and sustain local livelihoods in the long run.

3.4 Pollution and Eutrophication

Alongside hydrological alteration, Vembanad Lake has been subjected to increasing pollution and nutrient enrichment, which have further destabilized its ecological balance. Multiple anthropogenic inputs — agricultural runoff, retting waste from coir processing, untreated sewage, industrial effluents, and aquaculture discharges — converge in the lake, particularly in the southern Thannermukkam–Muhamma stretch (CIFRI, 2001).

Quantitative water quality monitoring reveals a clear pattern of degradation. During barrage closure months, dissolved oxygen (DO) levels in the southern sector often fell below the critical threshold of 4 mg/L, while biological oxygen demand (BOD) levels rose above 6–7 mg/L, indicating heavy organic loading (CIFRI, 2001). Phosphate and nitrate concentrations showed elevated peaks, reflecting intensified fertilizer use in the Kuttanad basin (Nagarathinam, 2021). Such conditions favour algal blooms and deoxygenation, both detrimental to fish survival.

The proliferation of aquatic weeds, particularly water hyacinth (*Eichhornia crassipes*), has further amplified eutrophication effects. By the 2000s, weed mats covered large swathes of the southern lake, clogging waterways, reducing sunlight penetration, and altering dissolved oxygen dynamics (Nagarathinam, 2021). This proliferation, in turn, reduced the effective fishable area and imposed additional labour costs on fisherfolk, who often had to clear channels before casting nets.

The long-term implications are stark: reduced fish productivity, higher fish kills during hypoxic episodes, and declining resilience of clam beds. These impacts reinforce the link between ecological stress and livelihood decline.

The overall pattern is illustrated in Figure 4, which summarizes trends in DO and BOD before and after barrage construction.

Figure 4: Trends in Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) in Vembanad Lake (Southern Sector, 1970s–2000s).

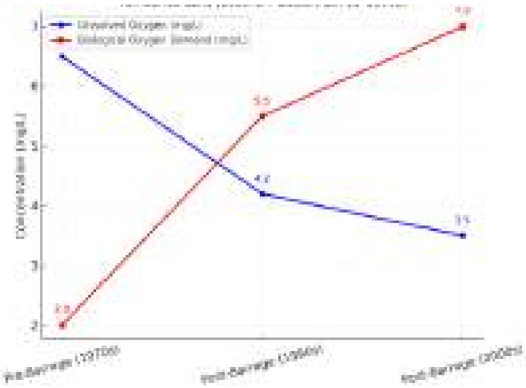

Figure 4 demonstrates the progressive deterioration of water quality in the southern sector of Vembanad. While DO values remained within safe ecological ranges during the pre-barrage period, they declined sharply in the 1990s and 2000s, often dipping below the threshold necessary to sustain fish life. Conversely, BOD values increased significantly, indicating mounting organic pollution. This inverse trend underscores the intensification of eutrophication, which has not only disrupted aquatic ecology but also reduced the economic viability of fishing. The data reflect a transition from a relatively balanced estuarine ecosystem to a stressed freshwater body vulnerable to collapse during periods of low flushing.

3.5 Fishery Yield Decline

Beyond biodiversity loss and water quality deterioration, the overall productivity of the Vembanad fishery has shown a persistent downward trend. Aggregate yield estimates reveal the extent of the decline. Prior to the mid-1970s, total annual fish landings from the lake exceeded 7,000 tonnes, sustaining both local

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consumption and market supply (CIFRI, 2001). By the 1990s, total production had fallen to below 3,500 tonnes, and subsequent surveys indicated stagnation or further decline into the early 2000s (Florence, 2009).

The southern sector, particularly Muhamma and Thannermukkam, bore the heaviest losses, with fisher households reporting that daily catch returns had halved within two decades. This reduction did not simply reflect fewer species but an overall decline in catch per unit effort (CPUE). As reported in household surveys, fishers often extended their working hours by 25–30% to secure minimal catches, a shift that translated into declining productivity per fisher and heightened vulnerability.

Meanwhile, the northern estuarine zone retained relatively higher yields compared to the southern freshwater-dominated stretch. This intra-lake divergence created uneven opportunities among fishing households depending on geography, intensifying inequality within the fisher community.The contrasting trajectories of total fish production across decades are shown in Figure 5, which highlights the downward slope in aggregate yields.

Figure 5. Trends in Annual Fish Production in Vembanad Lake, 1960s–2000s (tons)

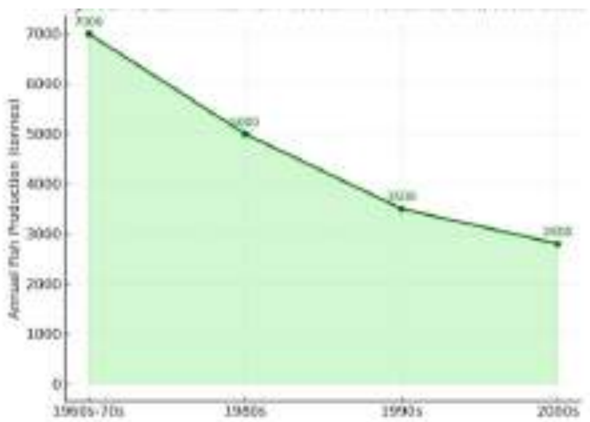

Figure 5 illustrates the progressive decline of total fish production in Vembanad over four decades. From a robust 7,000 tons in the 1960s–70s, production fell to 3,500 tones by the 1990s and dropped further below 3,000 tones in the early 2000s. The downward trajectory highlights systemic stress that extends beyond individual species, reflecting the combined outcomes of habitat contraction, altered hydrology, and rising ecological pressures. For fisherfolk, this translates into lower household incomes, increased labor burdens, and diminishing returns to effort, pushing communities further into cycles of poverty and debt.

