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Research Article

An Exploratory Analysis of Livelihood Conditions and Socio-economic Challenges Among Fishermen in the Southern Bengal Wetlands

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Abstract

Socio-economic status of an individual is their position in the society based on education, occupation and income. Artisanal fishermen who practise fishery in beels, boars or jheels use traditional crafts and gears for their economic status is precarious which hinders them to move on to sophisticated scientific tools and advanced machineries. In freshwater wetland ecosystems, the artisanal fishermen rely solely on seasonal catches and often face unpredictable yields due to environmental conditions. Educational attainment among the fishermen communities of South Bengal is still on the lower side which limits their ability to attain a secure livelihood through alternative or secondary sources Incomes are typically modest and irregular which barely covers their basic needs while leaving little to no room for savings and/or emergencies. The skills involved in fishing might get specialised with experience but these skills are non- transferable in nature. Adding to these challenges, larger family sizes put a heavy strain on the limited resources further as more members depend on a single and unstable income source. These factors such as poor education, uncertain income, specialised but narrow skills, family with many members all create a cycle of economic vulnerability that keeps many artisanal fishing families trapped in poverty.

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1. INTRODUCTION

Artisanal wetland fisheries have formed the backbone of livelihoods for millions of people in South Asia [1], it serves as a cornerstone of rural livelihoods, local economies for Eastern India and food security for the whole of India. In Southern Bengal, wetland fishermen face tremendous uncertainty due to fluctuating availability of fishes, limited starting capital/assets, weak bargaining power, degradation of the fragile wetland ecosystem, lack of other skills and shortage of any alternative work [2].

Tidal floodplain wetlands support millions of rural people in the south Bengal regions, where Artisanal fishery serves as a primary source of income, along with the primary source of essential animal proteins to fishing households. Studies from the Eastern parts of India, viz. West Bengal and Assam show that fishing is the primary occupation for about 70-90% of fishermen, with fisheries contributing to up to 60% of household income in many cases. [3,4]. On a national scale, India's 0.5 million ha of floodplain wetlands hold high fisheries potential but remain under-utilised and stressed by ecological degradation and weak management [5]

Despite their significant contribution, the communities of fishermen vet been largely found to be extremely poor, with very low to negligible asset bases, limited access to education, services and proper infrastructure [4,6-8]. Inland fishermen in India are the most marginalized community with vulnerability ranging from chronic poverty to lack of any other sources of income [3,7,9]. Economic vulnerability assessments in wetlands of Eastern India including parts of West Bengal and Assam fisheries reveal moderate to high vulnerability scores; These vulnerability scores can be highly regulated by better management of Co-operative societies stocking of fishes scientifically, diversification of their income portfolios, having landholdings [3]. Socio-economic studies of the fishermen in West Bengal have reported poor housing (permanent or temporary), very low rate of literacy, dependence on informal credit, and low and uncertain income from fishing which often necessitates the members of these communities for distress borrowing [7,8].

These chronic condition of their livelihood is fuelled further by multiple stressors. The wetlands have been degrading rapidly in the past decade due to siltation, land conversion, disruption or loss to river connectivity, pollution which ultimately undermines fishing habitats and threatens the live of the fishermen [3-5]. Climate and ecological changes and variability have further heightened the livelihood risks for wetland fishers [5,10]. The COVID-19 lockdown was a striking example of shock exposure, small-scale tidal floodplain wetland fishermen in Bihar, West Bengal and Assam lost a substantial number of fishing days, production, and income, with many became jobless intermittently and reported a high degree of psychological stress. Structural causes for artisanal fishery have been mainly attributed to economic exclusion, marginalization of the labourers, weak governance or poor government policies, unequal distribution of benefits which further deepens vulnerability and limits the adaptive capacity of the community [5,9,11].

Studies on Indian tidal floodplain wetlands highlights major governance gaps which includes lack of jurisdictional coordination, inequitable distribution of benefits, poorly managed co-operatives, and limited access to scientific knowledge and technology in fisheries serves as a block to ecological sustainability and economic vulnerabilities of the fishermen [3-512]. Integrated development approaches that combine culture-based fisheries (e.g., pen culture), improved stocking densities and participatory management have substantially increased fish production and incomes in West Bengal wetlands, including Duma [5,12].

The role of gender is becoming an important area to consider, since women may be involved in small-scale fishing practices and may attain economic freedom through proper support [12-14]. Although women have started taking part in fishing activities, their involvement in decision making and assessment process is negligible and still to gain momentum [11,13].

This paper aims to examine the livelihood conditions and socio-economic challenges faced by fishermen in the Southern Bengal wetlands through an exploratory study. The paper seeks to capture the high livelihood dependence, ecological stress, institutional complexity, and exposure to shocks of these fishermen whose households remain poorly understood at a fine-grained, local scale [3-5,12,15]. while also marking these realities with small-scale fisheries and wetland vulnerability. The study aims to provide an account of the fishermen community of southern Bengal whose labour sustains local food systems, but whose own livelihoods remain deeply uncertain and precarious.

