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Coastal Livelihoods under Pressure: Vulnerability and Adaptation among Bangladesh's Small-Scale Fishers

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Abstract: The Small-scale fisheries are crucial for sustaining livelihoods and ensuring food security in coastal Bangladesh. These communities encounter increasing socio-ecological challenges stemming from climatic unpredictability, institutional neglect, and policy deficiencies. This research combines the Livelihood Vulnerability Index (LVI) and the Sustainable Livelihoods Approach (SLA) to evaluate household vulnerability and adaptation capability in Char Bhaga Union, in the Lower Meghna River estuary. The study used a mixed-methods methodology, comprising 130 household surveys, eight focus group discussions (FGDs), and 12 key informant interviews (KIIs), therefore offering both quantitative data and qualitative insights. The LVI score of 0.62 signifies substantial vulnerability, especially among households with less education, erratic income, and restricted access to institutional safety nets. Gender studies indicate the structural marginalization of women from fishing cooperatives, training initiatives, and compensation programs, despite their significant involvement in post-harvest operations. Institutional deficiencies, such as ineffective enforcement of sanctuary legislation, politicized allocations of aid, and insufficient participatory planning, further erode resilience. Coping mechanisms are predominantly reactive (e.g., seasonal relocation, asset liquidation), whereas proactive adaptation is confined to households with access to remittances or NGO assistance. The study provides a thorough understanding of resilience pathways by integrating LVI measurement with SLA's asset-based perspective. The findings enhance the literature on fisheries governance in South Asia and promote inclusive co-management, gender-responsive initiatives, and focused livelihood investments in accordance with Sustainable Development Goals 1, 5, 13, and 14. The suggested dual-framework approach functions as a repeatable instrument for policymakers seeking to include vulnerability diagnostics in national adaptation programs.

Keywords: Coastal livelihoods, Vulnerability Index, Sustainable Livelihoods Approach, Small-scale Fisheries, Bangladesh

Article History:

Received: 12 February 2025

Accepted: 22 April 2025

Online: 23 April 2025

Corresponding author: sazzad@pathfinderconsultant.com

Citations: Ema, S. J., Das, A. R., & Sazzad, S. A. (2025). Coastal Livelihoods under Pressure: Vulnerability and Adaptation among Bangladesh's Small-Scale Fishers. *Pathfinder of Research*, *3*(1), 42-71

1. Introduction

Bangladesh, located at the confluence of the Ganges, Brahmaputra, and Meghna rivers, is one of the most densely inhabited and environmentally varied coastal areas globally. These estuaries sustain abundant biodiversity and function as essential livelihood centres, particularly for those involved in small-scale artisanal fisheries. In these areas, where industrial job prospects are limited, small-scale fishermen play a crucial role in maintaining food supply and family economics **(Islam et al., 2025).** The artisanal fisheries industry accounts for more than 80% of the nation's total fish harvest and employs about 12 million individuals, either directly or indirectly **(DoF, 2023; Chen et al., 2024)**. Notwithstanding their critical function, these communities continue to be socioeconomically marginalized, ensnared at the intersection of environmental vulnerability, institutional disregard, and persistent poverty.

The lower Padma and upper Meghna rivers are essential, functioning as vital spawning and migratory sites for hilsa (*Tenualosa ilisha*), the national fish of Bangladesh. Hilsa constitutes over 11% of national fish output and provides nearly 1% to GDP, directly sustaining over 500,000 fishers and helping more than 2.5 million individuals across its value chain **(Alam et al., 2023; DoF, 2023).** The government has established many sanctuary zones and enforced seasonal fishing prohibitions to protect hilsa numbers, especially during their mating season. Although biologically essential, these conservation efforts considerably impede the livelihoods of fishermen reliant on seasonal fishing access. These disruptions are intensified by increasing climatic variability and environmental deterioration. The area has seen heightened river erosion, saline intrusion, siltation, and unpredictable monsoons in recent decades. These stresses have resulted in decreased catch per unit effort (CPUE), recurrent damage to fishing gear during erratic storms, and alterations in hilsa migratory pathways rendering conventional ecological information more unreliable **(Kabir et al., 2021; Alam et al., 2022).** Such shocks reduce household income and threaten access to food, healthcare, and children's education, thereby exacerbating cycles of precarity. Ecological conservation policies frequently lack sufficient societal protection. The government's 22-day yearly restriction on hilsa fishing, while scientifically warranted, inflicts significant suffering. Support initiatives such as the Vulnerable Group Feeding (VGF) plan are designed to offer rice-based compensation but sometimes face criticism for irregular coverage, political bias, and accusations of corruption **(Hossain et al., 2018; Mohammed et al., 2020).** Numerous qualifying households indicate postponed or rejected assistance, undermining confidence in governmental institutions.

The lack of gender-sensitive programming undermines the effectiveness of social protection. The majority of fishermen lack legal acknowledgement, strong property rights, and access to institutional financing. Numerous individuals remain ensnared in exploitative connections with aratdars (middlemen), who impose exorbitant interest rates in exchange for exclusive fishing rights. Infrastructural deficiencies such as insufficient cold storage, cyclone shelters, and embankments further constrain resilience. These limitations are exacerbated by pervasive illiteracy and insufficient access to capacity-building initiatives, particularly among women and youth **(Dasgupta et al., 2010).** Although current literature has examined the economic difficulties faced by small-scale fisheries, most studies depend on limited indicators such as income levels or fish yield to evaluate susceptibility **(Imbwae et al., 2025)**. These measurements do not adequately reflect the complex character of vulnerability, which is influenced by several intersecting factors such as exposure to shocks, sensitivity to pressures, and adaptive capability **(Allison et al., 2009).** The Sustainable Livelihoods Approach (SLA) mitigates this constraint by evaluating five kinds of livelihood assets: natural, physical, financial, human, and social capital. This asset-based approach, created by the UK Department for International Development (DFID), provides a comprehensive understanding of individuals' responses to risk.