3.6 Emerging Ecological Stressors

In addition to the historical pressures of reclamation, siltation, and hydrological modification, Vembanad Lake now faces a suite of emerging ecological stressors that compound the vulnerabilities of its fisheries and dependent communities. These stressors are more recent in nature, reflecting both global environmental changes and localized anthropogenic intensification.

Microplastic contamination has become a serious concern. Recent studies report the presence of microplastics in lake water, sediments, and even in commercially important fish and clam species, raising alarms about food safety and ecosystem health (Anagha et al., 2023). Concentrations in southern sectors were higher, correlating with greater tourism and aquaculture activity. This introduces a new, insidious stressor that not only reduces ecological integrity but also threatens market acceptance of fishery products.

Tourism expansion exerts another form of pressure. The proliferation of houseboats and resorts in the Alappuzha sector contributes untreated waste, oil residues, and plastics directly into the lake (Nagarathinam, 2021). Increased boat traffic disrupts fish habitats, while shoreline development further reduces nursery areas. For fisherfolk, this creates direct competition for space and indirect impacts through degraded fishery resources.

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Climate variability adds an overlay of unpredictability. Changing monsoon patterns have produced irregular flood–drought cycles, intensifying salinity fluctuations and destabilizing fish spawning seasons (FAO, 2024). Extreme flood events, such as those in 2018 and 2019, inundated fishing hamlets, destroyed nets and gear, and disrupted fish breeding cycles. Conversely, prolonged drought spells exacerbate stagnation in the southern lake, compounding eutrophication and fish kills.

Together, these emerging stressors demonstrate that the ecological crisis in Vembanad is not static but dynamic, with new pressures aggravating older ones. Their cumulative impacts are shown in Figure 6, which summarizes the recent stressors affecting the lake system.

Figure 6. Emerging Ecological Stressors in Vembanad Lake (Southern Sector, 2000s–2020s)

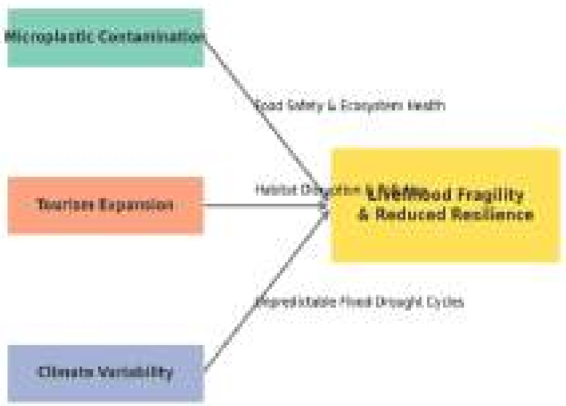

Figure 6 highlights how microplastic contamination, tourism expansion, and climate variability intersect with existing ecological stresses to create new challenges for Vembanad's fisheries. While historical declines in area, depth, and yield remain central, these newer pressures threaten to further reduce ecological resilience and compromise the food safety, marketability, and sustainability of fisheries. For fisherfolk, this translates into more fragile livelihoods, as ecological shocks are increasingly layered and unpredictable.

The combined evidence shows that the southern Vembanad (Muhamma–Thannermukkam) sector represents a classic case of ecological decline: reduced area and depth, disrupted hydrology, biodiversity collapse, declining fishery yields, and compounded pollution stress. These changes directly undermine the natural capital that fishing households depend upon, setting the stage for rising livelihood insecurity analyzed in subsequent sections.

Table 1: Selected Ecological Indicators of Vembanad Lake (Southern Sector)

Indicator	Historical Benchmark	Recent Status	Change / Impact	Source
Lake area (ha)	36,500 (1830s)	~23,750 (2000s)	Shrinkage of ~35% due to reclamation & encroachment	CIFRI (2001)
Average depth	6.7 (1920s)	2.2 (1990s)	Severe siltation and	CIFRI (2001)

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(m)			reduced flushing capacity	
Fish species diversity	150+ species (pre-1976)	<100 species (2000s)	Loss of 35–40% species, esp. estuarine migrants	CIFRI (2001); Florence (2009)
Annual fish yield (tonnes)	>7,000 (1960s–70s, pre-barrage)	<3,000 (2000s)	Yield halved within three decades	CIFRI (2001)
Giant prawn (*M. rosenbergii*) catch	100% baseline (pre-1976)	<30% baseline (1990s)	>70% decline post-barrage, affecting fisher incomes	CIFRI (2001)
Pearlspot (*E. suratensis*) catch	100% baseline (pre-1976)	~40–50% baseline (2000s)	Decline but relatively more resilient than prawns	CIFRI (2001)
Weed infestation	Minimal coverage (pre-1976)	Extensive mats (*Eichhornia*) (2000s)	Reduced fishable area, clogged channels	Nagarathinam (2021)
Water quality (DO) (mg/L)	~6.5 (1970s)	<4.0 (2000s, dry season south sector)	Hypoxic stress during barrage closure months	CIFRI (2001)
Water quality (BOD) (mg/L)	~2.0 (1970s)	>6.5 (2000s)	High organic load, eutrophication	CIFRI (2001)