2. LITERATURE REVIEW

Floodplain wetlands (bells/boars) provide varied ecosystem services like groundwater recharge, retention of nutrients and conservation of biodiversity in eastern India and they are often called as "biological supermarkets" as they are rich in fish diversity. [4,5,16]. India has ~0.5 million hectares of tidal floodplain wetlands harbouring about 96 fish species but the yield of fishery remains far below the potential (50 kg ha^{-1} yr^{-1} vs. 2000 kg ha^{-1} yr^{-1}), which prompts promotion of culture-based fisheries to raise production to ~400 kg ha^{-1} yr^{-1} [5].

In the lower Gangetic floodplain wetlands of West Bengal, (including North/South 24 Parganas and adjoining districts) which covers about 42,500 hectares and includes freshwater and brackish fishery systems which are locally called beel, baor and heel provides livelihood and nutritional security to fishermen and other wetland-dependent groups [12,17,18]. Coastal Sundaram wetlands, a tidal estuarine–mangrove complex serves the function of nursery grounds to brackishwater finfishes, shellfishes and support rich biodiversity, they are subjected to intense resource extraction and degradation [19,20].

As per several empirical studies carried out in the flooplain wetlands of West Bengal and Assam it was observed that fishing is the primary occupation of 60-90% of the fishermen surveyed contributing ≥60% of household income for large proportions of households; in Deepor Beel, all the households

derived at least 40% of their livelihood from the wetlands. Beel fishes serve as the only source of high-quality protein for about 68 to 71% of households in West Bengal which further underscores the nutritional role of wetland fisheries [4].
In the lower Gangetic wetlands of North 24 Parganas, artisanal fishermen communities are viewed within the frameworks of the Sustainable Development Goals. Wetland fisheries support "Life below water" (SDG 14), provisions for providing food (SDG 2), health (SDG 3) and gender-inclusive livelihood opportunities since women have started actively participating in artisanal fisheries. SIF from wetlands especially caters to "hidden hunger" by supplying essential micronutrient-rich animal protein to the local populations [12,21].

Despite their key role in sustaining the livelihood of millions of people, floodplain fishermen are themselves highly marginalised with low education, limited off-farm income and poor access to basic amenities [4,7,16]. In the studies conducted by Das et. al, (2021), he found that the economic vulnerability indices for fishermen households ranged from 0.14 to 0.33 on a 0-1 scale [16].

Numerous surveys on the living standards of the coastal fishermen in west Bengal have all directed that they have poor standards of living, low to no access to skill development or training, health insurance, credit and faces major stress due to uncertainty of catch and an unstable source of income. The development of inland fishery is jeopardized if there is no improvement in the livelihood of the fishermen [22]. Chakraborty, (2023) in their work on "Participatory Rural Appraisal for Assessing Freshwater Wetland Status and Fishery Potential in West Midnapore, West Bengal, India" have attributed low fishery productivity and dereliction of wetlands to poor management of the wetlands, pollution leading to declining water quality, low awareness and lack of scientific knowledge, technology and training. They also emphasised that if these barriers are addressed, the full potential of wetland fisheries will upliftment the standards of livelihood not just of the co munity but also of all Indians [18].
The prawn seed collection in tidal floodplain wetlands of Sundarbans is associated with large bycatch of juvenile finfishes and shellfishes which poses significant health risk to fishermen and ecological degradation. To combat this and promote sustainable harvesting regulatory intervention and environmental education needs to be provided to the fishermen [19]. Restrictive measures such as banning fishing to protect the Royal Bengal Tigers are counterproductive as this could lead to exacerbated socio-economic vulnerability and push the fishermen towards unsustainable and negotiated forms of fishing access, which might lead to corruption in the Sundarbans [23].
Beyond India, studies on various floodplain wetland fisheries in Indonesia and Bangladesh highlights that environmental change, large-scale development and climate hazards increase livelihood risk, while cultural assets and social capital strategies shape resilience and promote staying in coastal wetlands rather than emigrating [24,25].

Global warming which has led to a rise in temperatures by 0.18–0.28 °C over three decades and declining rainfall (135–257 mm) have been observed in North 24 Parganas, Nadia and Kolkata whichare the key West Bengal wetland districts. These changing trends in climate and rainfall higlights the sensitivity of floodplain wetlands [5]. Indigenous "climate smart" fisheries practice such as temporary enclosures, *kata*, autumn stocking, torch-light fishing, *komor* and *pana chapa* conserves base stocks and maintain recruitments [5].

3. RESEARCH METHODOLOGY

A. Study Area

The present study was conducted in the southern Bengal wetlands of the Sundarban region, West Bengal, India. Four major fishing sites, namely Fraserganj, Madanganj, Gobindapur, and Rakhalpur, were selected for the survey due to their active fisheries-dependent communities and livelihood reliance on marine and estuarine fishing activities.

B. Sampling Design

A cross-sectional survey design was adopted for the study. A total of 150 fishermen (N = 150) were selected through purposive random sampling, and the individual fisherman was considered as the unit of analysis. Data were collected using a structured and pre-tested interview schedule covering socio-personal, economic, occupational, and institutional variables. Information regarding age, education, family size, fishing experience, income pattern, indebtedness, social participation, craft and gear ownership, fishing effort, off-season occupations, women's participation in livelihood activities, communication channels, marketing practices, and occupational constraints was recorded.