However, SLA alone is inadequate for quantifying vulnerability levels or facilitating comparisons among families and regions. The Livelihood Vulnerability Index (LVI) has evolved as a supplementary tool to address this gap, converting the concepts of the Sustainable Livelihoods Approach (SLA) into quantifiable indicators, classified into exposure, sensitivity, and adaptive capability **(Hahn et al., 2009).** When combined, SLA and LVI provide a comprehensive framework for assessing and comparing household vulnerability while reflecting context-specific reality. The incorporation of gender and intersectionality into vulnerability assessments is equally essential. Women in coastal fishing villages have a significant role in net mending, fish processing, drying, and selling; nonetheless, their contributions are predominantly overlooked in surveys and policy **(Jentoft, 2014; Adam et al., 2024).** Social norms, movement constraints, and institutional disregard further impede their access to training, financing, and decision-making opportunities. Similarly, marginalized groups, including ethnic minorities, migrant families, and households with handicapped individuals, experience systematic exclusion from social services, permissions, and co-management frameworks **(Ellis, 2000; Badjeck et al., 2010)**. Despite the introduction of community-based co-management systems in Bangladesh, their effectiveness is frequently undermined by top-down implementation and elite capture. The limits of sanctuaries are sometimes ambiguous, and community involvement in oversight or regulation formulation is limited. Fisheries committees often lack credibility due to the predominance of absentee stakeholders or political figures **(Islam et al., 2022; Hossain et al., 2024).** As a result, fishermen

experience alienation from policy processes and are less inclined to adhere to legislation they did not help formulate, especially when support is uneven or lacking.

This study investigates the multifaceted aspects of livelihood vulnerability and adaptability among small-scale fishermen in Char Bhaga Union, Bhedarganj Upazila, in one of Bangladesh's ecologically vital yet economically disadvantaged hilsa sanctuary zones. The study used SLA and LVI frameworks to examine how layered hazards, encompassing environmental to institutional factors, are encountered and managed at the home level. The study utilizes a mixed-methods approach, incorporating 130 household surveys, eight focus group discussions (FGDs), and twelve key informant interviews (KIIs) with fishery officials, NGO personnel, and community leaders. This triangulation provides empirical breadth and qualitative depth, emphasizing both the existence of vulnerabilities as well as their perception and negotiation. This study, defined in national development frameworks like the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) and Delta Plan 2100, contributes in three significant ways: it operationalizes the SLA-LVI synergy to reveal systemic livelihood vulnerabilities, it prioritizes gender and intersectionality in the climate adaptation discourse, and it provides informed policy recommendations that encapsulate the lived experiences of coastal fishing communities. This research ultimately contests the portrayal of small-scale fishermen as passive beneficiaries of aid, repositioning them as custodians of knowledge and agents of resilience, warranting inclusive policy involvement and strategic investment.

2. Methodology

2.1 Study Area

This study was conducted at Char Bhaga Union, under Bhedarganj Upazila of Shariatpur District, positioned along the central coastline region of Bangladesh. This region is situated within the lower Padma and upper Meghna River systems, ecologically vital areas designated as hilsa sanctuaries. Char Bhaga was intentionally chosen because of its significant dependence on small-scale fishing, susceptibility to climate-related risks, and restricted access to institutional resources. The area undergoes seasonal river movement, frequent flooding, inadequate embankment protection, and a significant reliance on aquatic resources for subsistence. The contextual circumstances provide Char Bhaga an exemplary location for examining multidimensional livelihood risk.

2.2 Research Design

A mixed-methods study approach was used to thoroughly elucidate the intricate and multifaceted aspects of livelihood vulnerability and resilience. This methodology combines quantitative and

qualitative data to facilitate triangulation, enhance internal validity, and provide contextual depth **(Creswell & Plano Clark, 2017).** The research employed the Sustainable Livelihoods Approach (SLA) as its principal analytical framework, assessing five categories of livelihood capital: natural, physical, human, social, and financial.

The study developed the Livelihood Vulnerability Index (LVI) to operationalize vulnerability using the Intergovernmental Panel on Climate Change's (IPCC) framework, which categorizes indicators into three components: exposure, sensitivity, and adaptive capability **(Hahn et al., 2009).** The amalgamation of SLA and LVI facilitates both diagnostic understanding and measurable evaluation of household-level vulnerability across several dimensions.

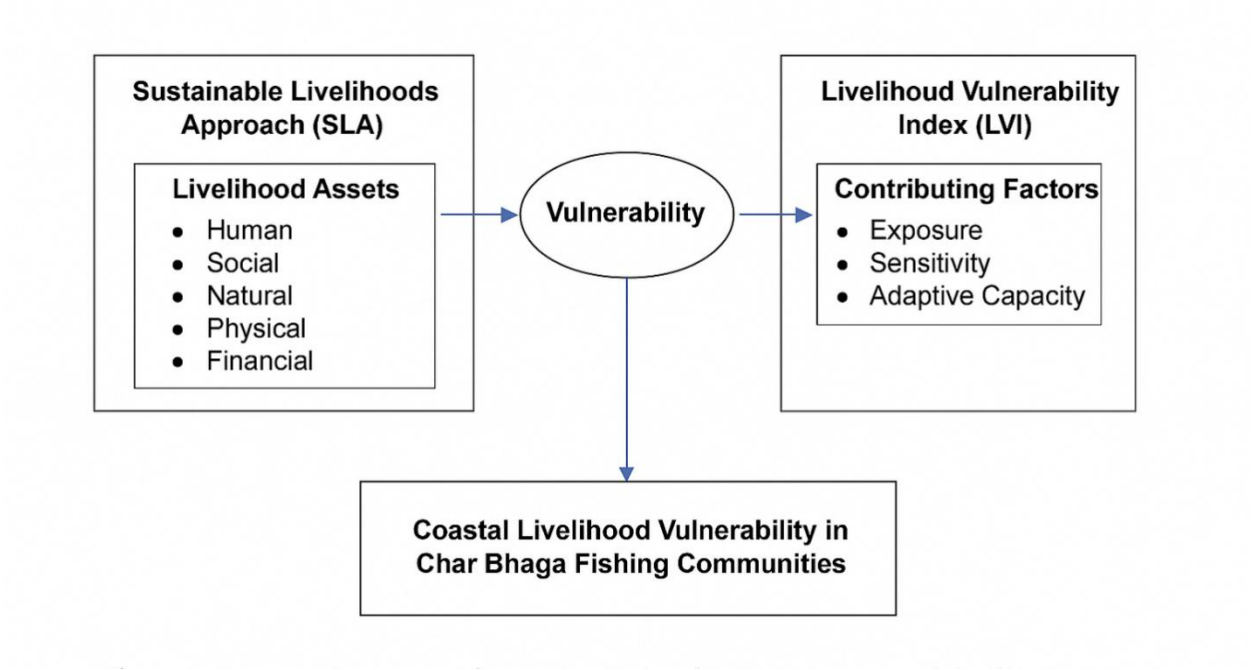

Figure 1. *Conceptual Framework: Integrating SLA and LVI*

This framework merges SLA's asset-based lens with LVI's vulnerability quantification across exposure, sensitivity, and adaptive capacity providing a robust, hybrid methodology for diagnosing vulnerability and guiding policy interventions.