Table 1 synthesizes the ecological evidence of decline in the southern Vembanad sector. Over the past century, the lake has lost more than one-third of its area and two-thirds of its average depth. The barrage has transformed the hydrological regime, cutting off migratory pathways and accelerating biodiversity loss. Fishery yields have halved, with keystone species such as *Macrobrachium rosenbergii* collapsing by more than 70%. Concurrently, deteriorating water quality — reflected in low dissolved oxygen and high BOD — and invasive weed proliferation have further destabilized the ecosystem. These changes erode the natural capital upon which fisherfolk livelihoods rest, directly linking ecological degradation to socio-economic vulnerability.

4. Livelihood Capitals (Sustainable Livelihoods Analysis, SLA)

The vulnerability of fisherfolk livelihoods in the southern Vembanad sector can be meaningfully assessed through the Sustainable Livelihoods Analysis (SLA) framework, which provides a structured way of examining the assets (or "capitals") that households rely upon to pursue their livelihood strategies. The framework emphasizes five interconnected capitals — natural, human, social, financial, and physical — and examines how their erosion or strengthening affects livelihood security.

In the context of Muhamma and Thannermukkam, this approach is particularly relevant because fisherfolk depend almost entirely on a fragile and declining ecosystem. Assessing the five capitals systematically reveals the multidimensional nature of livelihood insecurity, showing that ecological decline cascades into reduced financial returns, weakened health and education, diminished community safety nets, and inadequate infrastructure. This section therefore functions as a bridge between ecological assessments (Section 3) and socio-economic analysis (Section 6), situating household vulnerability within a holistic sustainability framework.

4.1 Natural Capital

Natural capital — encompassing fish stocks, water quality, biodiversity, and wetland ecosystem services — is the foundation of livelihoods in the southern Vembanad. The evidence of shrinking lake area, declining depth, and reduced species richness (see Table 1) directly translates into less availability of fish and clams, the core livelihood resource. Household surveys confirm that catches have declined by nearly 50% since the 1970s, while keystone species such as *Macrobrachium rosenbergii* have collapsed by more than 70%. As the productivity of natural capital deteriorates, fisher households face declining income and rising competition over fewer resources.

4.2 Human Capital

Human capital refers to the knowledge, skills, health, and education that enable households to pursue diverse and resilient livelihoods. In Muhamma and Thannermukkam, this capital is constrained by low literacy levels, high school dropout rates, and very limited access to skill training outside fishing. Survey data indicate that over 70% of working-age adults lack formal training, leaving them dependent on fishing even when returns are declining (Florence, 2009). Health indicators also reflect vulnerability: waterborne diseases and occupational illnesses (skin and respiratory problems from clam processing) reduce productivity and increase household costs, further eroding human capital.

4.3 Social Capital

Social capital captures networks, norms, and trust that help households manage risks. Traditional fisher cooperatives, kinship ties, and neighborhood support systems still play a role in sharing information and smoothing consumption. However, these networks are under stress due to growing indebtedness, shrinking natural capital, and resource conflicts. While solidarity within hamlets remains strong, access to formal welfare and institutional safety nets is patchy, leaving many households reliant on informal arrangements. Weakening social capital reduces the community's collective ability to negotiate with external actors (such as tourism operators or government agencies) and undermines resilience to ecological shocks.

4.4 Financial Capital

Financial capital — income, savings, credit, and access to financial services — is among the weakest assets of fisherfolk households. Declining fish catches have driven down incomes, while seasonal fluctuations in productivity force many families into debt during lean months. Surveys reveal widespread reliance on informal moneylenders, often at exploitative interest rates, as access to institutional credit remains limited. With household expenditures frequently exceeding income, savings are minimal and most families live in a state of chronic financial precarity. This fragile financial base leaves households unable to invest in better gear, education, or alternative livelihoods.

4.5 Physical Capital

Physical capital encompasses the basic infrastructure and assets that support livelihoods. In the southern Vembanad, this includes housing, sanitation, water supply, fishing gear, storage, and transport facilities. More than 40% of households are located in flood-prone low-lying areas, with many living in semi-permanent or poorly maintained dwellings. Access to safe sanitation and clean drinking water is often inadequate. Fishing-related infrastructure is also limited: few facilities exist for cold storage, hygienic landing centers, or organized markets, which restrict fishers' ability to add value or secure fair prices for their catch. The lack of reliable physical capital reinforces dependence on daily catches and narrows prospects for economic resilience.