C. Data Collection

Primary data were collected through face-to-face interviews conducted at the selected fishing sites using the structured interview schedule. The questionnaire included both close-ended and open-ended questions to obtain quantitative and qualitative information related to livelihood dependency, economic status, occupational diversification, borrowing behaviour, and fisheries-related challenges. The pioneer interview was conducted prior to the final interview and the necessary modifications were incorporated accordingly.

D. Weighted Household Asset Bubble Framework

A semi-quantitative Wealth/Asset Bubble Gradient Framework was developed as described by Hahn et al., (2009), with slight modification [27]. To assess the distribution and relative economic significance of household and productive assets among fishermen households. Asset ownership data were collected through structured household surveys. The surveyed assets included housing type (pucca house, tile shed, thatched hut), household assets (television, radio, wristwatch, mobile phone), and transport-related assets (cycle, rickshaw/van). Ownership percentage was calculated using,

$$\textbf{Ownership Percentage} = \frac{\mathbf{n_i}}{\mathbf{N}} \times \mathbf{100}$$

where $n_i$represents the number of households possessing the asset and Ndenotes the total number of surveyed households.

A semi-quantitative economic value score (EVS) was assigned to each asset based on its approximate replacement cost, socioeconomic importance, and livelihood relevance within the fishing community. Assets were scored on a five-point scale ranging from 1 (very low economic value) to 5 (very high economic value). A weighted asset score was subsequently calculated as:

$$\mathbf{WAS_i = O_i \times EVS_i}$$

were,

WAS_i- weighted asset score of the i^{th}asset

O_i- ownership percentage

EVS_i- assigned economic value score.

An economic value score was assigned based on the method given in **Table 1**.

Table 1. Economic value scoring framework for household assets among the fishermen communities

S. No.	Economic Interpretation	Assets Assigned	Rationale
1	Very low economic value	Thatched hut, Radio, Wristwatch	Common low-cost assets with minimal investment and limited economic significance
2	Low economic value	Tile shed (1 room), Cycle, Mobile phone	Basic utility assets with low replacement cost and moderate household importance
3	Moderate economic value	Tile shed (2 room), Television	Improved household assets reflecting moderate economic stability and living standard
4	High economic value	Pucca house (1 room), Rickshaw/Van	Assets associated with improved economic condition and/or income-generating potential
5	Very high economic value	Pucca house (2 room)	Major long-term household investments indicating higher socioeconomic status and wealth stability

Assets were assigned scores ranging from 1 to 5 based on ownership cost, utility, income-generating potential, and contribution to household stability.

E. Statistical Analysis

All statistical analyses were performed using GraphPad Prism. The normality of the data was evaluated using the Shapiro–Wilk test. As the data showed non-normal distribution, non-parametric tests were employed for further analysis. Differences between two groups were analysed using the Mann–Whitney U test, while correlations between variables were determined using Spearman's rank correlation coefficient. Correlation analysis was performed to determine the association among education score, seasonal income, fishing experience, family size, and debt level. Correlation coefficients were visualized using a heatmap matrix. Data are expressed as median values, and percentage-based data were presented graphically where applicable. A p-value < 0.05 was considered statistically significant.

All graphical representations including bar plots, pie charts, doughnut charts, scatter plots, bubble plots, Sankey diagrams, and heatmaps, were prepared using Origin pro, online tool Sankey MATIC (sankeymatic.com) and Microsoft PowerPoint.

4. RESULT

A. Socio-demographic profile of the surveyed fishermen community in the Sundarban region.

The socio-demographic characteristics of the surveyed fishermen community are presented in Figure 1. The age distribution of the respondents (Figure 1A) revealed that the majority of fishermen belonged to the 31–35 years age group (22.67%), followed by 36–40 years (16.00%) and 41–45 years (15.33%) categories (Figure 1A). Lower representation was observed among older age groups, particularly 51–55 years (6.00%) and 56–60 years (4.00%), indicating comparatively lower participation of elderly individuals in fishing activities.