2.3 Sampling Strategy

A stratified random sampling method was employed to select a representative sample of 130 homes involved in small-scale fishing. The sample frame was sourced from the local union council register

and corroborated with community leaders. Stratification was predicated on three key variables: proximity to river channels; type of principal fishing apparatus employed (e.g., gillnets, set-bagna); and household income status.

This ensured the integration of various fisher sub-groups inside the union. The structured questionnaire was piloted in a neighboring community and subsequently revised to improve clarity, cultural suitability, and local relevance. The household survey collected comprehensive data on demographics, education, income diversity, fishing methods, asset ownership, exposure to climatic events, and access to institutional support systems. Intra-household gender roles and their contributions to livelihoods received particular attention.

2.4 Qualitative Approaches

Researchers executed eight Focus Group Discussions (FGDs) and twelve Key Informant Interviews (KIIs) to enhance survey data and explain the socio-cultural and institutional aspects of vulnerability. The focus group discussions were conducted with certain sub-groups, comprising male fishermen, women from fishing homes, youth, senior participants, and community leaders. Each focus group discussion included 6–10 participants and was directed by a semi-structured methodology examining issues such as seasonal migration, adaptation techniques, credit systems, and views of policy efficacy.

The key informant interviews focused on individuals with institutional expertise and community understanding, such as fisheries officers, NGO representatives, local government officials, educators, and traditional leaders. The interviews provide essential contextual insights into co-management techniques, social safety nets, and governance issues. All qualitative sessions were audio-recorded (with consent), transcribed verbatim, and thematically coded with NVivo software.

2.5 LVI Construction and Scoring

The **Livelihood Vulnerability Index (LVI)** was constructed following the method developed by Hahn et al. (2009), which standardizes diverse indicators into a composite index. The LVI framework is divided into three core components:

- **Exposure**: Frequency and severity of climate-related shocks (e.g., cyclones, river erosion, rainfall variability)
- **Sensitivity**: Dependence on fisheries income, food insecurity levels, and access to infrastructure
- **Adaptive Capacity**: Education level, asset ownership, institutional linkages, and participation in collective action

In total, 26 sub-indicators were selected based on their contextual relevance to coastal fishing communities and alignment with existing literature on livelihood vulnerability **(Hahn et al., 2009; Islam et al., 2022).** These indicators reflect the socio-environmental, financial, and institutional stressors prevalent in the Char Bhaga context. Each indicator was normalized to a unitless scale ranging from 0 (least vulnerable) to 1 (most vulnerable) using the min-max transformation formula:

$$\text{Standardized Value} = \frac{S_i - S_{min}}{S_{max} - S_{min}}$$

Standardized value =

Sub-component scores were aggregated using weighted means to calculate component scores. The final LVI was computed as:

$$\text{LVI} = (E - AC) \times S$$

LVI =

where E = Exposure, AC = Adaptive Capacity, and S = Sensitivity.

This formula captures how exposure and sensitivity amplify vulnerability when not adequately balanced by adaptive capacity. This approach allows for cross-household comparison and identifies specific dimensions of vulnerability requiring targeted policy attention. Component scores were also compared across demographic variables (e.g., female-headed households, income quintiles) to reveal distributional inequities.

2.6 Ethical Considerations

Ethical adherence was maintained throughout all phases of the investigation. Participants were informed about the study's aims, confidentiality measures, and their entitlement to withdraw at any moment. Informed verbal consent was secured from all subjects before data collection commenced. No personal identities were documented in the survey or qualitative transcripts. The ethics committee of the principal research institution examined and approved the research protocol in compliance with the Helsinki Declaration on research involving human subjects **(WMA, 2013).**

Particular caution was taken during focus group discussions and key informant interviews with marginalized groups (e.g., female-headed families, individuals with disabilities) to guarantee inclusive participation and prevent exploitative data-gathering methods. Participation was wholly voluntary,

and respondents received no pecuniary incentives, consistent with ethical best practices in development research.

2.7 Data Evaluation

Quantitative data was analyzed using SPSS (v26) and Microsoft Excel for descriptive statistics, frequency distributions, and index computation. Livelihood assets and LVI components were organized and illustrated using bar graphs and radar plots for improved comprehension.

We conducted a thematic analysis of qualitative data from focus group discussions and key informant interviews using a grounded theory methodology. Transcripts were categorized into first-order themes (e.g., debt, food insecurity, institutional trust), which were further grouped into higher-order categories according to the SLA and LVI frameworks. We utilized NVivo software to ensure coding reliability and uniformity in data handling.

This combined method of using exact numbers along with in-depth information helped us fully assess the structural problems that lead to vulnerability, the ways locals adapt, and how resilience patterns develop among small-scale fishermen in the area we studied.

3. Results

3.1 Demographic and Livelihood Profile

The small-scale fishing households explored in the Char Bhaga Union exhibit a demographic profile characterized by socioeconomic marginalization and environmental vulnerability. The mean household size was 5.2 individuals, aligning with national rural statistics. Of the 130 households polled, 84% designated fishing as their principal profession, and the other 16% indicated supplementary income sources, such as wage labor, poultry keeping, homestead gardening, and minor commerce. Approximately 21% of families participated in seasonal migration to urban centers, especially for employment in construction and brick kiln industries, during fishing ban seasons. This finding indicates an increasing trend of adaptive labor mobility in the context of limited livelihood opportunities **(Sunny et al., 2019).**

Educational achievement was significantly deficient, with about 28% of household heads indicating literacy. This educational disparity obstructs access to formal credit, understanding of fishing legislation, and participation in bureaucratic processes. Focus group discussions indicated that illiteracy continues to be a substantial obstacle to educational programs and alternative career opportunities. Only 35% of youngsters aged 15 to 25 indicated an interest in pursuing fishing as a long-term career, attributing their reluctance to economic instability, social shame, and a perceived absence

of feasible opportunities in the field.