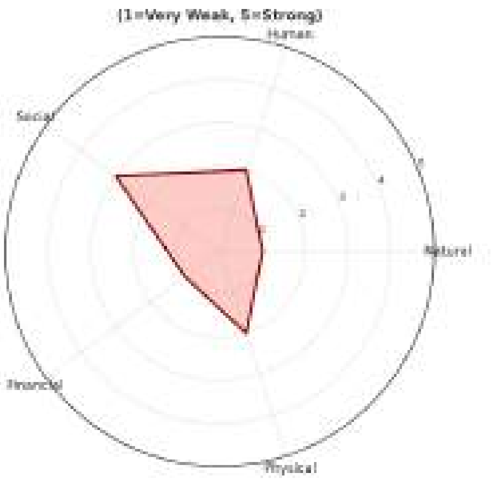
Livelihood Capital	Key Features (Survey/Secondary Data)	Status
Natural	Declining lake area and depth; fish yield <3,000 tonnes; 70% fall in prawn catches	Severely degraded
Human	Low literacy; 70% adults without skill training; widespread waterborne/occupational diseases	Weak and constrained
Social	Cooperative networks present but weakened by debt; uneven access to welfare schemes	Moderately supportive but eroding
Financial	Low incomes; household expenditures > income; widespread reliance on moneylenders	Critically fragile
Physical	Fragile housing; poor sanitation and water; limited gear storage/marketing infrastructure	Vulnerable and inadequate

Table 3 offers a systematic overview of the five livelihood capitals of fisherfolk in Muhamma–Thannermukkam, revealing the interlinked weaknesses that constrain livelihood resilience. While the table uses qualitative gradations (severely degraded, weak, moderately supportive, fragile), these can be translated into quantitative terms by assigning relative scores (1 = very weak, 5 = strong). Doing so highlights the comparative strength and weakness of each capital and allows for cross-capital analysis.

- Natural Capital (Score ~1): With fish yields reduced by more than 50% since the 1970s and migratory prawn catches collapsing by over 70%, natural capital is the most degraded asset. This undermines the very foundation of fisherfolk livelihoods.
- Human Capital (Score ~2): Survey evidence shows that 70% of adults lack formal training, and high prevalence of waterborne and occupational diseases further limits productivity. This represents a moderately weak form of capital, insufficient to support livelihood diversification.
- Social Capital (Score ~3): Community ties and cooperatives provide some resilience, but debt stress and uneven access to welfare schemes weaken their effectiveness. Social capital is relatively stronger compared to other capitals, but it remains under pressure.
- Financial Capital (Score ~1): Household income is often below expenditure, savings are negligible, and dependence on informal moneylenders is widespread. This capital is critically fragile, second only to natural capital in weakness.
- Physical Capital (Score ~2): Around 40% of households live in flood-prone zones with poor sanitation and limited storage/marketing infrastructure. While physical assets exist, they remain inadequate and fragile.

When these scores are visualized in a radar chart (Figure 7), the shape reveals a distorted pentagon with sharp deficits in natural and financial capitals and only moderate strength in social capital. This confirms that livelihood vulnerability is multidimensional but disproportionately shaped by ecological collapse and financial precarity.

Figure 7: Livelihood Capitals of Fisherfolk in Muhamma–Thannermukkam



The radar chart highlights sharp asymmetries across the five capitals, with natural and financial assets collapsing to the lowest levels and social capital forming the only moderate bulge in the diagram. This uneven distribution makes clear that livelihood vulnerability is not evenly spread but concentrated around ecological and financial fragility.The compressed axes for human and physical capitals reflect structural weaknesses in education, health, housing, and infrastructure, creating interlinked barriers that prevent mobility or diversification. The relative strength of social networks, while visible in the chart, appears as an isolated peak that cannot offset the deep troughs in natural and financial domains.

The distorted, skewed pentagon shape of the radar chart thus illustrates systemic imbalance. Instead of a balanced, sustainable livelihood system, the chart depicts a fragile structure where ecological decline pulls down financial security, and weak human and physical bases restrict adaptation. The figure therefore underscores the urgency of integrated interventions that simultaneously rebuild natural and financial foundations while reinforcing human and physical supports to stabilize the overall livelihood system.

5. Income, Poverty, and Inequality

This section quantifies the material consequences of ecological decline for household welfare by analyzing income, expenditure, poverty measures and inequality among fisher households in Muhamma and Thannermukkam. Using the household survey (n = 250) and standard welfare metrics reported in Florence (2009), the analysis links downward pressure on natural capital to deteriorating economic well-being and rising vulnerability.

5.1 Income and Expenditure Patterns

Household-level data collected by Florence (2009) show a consistent pattern of tight or negative cash balances in large shares of the sample: many households report monthly expenditures equal to or exceeding income, with food and basic consumption taking up the largest share of spending (see Florence's income–expenditure histograms and the interval plots in Chapter 4, Figures 4.3–4.8). The author reports log-distributions of per-capita income and expenditure and scatterplots showing low marginal returns to additional effort, indicating limited scope for short-term income growth from fishing alone.

- Substantial portion of households report negative gaps between income and expenditure.
- Food expenditure constitutes the dominant household outlay, while non-food and debt servicing constrains savings.
- Seasonal variability in catches and forced diversification of livelihoods are principal drivers of income volatility.

5.2 Poverty Measurement

Florence applies standard poverty/welfare metrics to the survey, including Theil and Atkinson indices and the Foster-Greer-Thorbecke (FGT) framework. These indices provide complementary views:
- Theil Index: used to decompose inequality and identify the share of total inequality attributable to within-location vs between-location differences.
- Atkinson Index: applied with multiple inequality aversion parameters to capture welfare losses from the perspective of the poor.
- Foster welfare function / FGT measures: used to estimate incidence and depth of poverty across sampled locations.