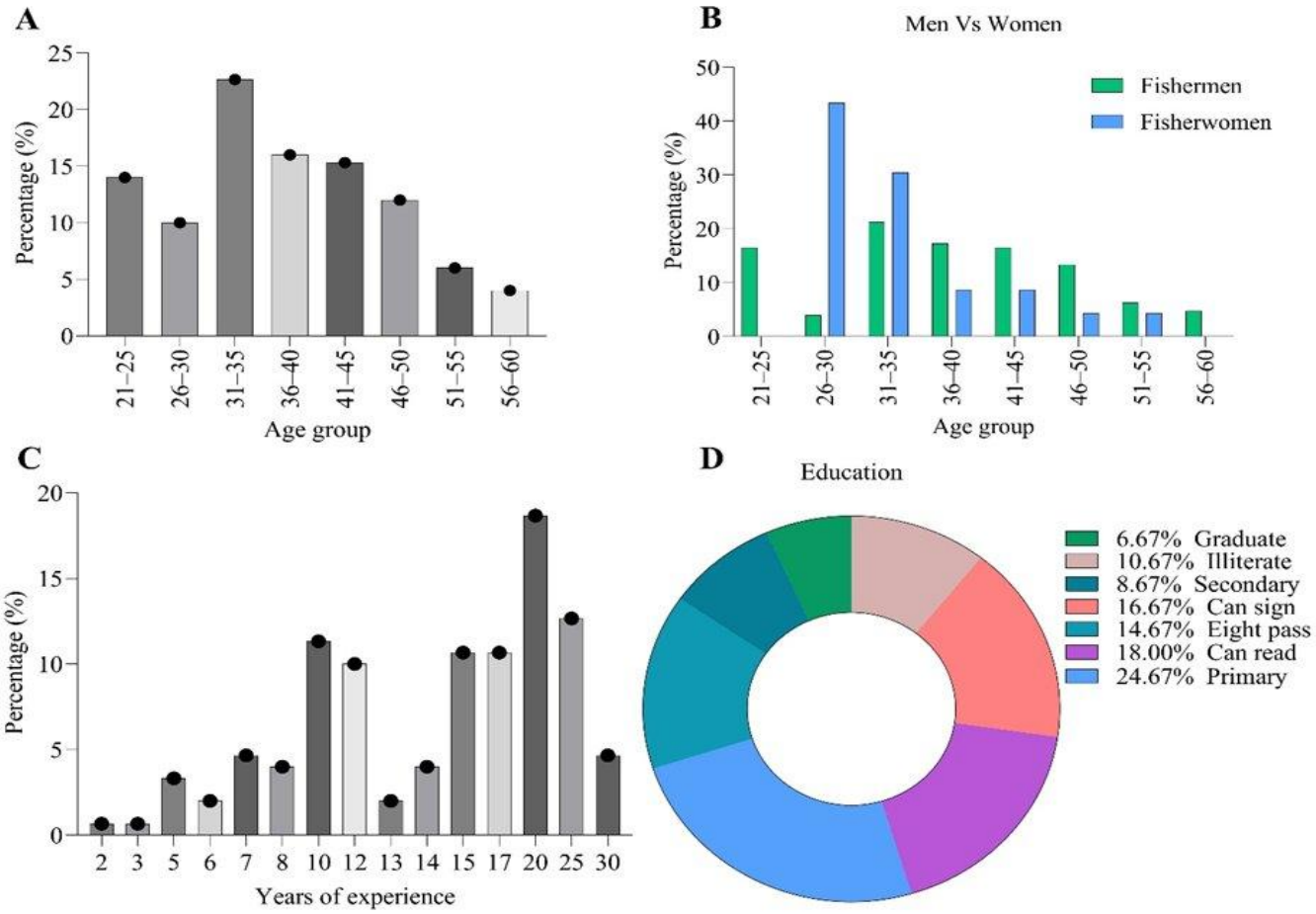

Figure 1: (A) Age-wise distribution of the respondents showing the highest representation in the 31–35 years age group. (B) Comparative age distribution between fishermen and fisherwomen across different age classes. (C) Distribution of fishing experience among respondents, indicating predominance of individuals with 20–25 years of fishing experience. (D) Educational status of the respondents represented as a donut chart, demonstrating that the majority of fishermen possessed primary-level education, while comparatively fewer respondents attained secondary and graduate-level education. (n=150)

Gender-wise age distribution (Figure 1B) showed noticeable variation between fishermen and fisherwomen (Figure 1B). Fisherwomen were predominantly concentrated within the 26–30 years (43.33%) and 31–35 years (30.33%) age groups, whereas fishermen were more evenly distributed across the productive age categories, especially 31–35 years (21.33%), 36–40 years (17.33%), and 41–45 years (16.67%). Participation of women sharply declined beyond 50 years of age.

Fishing experience (Figure 1C) among respondents ranged from 2 to 30 years (Figure 1C). The highest proportion of respondents possessed approximately 20 years of fishing experience (18.67%), followed by 25 years (12.67%) and 15–17 years (10.67% each), suggesting substantial long-term occupational dependence on fisheries.

Educational status (Figure 1D) analysis revealed that the majority of respondents had only primary-level education (24.67%), followed by those who could read (18.00%) and could sign only (16.67%) (Figure 1D). Relatively smaller proportions attained secondary education (8.67%) and graduation (6.67%), while 10.67% of respondents were illiterate.

The family size structure (Table 1) of the surveyed fishermen households is presented in **Table 2**. The majority of households consisted of 4 and 5 family members, each accounting for 22.67% of the total respondents. Households comprising 6 members constituted 17.33%, followed by 7-member families (10.67%) and 8-member families (9.33%). Smaller family units containing 3 members represented 8.67% of the respondents, whereas comparatively fewer households had larger family sizes of 9 (5.33%) and 10 members (3.33%).

Table 2: Distribution of family size structure among the surveyed fishermen households of the Sundarban region.

S. No.	Economic Interpretation	Assets Assigned	Rationale
1	Very low economic value	Thatched hut, Radio, Wristwatch	Common low-cost assets with minimal investment and limited economic significance
2	Low economic value	Tile shed (1 room), Cycle, Mobile phone	Basic utility assets with low replacement cost and moderate household importance
3	Moderate economic value	Tile shed (2 room), Television	Improved household assets reflecting moderate economic stability and living standard
4	High economic value	Pucca house (1 room), Rickshaw/Van	Assets associated with improved economic condition and/or income-generating potential
5	Very high economic value	Pucca house (2 room)	Major long-term household investments indicating higher socioeconomic status and wealth stability

The table represents the frequency and percentage distribution of fishermen households according to the number of family members. The majority of households consisted of 4–5 members (22.67% each), followed by households with 6 members (17.33%). Smaller proportions of households contained 9–10 family members.