The divisions of labour by gender were significant. Despite 43% of women contributing to household income via post-harvest activities such as fish drying, net mending, and bait preparation, their labour predominantly remained informal and uncompensated. Women were systematically marginalized from training programs, cooperatives, and safety net initiatives. Younger women expressed interest in alternative livelihood options, such as tailoring and ICT-based microenterprises, but encountered obstacles owing to restricted access to training, dangerous transportation, and societal constraints **(Alam et al., 2023; Ifty et al., 2023b)**.

Multi-generational accounts of livelihood decline surfaced among respondent groups. Veteran fishermen reminisce abundance, while younger participants characterized participants the industry as become 47-year-old male participant expressed, "Fishing has no longer been a noble profession; it has now become a risk against nature and legislation." This emotion illustrates the existential difficulty encountered by several households: a profound cultural affinity for fishing contrasted with diminishing ecological and economic sustainability. The demographic figures reveal a community at a pivotal juncture rooted in tradition yet increasing the combination of low education, rigid job opportunities, and disappointment about jobs passed down through generations indicates that the community struggles to adapt, similar to trends seen in coastal South Asia **(Islam et al., 2022; Sunny et al., 2025a).**

3.2 Status of Livelihood Assets

The study evaluated five essential livelihood assets: natural, physical, human, and social capital, using the Sustainable Livelihoods framework. The results show major problems in all areas, indicating that families are at risk due to environmental issues and ongoing lack of development, along with a long-term decline in their resources. their resources.

Natural Capital

Natural capital is under significant strain from river siltation, estuary contamination, overfishing, and the mechanized trawlers in artisanal fishing areas. Approximately 67% of families indicated a decrease in fish catches during the preceding five years. Focus group discussions linked this tendency to modified hilsa migratory pathways, habitat deterioration, and increased competition from commercial fleets. Participants observed that previously fruitful fishing areas had turned “ecologically desolate” during peak seasons, jeopardizing both food security and economic stability.

Physical Capital

Households had considerable deficiencies in physical infrastructure. Appareled on non-motorized vessels, which restricted fishing range and safety. Furthermore, 70% inhabited tin-roofed dwellings that are significantly susceptible to floods and tidal surges. Merely 6% have access to cyclone shelters within a 1 km radius, presenting life-threatening hazards during storm. People often identified the absence of cold storage and preservation facilities as a significant obstacle to engaging in fisheries value chains **(Fakhruddin et al., 2022)**.

Financial Capital

Financial capital was constrained resources Only 12% of families utilized conventional banking or microfinance institutions, while institutions, while 88% relied on informal moneylenders or *aratdars* (intermediaries), sometimes at interest rates of 10-15% each month. These exploitative relationships diminish profitability, constrain financial liberty, and obstruct investment in alternative income-generating activities (AIGAs).

Human Capital

In addition to poor literacy rates, households had persistent health and nutritional issues. Survey findings indicated that 43the age of five under the age of five were underweight during fishing restriction times, highlighting seasonal food insecurity. Less than 9% of individuals have undergone vocational or disaster preparedness training in the preceding five years. The deficiencies in skills and knowledge markedly diminish household ability to adjust to climatic shocks or attain diverse jobs.

Social Capital

Social cohesiveness and institutional engagement were inadequate. Merely 17% of families indicated membership in cooperatives, savings clubs, or fishery committees. Participants identified distrust, historical corruption, and elite hegemony as factors contributing to disengagement. The degradation of social capital diminishes both communal risk-sharing and access to institutional resources.

Table 1. Livelihood Asset Capital Assessment for Small-Scale Fishers in Char Bhaga Union

Capital Type	Mean Score (0–1)	Key Indicators	Observed Challenges	Policy/Intervention Implications
Natural	0.34	Fish catch, river health, access to fishing	River siltation, pollution, hilsa migration disruption	Ecological restoration, gear zoning, trawler enforcement
Physical	0.38	Housing, boat type, cyclone shelters, storage	No cold storage, unsafe housing, limited transport	Infrastructure upgrades, solar cold chains, boat subsidies
Financial	0.28	Credit access, savings, debt burden	Dependence on moneylenders, banking exclusion	MFI access for fishers, group savings, subsidized loans
Human	0.31	Literacy, health/nutrition, vocational skills	Underweight children, low literacy, lack of training	Literacy drives, food aid during bans, targeted training
Social	0.33	Group participation, trust in institutions	Weak cooperatives, elite capture, declining trust	Co-management revival, women-led groups, transparent representation

The results indicate that financial capital (0.28) and human capital (0.31) were the most underdeveloped, underscoring systemic barriers to resilience. These findings resonate with similar studies from the Bay of Bengal that emphasize how asset deficits constrain adaptation in fishing communities **(Islam et al., 2016 Adam et al, 2024).**

3.3 Household-Level Livelihood Vulnerability Index (LVI) Analysis

The Livelihood Vulnerability Index (LVI) for Char Bhaga Union was determined to be 0.62, indicating significant vulnerability among small-scale fishing households. This index was generated from 26 sub-components within the three primary domains: exposure, sensitivity, and adaptive ability. The most

elevated vulnerability ratings were noted in the financial and natural capital sectors. Households exhibited a significant reliance on fishing revenue and limited access to finance, rendering them particularly vulnerable to seasonal disruptions. Exposure ratings were heightened because of recurrent cyclones, river erosion, and diminishing fish populations. Despite the persistence of social capital via informal networks, these networks were frequently male-dominated and devoid of institutional backing. The vulnerabilities of human capital were exacerbated by inadequate literacy, substandard health, and exclusion from educational opportunities. Physical capital, including access to storm shelters and secure housing, was significantly deficient in distant regions **(Sunny et al., 2025b)**.