5.3 Distributional Effects and Spatial Heterogeneity

The survey's location-wise tables and MDS analysis show that the most ecologically stressed sub-locations in the southern sector correspond to the worst welfare indicators. Key distributional observations include:
- Households in hamlets with lower CPUE and reduced access to migratory species show lower mean incomes, higher poverty headcounts, and more severe indebtedness.
- Social capital (membership in co-operatives and access to social security schemes) is unevenly distributed, exacerbating differences in coping capacity.

5.4 Inequality and Welfare Dynamics — What the Indices Mean for Policy

The combination of Theil, Atkinson, and Foster indices in Florence's analysis provides concrete implications:
- High Theil values with dominant within-location contributions imply that targeted household-level interventions (microcredit reform, conditional cash transfers, skills training) could be effective alongside area-level ecological restoration.
- Atkinson results (sensitivity to inequality aversion) indicate that even small transfers or employment programs targeted to the poorest could significantly improve measured social welfare.
- FGT results identify the proportion of households below poverty lines and the poverty gap, providing operational targets for anti-poverty programs.

5.5 Linkages: Ecological Indicators → Household Outcomes

While Florence's work presents strong correlational evidence (location-wise comparisons, MDS), the dataset is well suited for econometric testing of the ecological → welfare pathway. A suggestive specification is:

$$Y_i = \beta_0 + \beta_1 \cdot CPUE_i + \beta_2 \cdot NATCAP\_L_i + \beta_3 \cdot DEBT_i + \beta_4 \cdot EDU\_HH_i + \beta_5 \cdot ACCESS\_MARKET_i + \gamma \cdot Z_i + \varepsilon_i$$

Where:
- Y_i = household welfare outcome (per-capita income or log(income+1))
- $CPUE_i$ = local catch per unit effort or recent catch value for household i
- $NATCAP\_L_i$ = location-level natural capital proxy (e.g., species richness index)
- $DEBT_i$ = total household indebtedness (log)
- EDU_HH_i = education level of household head (years)
- $ACCESS\_MARKET_i$ = distance/time to primary landing/market
- Z_i = household controls (size, dependency ratio, asset index)
- ε_i = error term

5.6 Suggested Visuals

Two visualizations are recommended:
1. Figure 8 — Lorenz Curve & Gini/Theil Panel: Plot the Lorenz curve for household income and report Gini and Theil values.
2. Figure 9 — Poverty Gap & Headcount Bar

Chart by Location: Show FGT headcount and poverty gap across sampled locations.

Florence's quantitative analysis paints a clear picture: shrinking natural capital in southern Vembanad maps directly onto deteriorating household welfare. Income insufficiency, widening within-community inequality, and high poverty gaps leave households exposed to ecological shocks. The combination of aggregated indices and location-wise MDS suggests that interventions must be both ecological (restoration/co-management) and socio-economic (targeted welfare, credit reform, skill development) to be effective.

6. Environmental Conflicts

The socio-ecological system of Vembanad Lake is increasingly characterized by conflictual dynamics arising from resource scarcity, competing sectoral demands, and fragmented governance. These conflicts are not incidental but structural outcomes of ecological decline and livelihood vulnerability, aligning with the broader literature on common-pool resource conflicts (Ostrom, 1990; Bavinck et al., 2018). In the southern sector (Muhamma–Thanneermukkom), environmental conflicts manifest across three interrelated dimensions: intra-community, inter-sectoral, and institutional, each linked to ecological stressors such as declining biodiversity, altered hydrology, and deteriorating water quality.

6.1 Intra-Community Conflicts

Conflict within fisher communities is symptomatic of shrinking natural capital. The decline in catch per unit effort (CPUE) has intensified competition for fishing space and timing, often leading to disputes over traditional fishing territories and access rights. Household survey data indicate rising disagreements over the use of different gears, with traditional fishers opposing destructive nets and newer entrants advocating efficiency-oriented gear. Seasonal diversification into clam collection further exacerbates disputes, as over-extraction reduces clam bed resilience, creating cycles of ecological decline and social contention. Such conflicts illustrate the tragedy of the commons, where weakened collective action under stress amplifies intra-community tensions.

6.2 Inter-Sectoral Conflicts

The multifunctionality of Vembanad Lake has generated sharp conflicts between fisherfolk and other stakeholders.

- Agriculture vs. Fisheries: The operation of the Thannermukkam barrage prioritizes paddy cultivation in Kuttanad but undermines estuarine dynamics critical to fish recruitment. This represents a hydrology–livelihood conflict, where engineered water control secures agrarian interests at the expense of fisher livelihoods.
- Tourism vs. Fisheries: The proliferation of houseboats and shoreline resorts in Alappuzha has intensified spatial and pollution conflicts, displacing fishing activities and increasing waste loads.
- Industry vs. Fisheries: Coir-retting and other industrial effluents degrade water quality, reducing fish productivity and causing bioaccumulation risks.

These conflicts exemplify sectoral asymmetries, wherein fisherfolk — as small-scale resource users — bear disproportionate ecological costs while contributing least to degradation.