B. Seasonal income variation and off-season livelihood diversification among fishermen households of the Sundarban region.

The livelihood diversification pattern and seasonal occupational dependence of the fishermen households are presented in Figure 2. A significant reduction ($p<0.0001$) in income was observed during the off-season period compared to the active fishing season (Figure 2A). The mean seasonal income of the respondents was substantially higher than the off-season income, indicating strong economic dependence on fisheries as the primary livelihood source.

During the off-season period, fishermen adopted multiple secondary occupations to sustain household income (Figure 2B). Agriculture emerged as the predominant alternative livelihood activity, accounting for 35.33% of respondents, followed by net making (30.67%) and labour work (23.33%). Comparatively fewer respondents were engaged in fish culture (5.33%), rickshaw/van driving (3.33%), and craft repairing (2.00%).

The Sankey diagram further illustrated the transition of fishermen from primary fishing activities to diversified off-season occupations (Figure 2C). Among the 150 surveyed fishermen, the majority shifted toward agriculture (n = 53) and net making (n = 46), while smaller proportions engaged in labour work (n = 35), fish culture (n = 8), rickshaw/van driving (n = 5), and craft repairing (n = 3).

The seasonal livelihood calendar demonstrated clear temporal variation in occupational engagement throughout the year (Figure 2D). Agriculture, labour work, and rickshaw/van driving were mainly practiced between January and June, whereas net making was concentrated during January–May and again in December. Fish culture activities were observed primarily between February and May, while craft repairing was mainly carried out during January–April and December.

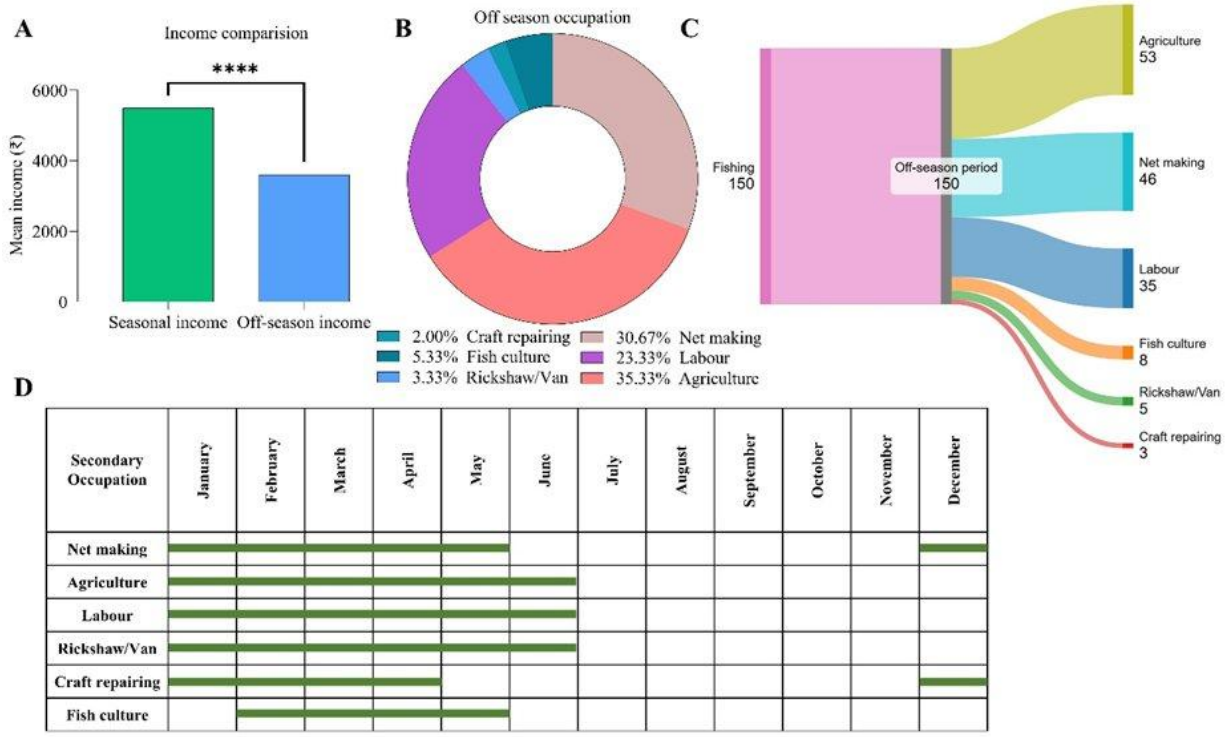

Figure 2: (A) Comparison between seasonal and off-season income of fishermen households, showing a significant decline in income during the off-season period (n=150; ****p < 0.0001; Mann–Whitney U test). (B) Percentage distribution of secondary occupations adopted during the off-season, indicating agriculture, net making, and labour work as the predominant alternative livelihood activities. (C) Sankey diagram illustrating the occupational transition of 150 fishermen from fishing activities to various off-season occupations, with agriculture and net making representing the major livelihood alternatives. (D) Seasonal livelihood calendar depicting month-wise engagement of fishermen in different secondary occupations such as net making, agriculture, labour work, rickshaw/van driving, craft repairing, and fish culture during the non-fishing period.