Table 2. Component-wise LVI Scores by Capital Asset and Vulnerability Dimension

Capital Asset	Adaptive Capacity	Sensitivity	Exposure	LVI Score
Human Capital	0.56	0.49	–	0.52
Natural Capital	–	0.61	0.67	0.64
Financial Capital	0.68	0.59	–	0.63
Social Capital	0.48	–	0.46	0.47
Physical Capital	0.52	0.53	0.59	0.55
Overall LVI	–	–	–	0.62

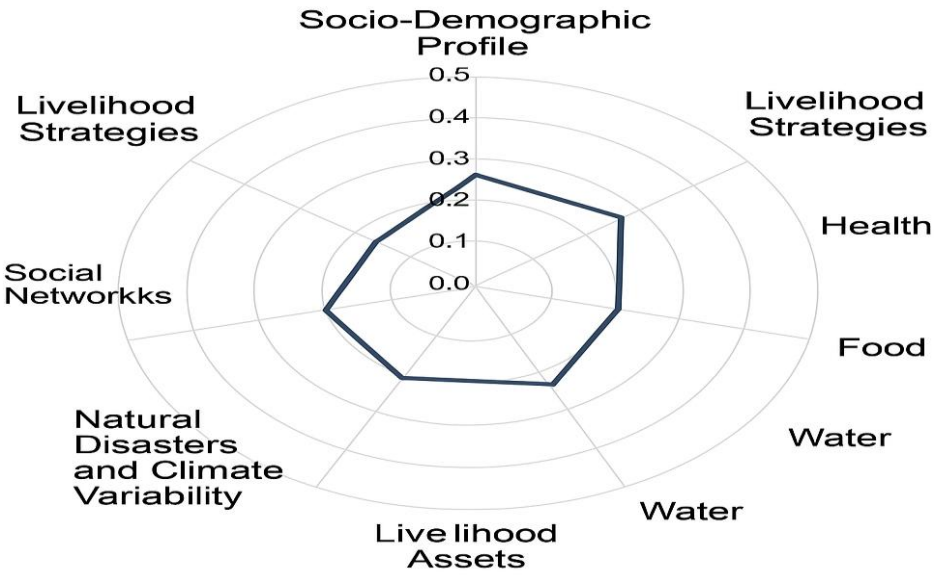

Figure 2. Radar Chart of Component-wise LVI Scores by Capital Asset

This visualization demonstrates the overlapping deficits in adaptive capacity, sensitivity, and exposure. Notably, households lacking cyclone shelters also faced limited income diversity and higher child malnutrition rates. Female-headed households consistently scored lower across human and financial capital domains, underscoring gendered barriers to resilience.

4. Discussion

4.1 Coping and Adaptation Strategies

Small-scale fishing households in Char Bhaga Union employed various tactics to address economic adversity and environmental pressures. A distinction must be made between coping strategies, which are immediate and reactive, and adaptation tactics, which are proactive and enduring. This difference is crucial in evaluating whether families are cultivating sustained resilience or just postponing greater vulnerability.

Coping Strategies

The predominant coping strategy described is the reduction in food intake during lean seasons, as indicated by 72% of households **(Ifty et al., 2023a)**. Implementing informal lenders or aratdars to fulfil daily needs (65%); seasonal labour migration to metropolitan regions for non-fishing employment (32%); and growing dependence on women's informal and unpaid labour for post-harvest activities

(46%) **(Sunny et al., 2021; Islam et al., 2025)**. These reactions, although crucial for life, provide little enduring risk reduction. Indeed, they may exacerbate vulnerability, particularly when they lead to persistent indebtedness, nutritional deficiencies, or exploitation. For example, acquiring loans to buy fishing equipment during the prohibition era frequently resulted in debt payback via profit-sharing or mandatory sell-back arrangements with aratdars, especially in homes devoid of male labour **(Sazzad., et al., 2024)**. Likewise, decreases in food intake can result in infant malnutrition and adult lethargy, compromising long-term health and productivity.

Adaptation Strategies

Only a couple of households indicated proactive adaptation initiatives, which were predominantly informal and motivated by necessity, rather than supported by institutions. Examples encompass livelihood diversification into duck breeding and homestead gardening (29%), transitioning to inland wage labour during the off-season (34%), and dispatching youngsters to urban regions for remittance money (18%). Insufficient resources, substandard infrastructure, and inadequate training hinder these behaviors aimed at reducing reliance on fishing **(Sunny et al., 2020)**. Focus group discussions indicated that such adaptation is frequently driven by desperation rather than opportunity. A substantial disparity exists between the language of adaptation in policy texts and its actual implementation within fishing communities.

A tiny fraction of respondents indicated they received external assistance for training, diversification funding, or climate resilience planning, highlighting an institutional disjunction between top-down frameworks and bottom-up reality. Numerous key interviewees acknowledged that climate-specific initiatives designed for fishermen's livelihoods are predominantly lacking at the local level **(Sunny et al., 2019)**. The study indicates that the majority of households function along a continuum of coping adaptations, predominantly employing urgent survival measures, whereas transformational adaptation is infrequent. Marginalized populations, including female-headed households, elderly fishermen, and minorities, lack the financial resources and institutional access required for a shift towards sustainable adaptation. The study underscores that vulnerability is influenced not just by external stresses but also by profound structural inequalities, aligning with larger research conducted in coastal Bangladesh **(Adam et al., 2024).**

4.2 Gendered Vulnerability and Labor Invisibility

Gender-based vulnerability in small-scale fishing households is rooted in long-standing socio-cultural norms and systemic institutional neglect. Women have significant roles in the fisheries value chain, engaging in activities such as fish drying, bait collecting, net maintenance, and small-scale selling;

nonetheless, their labour is frequently devalued and mischaracterized as "supportive" rather than economically productive **(Ifty et al., 2024; Akhter et al., 2025)**. While 62% of women indicated active involvement in fisheries-related revenue generation, hardly 11% had obtained any vocational training or financial assistance. Most women were unaware of skill-building programs, and patriarchal qualification restrictions favoring male household heads prevented some from participating, rehibitions, women frequently bear disproportionate burdens overseeing food security, childcare, and debt repayment with scant institutional assistance. Numerous individuals depend on informal community networks for food loans or childcare, highlighting the essential function of social capital among women in mitigating household shocks **(Rana et al., 2023; Mithun et al., 2024)**. Nevertheless, their contributions remain unrecognized in official policies.