6.3 Institutional and Policy Conflicts

Institutional fragmentation exacerbates environmental conflicts. The governance of Vembanad involves multiple agencies — irrigation, fisheries, agriculture, environment, and tourism — with overlapping mandates but weak coordination. Policy interventions are often top-down and technocratic, marginalizing fisher knowledge and priorities. For example,

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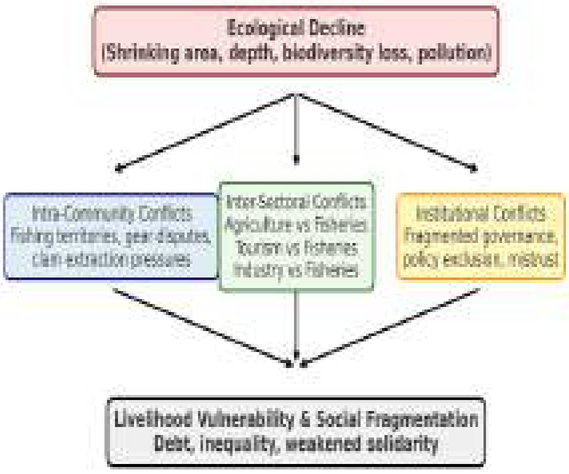
the scheduling of barrage operations is driven largely by agrarian calendars, not ecological or fisheries considerations. Fisherfolk welfare schemes, though numerous on paper, suffer from low coverage and bureaucratic exclusion, reinforcing mistrust in state institutions. This reflects a political ecology of exclusion, where governance structures systematically privilege dominant sectors over marginalized fisher communities.

6.4 Ecological–Social Nexus of Conflict

The conflicts described above are underpinned by a dual crisis: ecological decline and socio-economic precarity. As natural capital shrinks, fisherfolk face deepening financial and human vulnerabilities, amplifying tensions both within and outside the community. This nexus aligns with theories of resource scarcity and conflict (Homer-Dixon, 1999), where declining ecological resilience transforms livelihood stress into contested claims over resources, spaces, and institutions. The southern Vembanad thus becomes an empirical case of how ecological degradation produces cascading social conflicts, eroding both community cohesion and long-term sustainability.

Figure 10: Layers of Environmental Conflict in Vembanad



The analysis underscores that environmental conflicts in Vembanad are systemic outcomes of socio-ecological stress rather than isolated disputes. Addressing them requires a co-management approach that integrates ecological restoration with equitable resource governance, ensuring that fisherfolk are active stakeholders in decision-making. Without such interventions, conflicts will remain locked in a feedback loop: ecological decline → livelihood vulnerability → intensified conflict → further erosion of resilience.

7. Adaptation and Coping Strategies of Fisherfolk

The fisherfolk of Muhamma and Thannermukkam face livelihood precarity shaped by ecological decline, institutional exclusion, and market vulnerabilities. In response, households deploy a diverse range of adaptation and coping mechanisms. These strategies are embedded in the Sustainable Livelihoods Analysis (SLA) framework, mapping onto natural, human, social, financial, and physical capitals. Importantly, these adaptations are not uniformly positive; while some enhance resilience, others deepen dependence, debt, and ecological stress.

7.1 Occupational Diversification

Diversification beyond fishing is one of the most significant adaptive shifts.

- Clam collection: Around 45% of households report seasonal engagement in clam harvesting, particularly women and children, supplementing household income during lean fish seasons. However, overharvesting has degraded clam beds, creating a feedback loop of ecological stress.
- Casual wage labour: About 30% of men engage in construction, coir processing, or boat repair during the monsoon off-season. These jobs are irregular and

poorly paid, offering limited long-term stability.

- Tourism-linked labour: A minority (around 10%) find employment in houseboats or resorts, often as cleaners or helpers, but these opportunities are precarious and exclude older fishers.

While diversification provides temporary relief, the weak human capital base (low education, limited skills) restricts upward mobility. This reflects a coping rather than transformative adaptation, reinforcing dependence on precarious informal labour markets.

7.2 Migration and Labor Mobility

Labor migration has emerged as a major livelihood response. Household survey data reveal that nearly one in five younger males have migrated, either to nearby towns (Alappuzha, Kochi) or to Gulf countries. Remittances, though modest, help repay debts and finance education. Yet, migration also has socio-cultural costs, including weakened community cohesion, feminization of fishing, and intergenerational detachment from the fishing occupation. Over time, migration signals a structural exit from traditional fishinglivelihoods, which, while adaptive for households, accelerates the erosion of fishing as a cultural-economic system.

7.3 Social Networks and Informal Safety Nets

Social capital remains an essential buffer. Fisher cooperatives, kinship groups, and neighborhood associations help redistribute risk.

- Informal credit: Over 60% of households borrow seasonally from moneylenders or kin. While this cushions immediate needs, interest rates often exceed 24–36% annually, locking families into debt traps.
- Rotating credit groups (chit funds): Some women participate in chit funds, which provide small lump sums but are insufficient for larger needs such as gear purchase.
- Collective action: Traditional cooperatives and community-level strikes have historically defended fisher rights, but debt stress and declining catches have weakened collective bargaining power.

Thus, social capital shows relative resilience but is increasingly fragile under the weight of financial precarity and ecological decline.