C. Income distribution, borrowing behaviour, household asset ownership, and indebtedness status among fishermen households of the Sundarban region.

The income pattern, borrowing behaviour, household asset ownership, and indebtedness status of the surveyed fishermen households are presented in Figure 3. The comparative income distribution revealed substantial variation between seasonal and off-season earnings (Figure 3A). During the fishing season, the majority of respondents were concentrated within the ₹4000–6000 income category, whereas off-season income predominantly shifted toward the lower ₹2000–4000 category, indicating considerable economic instability during periods of reduced fishing activity. Higher income categories (>₹8000) were comparatively less represented during the off-season period. Borrowing behaviour analysis demonstrated that fishermen households largely depended on informal credit systems for financial support (Figure 3B).

Moneylenders constituted the primary source of borrowing for 30.00% of respondents, closely followed by relatives (29.33%) and middlemen (26.00%). In contrast, fewer respondents relied on friends (8.67%) and co-operative societies (6.00%) for financial assistance.

The Weighted Household Asset Bubble Framework illustrated the distribution of household asset ownership in relation to their relative economic value scores (Figure 3C). Assets with lower economic value scores exhibited comparatively higher household ownership percentages, whereas highly valuable assets were possessed by relatively fewer households.

Assessment of indebtedness levels revealed that the majority of respondents (58.00%) were concentrated within the ₹1000–2000 debt category (Figure 3D). Moderate proportions of households reported debt levels between ₹5001–10000 (18.67%) and less than ₹1000 (10.67%), while comparatively fewer respondents experienced debt burdens exceeding ₹10000 (3.33%).

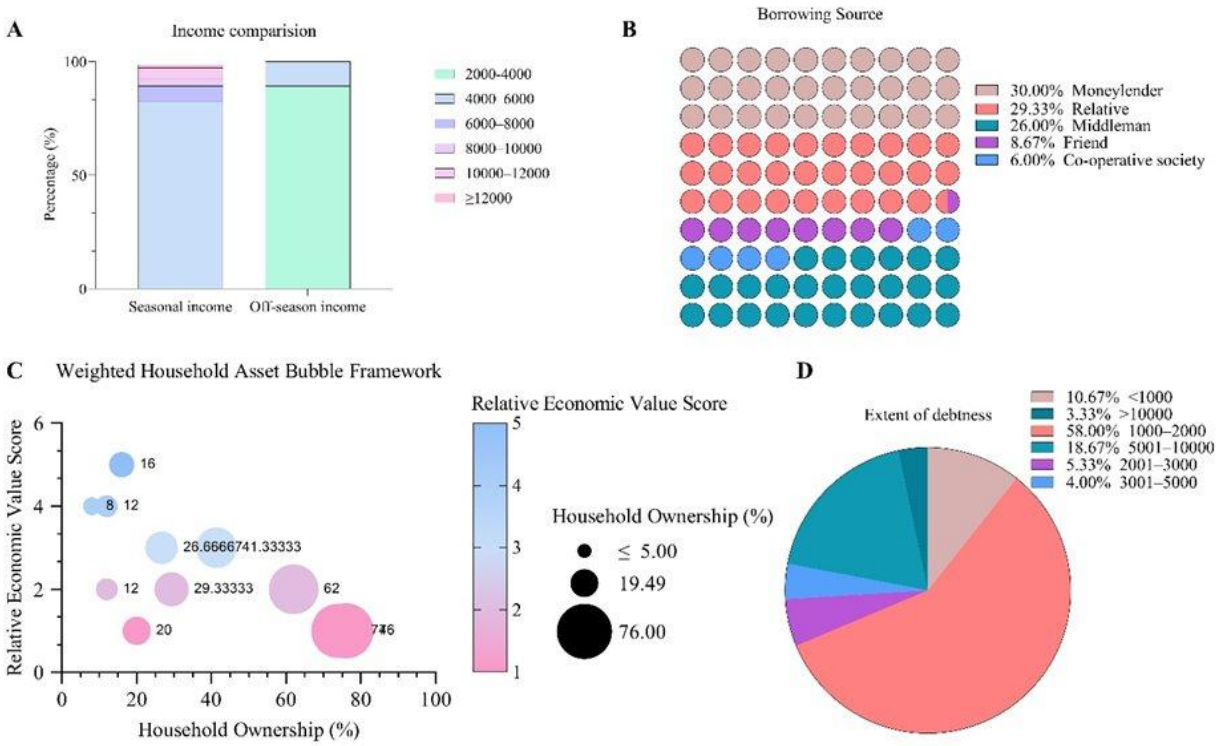

Figure 3: (A) Comparative percentage distribution of seasonal and off-season income categories among fishermen households, indicating a marked decline in income during the off-season period. (B) Distribution of major borrowing sources utilized by fishermen households, showing moneylenders, relatives, and middlemen as the dominant credit providers, while comparatively fewer respondents depended on friends and co-operative societies. (C) Weighted Household Asset Bubble Framework illustrating the relationship between household asset ownership (%) and relative economic value score. Bubble size represents the proportion of households possessing a particular asset, whereas color intensity indicates the relative economic value score (1–5). (D) Percentage distribution of indebtedness levels among respondents.