The lack of accessibility to transportation and resources exacerbates marginalization. Young women indicated a desire for ICT-based training or home-based companies, although they identified social stigma and logistical challenges as significant barriers. The incidence of school dropouts among females during moments of calamity has emerged as a significant concern. Interviews with local authorities corroborate that gender prejudice continues to exist in programs and skills training. The emphasis on male recipients demonstrates a systematic gender blindness that diminishes household resilience and constrains the overall potential of women's economic involvement. A critical necessity exists for the integration of gender considerations in fisheries and rural development. Policies must acknowledge women's unpaid labor, institutionalize their involvement in cooperatives, and advance gender-sensitive safety nets, savings clubs, and training centers **(Jentoft, 2014; Mahin et al., 2021).** These reforms are crucial for attaining SDG 5 and enhancing adaptive capacity at both household and community levels.

4.3 Institutional and Policy Limitations

Institutional fragmentation and implementation deficiencies have surfaced as significant obstacles to resilience enhancement. Notwithstanding governmental advancements in the creation of hilsa sanctuaries and co-management frameworks, these efforts frequently falter at the local level, especially in isolated and marginalized regions like Char Bhaga. Merely 23% of qualifying households indicated consistent receipt of Vulnerable Group Feeding (VGF) assistance during fishing prohibitions. Participants identified inconsistent distribution, ambiguous beneficiary criteria, and political bias as persistent problems. The deterioration of confidence in governmental institutions compromises adherence to sanctuary legislation and diminishes backing for conservation initiatives. Regulatory enforcement is often characterized as capricious or ambiguous **(Islam et al., 2018; Eckstein et al., 2021)**.

Fishers reported penalties and net confiscations without previous awareness of updated sanctuary borders or seasonal limitations. The absence of participatory rulemaking engenders animosity and diminishes the legitimacy of policies.

People perceived co-management. People perceived co-management committees as ineffective, politicized, or inert, often under the control of absent elites. These elites had neither attended meetings nor received invitations to participate. NGO delegates acknowledged that several government initiatives, such as boat motorization subsidies and training grants, are only theoretical due to inadequate inter-agency cooperation, budgetary delays, or administrative obstacles. Fisheries governance in Bangladesh is predominantly top-down and sectoral fragmented, lacking integration with wider climate adaptation and rural development initiatives. To restore institutional confidence, changes must progress beyond awareness initiatives to encompass inclusive engagement, openness, and accountability **(Islam et al., 2022; Haque et al., 2022).**

4.4 Deepening the Multi-Dimensional Vulnerability Analysis

The LVI and SLA evaluations show that the vulnerability in Char Bhaga Union is deep-rooted, ongoing, and built into the system, not just a response to occasional crises. Climate-related threats like floods, saltwater intrusion, and unpredictable rainfall have changed from unusual events to regular problems, making the community more vulnerable over time. This environmental exposure combines with socio-economic stresses such as indebtedness, food poverty, and inadequate education, leading to compounded vulnerability. The LVI scores show a concerning gap: high exposure (0.58) and sensitivity (0.63) are paired with low ability to adapt (0.54), making it harder to bounce back from even small problems. The analysis demonstrates the resilience framework comprising absorptive, adaptive, and transformational capacities **(Tanner et al., 2015; Sazzad., et al., 2025)**:

- Absorptive ability is constrained by insufficient funds, inadequate food reserves, and a deficiency of emergency shelters.
- Inadequate infrastructure, insufficient skills, and budgetary limitations impede adaptive capability.
- Transformative capability is observable just in homes with connections to NGOs or receiving remittances.

In general, adaptive techniques are fragmented and informal, without sufficient institutional support to facilitate the scaling of successful changes. The results confirm that climate resilience is not just an environmental concern; it is also political and institutional, influenced by access, agency, and representation **(Chowdhury et al., 2020b; Sarkar et al., 2024).**

4.5. Intersectionality and Social Exclusion

The vulnerability in Char Bhaga Union is markedly diversified by gender, handicap, ethnicity, age, and legal status. Women-headed families, comprising 14% of the sample, experienced exclusion from training, safety nets, and government services frequently owing to insufficient legal documents or political membership **(Chowdhury et al., 2020a)**.

Disabled family members imposed supplementary caregiving responsibilities, restricted economic prospects, and engendered mobility limitations. These households saw elevated reliance ratios and experienced difficulties in obtaining fundamental healthcare or engaging in resilience planning.

Migrant groups and minorities, particularly those residing near embankments, reported instances of harassment, exclusion from permits, and refusal of participation in cooperative or relief programs. Political patronage networks frequently played a crucial role in regulating resource access, hence sustaining horizontal disparities within the community.

Institutional frameworks, which neglect intersectional disadvantages, ground these exclusions; they are not arbitrary. An equitable governance approach would encompass legal assistance, inclusive training, mobile registration initiatives, and varied participation in co-management frameworks **(Ravera et al., 2016; Chowdhury et al., 2021).**

4.6 Obscurity of Women's Labor and Contributions

The labor of women is essential to the fishing economy in the Charbaga Union, although it is not recognized in official databases, regulatory frameworks, or economic assessments. Surveys and focus group discussions indicate that women undertake vital post-harvest activities such as bait collecting, net repair, fish sorting, drying, and trade, which support households during both peak and off-peak fishing seasons. This employment is frequently classified as "domestic" or "supportive", resulting in its omission from official statistics and subsequent exclusion from training, financial access, and decision-making processes. One person said, "My husband engages in fishing, whereas I work from dawn until dusk, drying and cleaning." Only his name remains registered.

This labour invisibility results in systematic exclusion from cooperatives, skill development, financial services, and safety net programs. For instance, hardly 8% of women participated in any type of vocational training, and only 3% obtained credit or grant assistance. These institutional deficiencies contradict SDG 5.4, which advocates recognition of unpaid care and domestic labor. The economic agency of women is unfulfilled not owing to insufficient contributions but rather because of governmental frameworks that overlook their involvement. Fisheries governance must consequently

implement gender-transformative frameworks that:

- Acquire and use gender-segregated labor statistics.
- Advocate for women-led cooperatives and access to market platforms.
- Enhance financial literacy through mobile banking programs.
- Provide childcare assistance along with training and business initiatives.