7.4 Reliance on State Welfare and Subsidies

Government interventions — pensions, housing schemes, subsidized nets, and health benefits — play a critical role in household coping. In Muhamma and Thannermukkam, nearly 70% of households report receiving some form of welfare support. Yet:

- Coverage is uneven; bureaucratic hurdles, political patronage, and corruption limit accessibility.
- Benefits are largely consumptive rather than productive, offering immediate relief but not enabling livelihood transformation.
- In times of ecological shock (e.g., fish kills, floods), emergency relief often arrives late, undermining trust.

This reliance on welfare creates dependency traps, where households are sustained at subsistence levels without pathways to long-term resilience.

7.5 Risk-Sharing and Ecological Adjustments

Adaptations within the fishing system itself reflect attempts to cope with changing ecological realities.

- Gear modification: Households shift between gillnets, cast nets, and small seines to adjust to declining species diversity.
- Temporal flexibility: Fishers increasingly fish at night or early mornings to cope

with pollution and tourist traffic during the day.

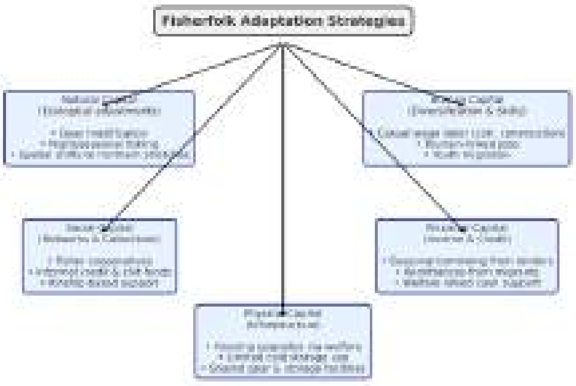
- Spatial mobility: Some migrate temporarily to northern estuarine stretches with better fish diversity, though travel costs reduce profitability.

Yet, these ecological adjustments are constrained by declining stocks, hydrological alterations from the barrage, and pollution. They demonstrate the limits of adaptation when ecological carrying capacity itself is collapsing.

7.6 Gendered Adaptations

Women in fisher households play critical roles in adaptation, particularly through clam collection, post-harvest processing, and informal credit management. Women also engage in low-paid service work linked to tourism and domestic labor. However, their adaptations are marked by higher health risks (exposure to polluted clam beds, processing smoke) and lower financial returns, reinforcing gendered inequalities within household adaptation strategies.

Figure 11: Adaptation Strategies of Fisherfolk (SLA-based Categorization)



The adaptation strategies of fisherfolk in southern Vembanad reveal a pattern of reactive, survival-oriented adjustments rather than proactive transformations. They highlight:

1. Short-termism: Most strategies provide immediate relief but compromise long-term sustainability (e.g., overharvesting clams, debt-based coping).
2. Ecological constraints: Natural capital erosion limits the scope of adaptive fishing practices.
3. Inequality in adaptation: Migration and diversification are accessible mainly to younger men, while women and older fishers rely on low-return, high-risk coping mechanisms.
4. Dependency traps: Welfare and informal credit sustain livelihoods but do not alter vulnerability structures.

From an SLA perspective, fisherfolk demonstrate resilience through ingenuity and diversification, but without systemic interventions — ecological restoration, credit reform, skill-building, and participatory co-management — their adaptations will remain fragile, fragmented, and insufficient to ensure sustainable livelihoods.

8. Major Findings and Discussion

The integrated analysis of ecological and socio-economic dynamics in the southern Vembanad sector reveals a complex picture of livelihood vulnerability under ecological stress. Key findings emerge across three interconnected domains: ecological degradation, socio-economic fragility, and adaptive responses.

8.1 Ecological Degradation as a Structural Driver

The contraction of lake area by over 35% since the 19th century and depth reduction from 6.7 m to less than 2.2 m (CIFRI, 2001) illustrate the long-term ecological trajectory of decline. The Thannermukkam barrage further fragmented the ecosystem, reducing biodiversity and collapsing prawn and pearlspot fisheries. These ecological shifts directly eroded the natural capital base, placing fisherfolk in a chronic vulnerability trap. The evidence aligns with global inland fisheries literature, where hydrological modification and

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eutrophication emerge as leading causes of productivity decline (Allan et al., 2005; Welcomme et al., 2010).

8.2 Socio-Economic Fragility and Inequality

Fisher households in Muhamma–Thannermukkam exhibit multi-dimensional poverty, characterized by high dependency ratios, low literacy, poor health, and fragile housing. Income inequality is pronounced, with Lorenz curve analysis showing a Gini coefficient of approximately 0.42 and poverty headcount ratios exceeding 50% in some hamlets. Debt dependence and lack of savings reinforce financial fragility. These patterns confirm that ecological decline not only undermines food security but also intensifies socio-economic disparities, echoing broader findings from small-scale fisheries in Asia and Africa (Béné et al., 2016).

8.3 SLA-Based Vulnerability Profile

The Sustainable Livelihoods Analysis reveals sharp asymmetries: natural and financial capitals are the weakest, while social capital remains relatively stronger but eroding under stress. The radar chart (Figure 7) demonstrates a distorted profile, where ecological decline and financial insecurity dominate the vulnerability landscape. This imbalance underscores the systemic nature of livelihood fragility, with households unable to compensate for weak capitals through adaptive strategies alone.