D. Correlation Analysis of Socio-economic and Livelihood Variables among Fishermen Communities

Figure 4 shows the correlation in the fishermen community among various socio-economic factors. The scatter plot (Figure 4A) demonstrates a strong positive correlation between fishing experience and seasonal income. Fishermen with greater years of experience generally earned higher seasonal income compared to less experienced fishermen. Individuals with 20–30 years of experience showed the highest income range, indicating that prolonged engagement in fishing improves technical skill, resource accessibility, market knowledge, and fishing efficiency. This suggests that occupational experience plays a major role in determining economic stability within the fishing community.

The relationship between seasonal income and debt amount (Figure 4B) appears weak and irregular. Although some fishermen with higher income also possessed higher debts, many individuals with moderate or low income were also indebted. The scattered distribution of points indicates that indebtedness is not solely dependent on income level. Other socio-economic factors such as family expenditure, fishing investment costs, seasonal uncertainty, weather dependency, and lack of financial security may contribute to debt accumulation among fishermen.

The heatmap (Figure 4C) provides an overview of interrelationships among socio-economic variables. Education score showed strong positive correlation with seasonal income ($r = 0.93$) and fishing experience ($r = 0.87$). Seasonal income and fishing experience were also highly positively correlated ($r = 0.94$). Family size exhibited strong negative correlations with education score ($r = –0.89$), seasonal income ($r = –0.91$), and fishing experience ($r = –0.82$). Debt level showed very weak correlations with all other variables ($r = 0.13–0.19$).

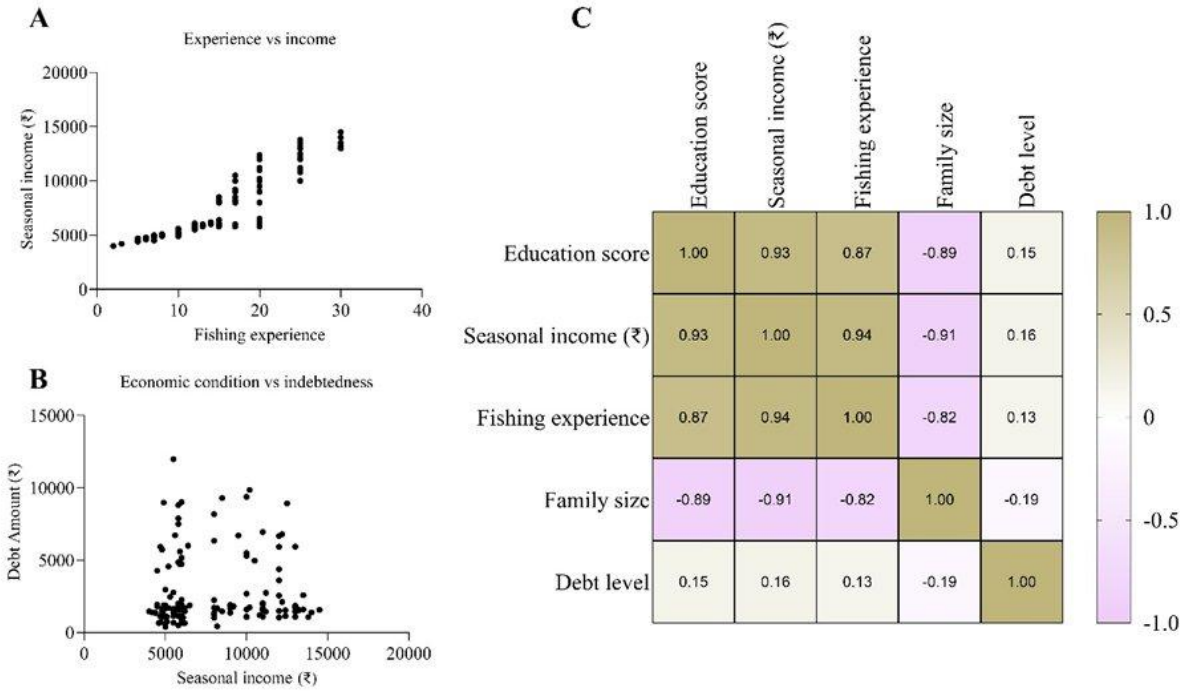

Figure 4: (A) Scatter plot showing the positive association between fishing experience and seasonal income among fishermen. (B) Scatter plot illustrating the relationship between seasonal income and debt amount, indicating variability in indebtedness across income groups. (C) Correlation heatmap representing the strength and direction of association among education score, seasonal income, fishing experience, family size, and debt level. Positive correlations are indicated by darker yellow shades, while negative correlations are represented by purple shades. Correlation coefficients range from −1 to +1.

5. DISCUSSION

The present study provides important insights into the socio-economic conditions, livelihood dependency, occupational diversification, and financial vulnerability of fishermen communities inhabiting the southern Bengal wetlands of the Sundarban region. The findings indicate that fisheries continue to serve as the principal livelihood source for coastal households, although the occupation remains highly vulnerable to seasonality, environmental uncertainty, and economic instability. Similar observations have previously been reported from the Indian Sundarbans, where fisheries-dependent households were found to experience multidimensional livelihood vulnerabilities associated with poor income security, ecological uncertainty, and limited livelihood alternatives [29].