Nasrin's Story - Unseen but Indispensable

"Nasrin Begum, a 38-year-old widow, mends net each morning prior to fulfilling domestic responsibilities. During fishing prohibitions, she further works in rice fields to sustain her family. Although she contributes more than 60% of home income during difficult times, she is not acknowledged as a fisher in official records and receives no institutional support. Her situation exemplifies the unacknowledged fortitude of several women who uphold the fishery economy without acknowledgement or assistance."

4.7 Critique of the Hilsa Conservation Model

The Hilsa conservation program, which includes seasonal bans, sanctuary zones, and catch limitations, has achieved ecological success but frequently overlooks social equality and distributive justice. The 22-day countrywide fishing prohibition during the hilsa reproductive season is among the most controversial measures. Although some fishermen comprehend and endorse conservation goals, they voice dissatisfaction with uneven and politicized compensation. Merely 23% of qualifying households said that they received whole monthly allocations under the VGF system. Multiple instances were referenced in which assistance was misappropriated for absent boat owners or persons with political affiliations, circumventing genuine subsistence fishermen **(Chowdhury et al., 2022)**.

The enforcement methods exhibit a lack of transparency and are characterized by arbitrariness. Fishers expressed dissatisfaction over the confiscation of their nets due to sanctuary regulations, a fact they were not fully aware of. Numerous traditional fishing zones were incorporated into sanctuary areas without enough community input, resulting in diminished access and legal uncertainty. Involvement in hilsa governance frameworks is only symbolic. Committees are frequently controlled by local elites, therefore marginalizing fishers, women, and under-represented groups. This diminishes credibility, decreases compliance, and fosters dissatisfaction with the overarching conservation aim.

To improve the hilsa conservation model, prioritizing the following measures is crucial:

- Align VGF assistance with household size and actual income reduction.

- Establish digital beneficiary tracking systems to mitigate corruption.
- Clearly delineate sanctuary boundaries and engage fishers in community mapping.
- Implement participatory rural appraisal (PRA) techniques for rule formulation.
- Guarantee the inclusion of women and minorities in conservation organizations.

In the absence of these measures, hilsa conservation may exacerbate vulnerability instead of fostering equitable sustainability **(Bladon et al., 2016; Shaffril et al., 2024).**

4.8 Technological and Infrastructural Barriers

Technological exclusion and neglect of infrastructure are significant causes that have not been adequately addressed, which intensify vulnerability. Merely 6% of examined families possessed access to cyclone shelters, while 89% used non-motorized boats, thereby constraining fishing range and heightening vulnerability to storm-related hazards **(Hamilton et al., 2021).** The lack of cold storage and preservation facilities necessitates fishers sell their catch promptly, frequently at reduced rates. Power interruptions and the absence of solar backup systems further constrain household production and storage capacity. Numerous households are deprived of access to digital services, like weather notifications, electronic marketplaces, or mobile banking. Focus group discussions indicated significant deficiencies in digital literacy, especially among women. Digital technologies provide significant promise for inclusive adaptation in coastal fisheries. However, without investment in infrastructure, training, and cost, these technologies remain unattainable for the most vulnerable populations **(Hazra et al., 2022).**

- Overcoming these obstacles necessitates a multifaceted approach, comprising:
- Installation of solar-powered cold storage units at landing locations.
- Provision of subsidized motorized boats and storm-resistant equipment.
- The initiative also involves the expansion of mobile services tailored for users with low literacy levels.
- The program also includes training in digital navigation, market systems, and early warning technologies.

These initiatives correspond with SDG 9 (Industry, Innovation, and Infrastructure) and SDG 13 (Climate Action), establishing a foundation for cohesive resilience **(Mozumder et al., 2023; Oloko et al., 2025).**

4.9 Pathways for Resilience-Building

The study identifies three interlinked resilience pathways:

1. Asset Strengthening

Invest in livelihood assets through microfinance access, community-run cold storage, vocational training, and ecological restoration. These enhance coping capacity and support economic diversification.

2. Governance Reform

Ensure participatory sanctuary planning, transparent grievance mechanisms, and fisher representation in decision-making. PRA tools can legitimize rules and increase compliance.

3. Knowledge Co-Production

Link traditional ecological knowledge with scientific tools through community mapping, citizen monitoring, and innovation hubs. This supports bottom-up innovation and ownership.

Table 4. Integrated Resilience Pathways for Small-Scale Fishers

Resilience Pathway	Strategic Focus	Expected Outcomes
Asset Strengthening	Microfinance, cold storage, training, river rehabilitation	Enhanced food security, diversification, household resilience
Governance Reform	Participatory design, quotas, PRA, grievance redress	Inclusive governance, increased trust, regulatory compliance
Knowledge Co-Production	Community monitoring, ecological documentation, innovation hubs	Culturally grounded learning, adaptive behavior, local innovation

These pathways support integration with national strategies like Delta Plan 2100, BCCSAP, and SDGs 1, 5, 13, and 14.

4.10 Comparative Reflection with Other Hilsa Zones and Transboundary Fisheries

The findings from Char Bhaga align with those from other hilsa regions, including Bhola, Chandpur, Barisal, and worldwide deltaic fisheries. Research from India's Chilika Lagoon and Vietnam's Mekong

Delta demonstrates analogous trends in ecological degradation, fishermen's exclusion, and gender-based marginalization. Chandpur benefits from more effective NGO presence and infrastructure, but Char Bhaga's isolation leads to inadequate institutional delivery. These regional disparities highlight the need for decentralized adaptation planning that aligns with local settings. This work contributes by integrating gendered vulnerability, LVI measurement, and microspatial analysis; therefore, it contests universal conservation approaches and advocates localized intersectional solutions **(Sunny et al., 2019; Islam et al., 2022).**

4.11 Integration of Climate Policy and Livelihood Resilience

Although Bangladesh's climate policies (NAPA, BCCSAP) acknowledge coastal vulnerability, small-scale fisheries continue to be inadequately prioritized. The majority of adaptation expenditures are allocated to agriculture or infrastructure, which excludes fishermen from accessing climate-smart finance, insurance, and early warning systems **(GoB, 2009; UNDP, 2020).**

Integration is crucial. Fisheries departments and climate organizations must collaborate to create programs that:

- Implement ecosystem-based adaptation strategies.
- Perform vulnerability mapping for focused assistance.
- Provide funding for livelihood diversification grants during off-seasons.
- Implement favorable insurance programs for fishermen and establish mobile notification systems.