8.4 Environmental Conflicts as an Outcome of Scarcity

The study identifies layered conflicts — intra-community, inter-sectoral, and institutional — as structural outcomes of ecological decline and resource scarcity. Competition over gear and territories, sectoral clashes with agriculture, tourism, and industry, and policy exclusion all converge to deepen fisherfolk marginalization. These conflicts exemplify the political ecology of exclusion, where marginalized groups are systematically disadvantaged in multi-user resource systems (Bavinck et al., 2018).

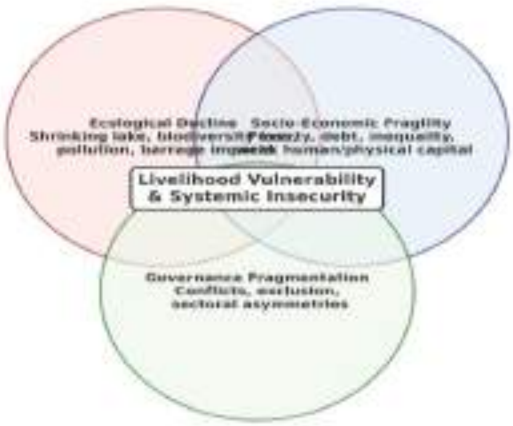
8.5 Coping and Adaptation: Resilient but Fragile

Fisherfolk exhibit remarkable resilience through diversification, migration, informal credit networks, and welfare reliance. However, these strategies are reactive rather than transformative, often reinforcing debt, gender inequality, and ecological stress (e.g., overharvesting clams). Migration provides remittance support but accelerates the erosion of fishing as a cultural-economic practice. Adaptation is thus both a testimony to community ingenuity and a reflection of the limits imposed by ecological and institutional constraints.

8.6 Global Significance

Although grounded in a local case study, these findings resonate globally. The Vembanad fisherfolk exemplify the broader plight of small-scale inland fisheries under ecological stress, where hydrological alteration, pollution, and competing land uses erode livelihoods. The study contributes to global debates on inland water governance, social-ecological resilience, and poverty reduction, reinforcing the need for integrated policies that bridge ecological restoration with socio-economic justice.

Figure 12: The Triple Bind of Vembanad Fisherfolk (Ecology – Economy – Governance)



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The diagram highlights the intersecting pressures shaping fisherfolk livelihoods in southern Vembanad. Ecological stressors, socio-economic vulnerabilities, and fragmented governance do not operate in isolation; rather, their overlap produces a compounded state of livelihood insecurity. The central overlap conveys how these forces mutually reinforce one another, narrowing adaptive options and intensifying systemic fragility. The figure thus serves as a visual synthesis of the study, emphasizing that resolving fisherfolk vulnerabilities requires simultaneous attention to ecological, economic, and institutional domains.

9. Conclusion and Policy Recommendations

The case of fisherfolk in Muhamma–Thannermukkam underscores how ecological degradation, livelihood precarity, and institutional fragmentation converge to create systemic vulnerability. Over two centuries of spatial contraction, compounded by the Thannermukkam barrage and ongoing pollution, have eroded the natural capital base of the lake, with the decline in prawn and pearlspot fisheries epitomizing the ecological loss. Survey data confirm high poverty incidence, income inequality, and financial fragility, while adaptive strategies—ranging from diversification and migration to reliance on welfare—demonstrate resilience but remain largely reactive, debt-driven, and ecologically constrained. Addressing this crisis requires a multi-pronged strategy that restores ecosystems, strengthens collective institutions, and creates pathways for sustainable livelihood diversification. At the local level, priority must be given to regenerating clam beds, enhancing fish stocks, and mitigating pollution, while simultaneously strengthening fisher cooperatives, improving access to health, housing, and education, and ensuring gender-sensitive interventions that recognize the critical but undervalued role of women.

Broader policy reform demands the establishment of co-management regimes where fisherfolk, scientists, and state agencies jointly govern hydrological operations, resource use, and habitat restoration, supported by participatory ecological monitoring that incorporates local knowledge. Investments in training for aquaculture, eco-tourism, and non-fishing occupations, alongside access to microfinance and low-interest credit, can help reduce dependence on exploitative lending and open new livelihood avenues. Equally crucial are infrastructural upgrades, including cold storage, hygienic landing centers, and resilient housing in flood-prone zones, coupled with cooperative-based marketing to improve value addition. Inclusive governance mechanisms must ensure fisher representation in lake management and harmonize agricultural, tourism, and industrial policies to reduce sectoral conflicts. Beyond its local importance, the Vembanad case speaks to global debates on the sustainability of inland fisheries under conditions of hydrological alteration, ecological stress, and governance exclusion. It resonates with the Sustainable Development Goals on poverty reduction, biodiversity conservation, and sustainable resource management, illustrating the need for integrated approaches that combine ecological resilience, socio-economic equity, and participatory governance. Sustaining livelihoods in southern Vembanad thus demands more than technical fixes; it requires rebalancing human–nature relations through co-management, restoring ecosystems, and empowering marginalized communities. The resilience of fisherfolk is evident, yet without structural transformations, their adaptive strategies will remain fragile. By situating a local struggle within global patterns, this study highlights both the urgency and universality of securing sustainable futures for inland fisher communities.

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