The age structure of the respondents demonstrated predominance of economically productive middle-aged fishermen, particularly within the 31–45 years category. This reflects the labour-intensive nature of fishing activities, which generally require physical endurance and long-term occupational engagement. Lower participation of elderly fishermen may be associated with declining work capacity and increasing occupational risk in marine and estuarine ecosystems. Similar demographic patterns among small-scale fishing communities of the Sundarbans have been reported previously, where fishing was found to be dominated by middle-aged individuals due to physically demanding working conditions and declining attractiveness of the occupation among younger generations [29].

Educational attainment among the respondents was generally low, with most fishermen possessing only primary-level education or basic literacy. Limited educational access is a common characteristic of remote coastal communities in the Sundarban region and often restricts occupational mobility and access to institutional opportunities [30]. The strong positive correlation observed between education score and seasonal income suggests that education may improve fisheries-related decision-making, communication ability, awareness regarding government schemes, and adoption of diversified livelihood strategies. Better educational status may additionally enhance fishermen's capacity to negotiate market prices and access institutional financial support, thereby contributing to improved economic resilience.

The predominance of medium-sized households further reflects the socio-economic structure of traditional fishing communities. However, the strong negative relationship between family size and seasonal income indicates that larger households impose substantial economic pressure on fisheries-dependent families. Similar findings have been reported from vulnerable coastal regions where household dependency ratios directly influence livelihood insecurity and debt accumulation. Larger families generally require greater expenditure on food, healthcare, and education, thereby reducing household savings and increasing vulnerability during periods of reduced fishing activity.

Fishing experience emerged as another important determinant of livelihood condition. Respondents possessing greater fishing experience demonstrated comparatively higher seasonal

income, supported by the strong positive correlation between fishing experience and income. Long-term occupational involvement likely improves technical knowledge, fishing efficiency, understanding of tidal systems, and access to productive fishing grounds. Previous studies on small-scale fisheries have similarly highlighted the importance of traditional ecological knowledge and experiential learning in sustaining fishing productivity and household income [28].

Despite the positive influence of experience and education, the fishing community exhibited pronounced seasonal economic instability. Seasonal income was significantly higher than off-season income, indicating heavy livelihood dependence on fisheries resources. Such dependence is characteristic of the Sundarban coastal ecosystem, where fishing opportunities fluctuate due to climatic variation, fishing bans, cyclones, and ecological changes [23]. The marked decline in off-season income explains the widespread adoption of supplementary occupations including agriculture, net making, and labour work. These activities represent adaptive livelihood strategies that enable households to maintain economic continuity during non-fishing periods. Similar occupational diversification has been documented among small-scale fisheries communities across the Sundarbans, where households rely on multiple low-investment livelihood activities to cope with seasonal uncertainty [28].

The Sankey analysis and seasonal livelihood calendar further demonstrated that occupational diversification is temporally synchronized with fishing inactivity. Agriculture and labour work were predominantly practiced during the early months of the year, whereas net making increased prior to active fishing periods. This reflects strategic labour allocation among fishermen households aimed at maximizing resource utilization throughout the year. Such adaptive behaviour is particularly important in ecologically fragile systems like the Sundarbans, where environmental disturbances and fishing restrictions frequently disrupt livelihood stability [23].

Financial vulnerability was further evident from borrowing behaviour and indebtedness patterns. Most fishermen depended on moneylenders, relatives, and middlemen rather than institutional credit systems. Dependence on informal lending systems has repeatedly been identified as a major socio-economic concern among coastal fishing communities due to poor access to formal banking facilities, lack of collateral security, and urgent financial requirements during lean fishing seasons [28]. Dependence on middlemen may additionally reinforce exploitative market structures, where fishermen remain economically tied to intermediaries for both credit and fish marketing.

Although most respondents belonged to low-to-moderate debt categories, the weak correlation between income and indebtedness suggests that debt accumulation is influenced by multiple interacting stressors rather than income alone. Seasonal unemployment, fishing gear maintenance, healthcare expenditure, climatic disasters, and household dependency may collectively contribute to chronic financial instability. The unequal ownership of economically valuable household assets further supports this observation, indicating varying degrees of livelihood resilience among households. Families possessing fewer high-value assets may remain more susceptible to occupational shocks and environmental uncertainty.

Overall, the findings demonstrate that livelihood sustainability among fishermen communities of the Sundarban region is shaped by complex interactions among education, occupational experience, household dependency, seasonal livelihood instability, and financial vulnerability. Strengthening institutional credit access, promoting diversified livelihood opportunities, improving educational support, and enhancing fisheries-related skill development programs may therefore contribute substantially toward improving socio-economic resilience and long-term livelihood security among coastal fishing households.

6. CONCLUSION

The socio-economic vulnerability of fishermen communities in the tidal floodplain wetlands of Sundarban indicates that fisheries remain the primary source of livelihood for a large number of people residing there. Strong seasonal dependence leads to significant income uncertainty during off-season periods and during periods with high environmental variability. To cope with economic vulnerability, fishermen have started adopting secondary occupations such as agriculture, net making, and labour work. Low educational attainment, dependence on informal credit systems, and unequal household asset ownership further contributed to livelihood insecurity. Correlation analysis have revealed that income is positively and strongly correlated with education and fishing experience and negatively correlated with larger family size. The study bolsters the need for livelihood diversification among the fishermen communities, institutional financial support, and sustainable fisheries management to improve the socio-economic status of this community.

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Conflict of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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