Incorporating fishermen into climate policy narratives will guarantee that adaptation is socially inclusive and tailored to specific sectors **(Ferdous, 2023).**

4.12 Limitations of the Study

This study provides a comprehensive mixed-methods analysis; nonetheless, it has limitations. The results are spatially confined to Char Bhaga and may not comprehensively reflect regional disparities. Cross-sectional design restricts the evaluation of seasonal and longitudinal dynamics. Moreover, while LVI offers quantification, it may trivialize the interplay between assets, agencies, and identities. Future studies should investigate intra-household decision-making, mobile-based adaptation tools, and seasonal vulnerability trajectories to improve understanding.

5. Conclusion and Policy Recommendations

This study provides a detailed analysis using different research methods to examine the risks to livelihoods, ways to adapt, and the challenges faced by small-scale fishermen in Char Bhaga Union, an important but economically struggling area for hilsa fishing in coastal Bangladesh. The study used a mix of the Sustainable Livelihoods Approach (SLA) and the Livelihood Vulnerability Index (LVI) to show that the vulnerability in this area is ongoing, complicated, and deeply rooted. The computed LVI score of 0.62 indicates significant overall vulnerability, which is attributed to the confluence of diminishing natural capital, insufficient infrastructure, financial marginalization, restricted human capital, and eroded social cohesiveness. The results indicate that coping mechanisms are predominantly reactive, focusing on food restriction, informal borrowing, and seasonal relocation. Conversely, proactive adaptation, such as livelihood diversification or skills acquisition, is restricted to households with access to remittances or external assistance from NGOs.

The study reveals that women's labor is systematically invisible, despite its essential role in the fishing economy, and it is excluded from formal policy, economic appraisal, and institutional support. Likewise, intersectional disadvantages pertaining to gender, disability, documentation status, and household composition diminish fair access to adaptation resources and institutional safety nets. The uneven application of rules, biased payment systems, and lack of fisher participation in decision-making make it challenging to effectively protect hilsa fish, even though the conservation plan is sound in theory. Regulatory uncertainty, elite domination of committees, and insufficient openness further erode community trust and adherence to conservation efforts. To enhance resilience in these contexts, policy frameworks must transcend technocratic solutions and relief-orientated measures. They must adopt a comprehensive, equity-focused, and asset-enhancing strategy that acknowledges small-scale fishermen as knowledge-bearers and resilience actors, rather than mere beneficiaries of assistance.

The research provides tangible contributions to the national and international dialogue on sustainable fisheries and climate adaptation. By illustrating the use of the LVI–SLA synergy in context-specific manners, it offers a reproducible framework for assessing vulnerability and formulating localized, gender-responsive, and institutionally inclusive remedies. Future research should expand on this study by including seasonal data, looking at family dynamics, and evaluating how digital tools like mobile banking, microinsurance, and AI flood alerts affect the ability to adapt. Longitudinal monitoring of LVI scores over climatic seasons can offer invaluable information about the progression of resilience over time. This work enhances local risk assessments and establishes an empirical basis for harmonizing fisheries governance with Bangladesh's Sustainable Development Goals, Delta Plan 2100, and climate

adaptation objectives.

The findings suggest the following policy recommendations. These are organized according to thematic priorities and intended for multi-tiered execution by governmental bodies, NGOs, funders, and local organizations.

5.1 Institutional Reform and Inclusive Governance

Institutionalize participatory rural appraisals (PRAs) for sanctuary planning, seasonal prohibition formulations, and compensation determinations. Guarantee quota-based representation for fishermen, particularly women, minorities, and those with disabilities, in HILSA committees and fisheries organizations. Implement open grievance resolution mechanisms at the union level to rectify the misallocation of VGF and training programs. Advocate for co-management frameworks that are responsible to local communities and directed by them.

5.2 Investment in Livelihood Assets and Infrastructure

Implement solar-powered cold storage facilities at fishing landing centers and construct cyclone-resistant shelters in flood-prone areas. Expand the availability of subsidized motor vessels for economically disadvantaged fishermen. Advocate for mobile banking and micro-savings solutions designed for informal workers. Initiate vocational training in climate-resilient agriculture, fish preservation, and net repair. Such activities will enhance the absorptive ability and diversity of household income.

5.3. Gender Mainstreaming and Intersectional Inclusion

Acknowledge women's contributions to fisheries by employing gender-disaggregated data collection and labour value methodologies. Establish cooperatives centered on women, implement financial literacy initiatives, and create training centers conducive to children. Modify safety net programs (e.g., VGF) to incorporate qualifying requirements pertaining to widowhood, disability, and migratory status. Deploy mobile documentation teams to register unregistered and marginalized households. Provide equitable access to adaptation resources and enhanced household resilience.

5.4 Integration of Climate Adaptation

Integrate mainstream fisheries into national climate policies, including BCCSAP, NAPA, and Delta Plan 2100. Designate climate adaptation funds explicitly for small-scale fishermen. Implement pilot ecosystem-based adaptation initiatives that connect riverbank restoration with fishing livelihoods. Advocate for weather-indexed insurance products and mobile alert systems for storm prediction. We

aim to enhance the alignment between climate resilience objectives and sector-specific risks.

5.5 Empirical Monitoring and Transparency

Establish community-oriented monitoring methods to oversee allocations, training, and collaborative management involvement. Create real-time dashboards at the upazila level to monitor LVI trends and program results. Encourage collaborations between fisheries and academia to jointly develop research and monitor adaptation advancements. Evidence, adaptive learning, and enhanced accountability form the foundation of policymaking **(Fahad & Chowdhury, 2022)**.

These recommendations seek to promote an inclusive, resilient, and equitable framework for fisheries governance and climate adaptation, in accordance with Sustainable Development Goals 1 (No Poverty), 5 (Gender Equality), 13 (Climate Action), and 14 (Life Below Water).

Funding

This work had no outside funding.

Author Contribution

The authors were involved in the creation of the study design, data analysis, and execution stages. Every writer gave their consent after seeing the final work.

Acknowledgments

We would like to thank the community people for their valuable cooperation.

A statement of conflicting interests

The authors declare that none of the work reported in this study could have been impacted by any known competing financial interests or personal relationships.

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