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Volume 7 **Number 1&2** **June–December 2025**

Contents

Impact Assessment of Mechanized Shelling on Maize Yield Efficiency and Farm Profit in Rural Bangladesh 1–16

Prianka Basak; Farhana Yeasmin; Jannatul Ferdous; Md. Nazmus Sadekin

Development Diplomacy in Changing Political Transition: Envisioning a Developed and Prosperous Bangladesh 17–39

Razia Sultana; Fahim Shahriar

Energy Transition and Carbon Emissions in Bangladesh: A Nonlinear Analysis of Renewable and Fossil Energy Consumption 40–65

Al Amin Al Abbasi

Climate Change, Biodiversity Loss, and Livelihood Adaptation: Perspectives from *Beel* Dependent Artisanal Fishers in Bangladesh 66–87

Md. Ariful Islam; Al-Amin Sarkar; Md. Firoz Hossain; Nahid Hasan; Fuad Hasan

Attaining SDG 13: Assessing Bangladesh Scenario 88–111

Segufta Hossain

Economic Participation Without Protection: A Systematic Literature Review on Women's Vulnerability in Bangladesh's Urban Economy 112–136

Maisha Akter Trina; Md. Ariful Islam

Jagannath University Journal of Economics ISSN: 2707-0689 (Print)
Vol. 7, No. 1&2, June-December 2025, (Page 66–87) ISSN: 3078-6614 (Online)

Climate Change, Biodiversity Loss, and Livelihood Adaptation: Perspectives from *Beel* Dependent Artisanal Fishers in Bangladesh

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Abstract

Bangladesh's freshwater beels support vital biodiversity and livelihoods but face severe climate threats. This study investigates climate change perceptions, ecological risks, and adaptation strategies among artisanal fishing communities in Beel Gajna. Using a mixed-methods approach, 195 households (124 fishers, 71 non-fishers) were surveyed. Fish species were classified using IUCN criteria, and an ordinary least squares (OLS) regression identified factors influencing a livelihood adaptation index (LAI). Findings reveal severe ecological degradation, identifying 31 threatened fish species (6 critically endangered, 15 endangered, 10 vulnerable). While 82% of respondents observed climatic changes and 68% noted declining catches, only 23% understood the scientific causes. The OLS model (R^2 = 34.5%) showed that fisher status and climate awareness are the strongest predictors of adaptation, alongside income, education, and cooperative membership. Socioeconomic vulnerability remains high: 74% of households lack alternative income, and only 29% adopted new fishing techniques. Ultimately, climate change intensifies ecological and livelihood pressures. These empirical insights provide a baseline for targeted wetland policy interventions. Strengthening conservation, climate awareness, cooperative institutions, and livelihood diversification is essential to improve resilience in these vulnerable wetland regions.

Keywords: *Beels*, artisanal fisheries, climate change, livelihood adaptation index, fish biodiversity, Bangladesh

JEL Classification: Q22, Q54, Q57

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1. Introduction

Aquatic ecosystems worldwide are experiencing unprecedented disruption due to climate change, which presents critical challenges for biodiversity conservation, ecosystem functioning, and the livelihoods of fisheries-dependent communities (IPCC, 2021). These environmental changes are particularly severe in Bangladesh, a country with high population density, extensive inland water resources, and an economy closely linked to fisheries production. Recent studies highlight escalating threats from rising temperatures, increasingly erratic rainfall, and more frequent extreme weather events in the region. These climatic pressures result in habitat degradation, shifts in species distributions, and significant declines in native fish populations, with serious implications for national food security and the well-being of rural communities (FAO, 2023; Shamsuzzaman et al., 2017).

Bangladesh is recognized as a global leader in inland fisheries and aquaculture, with freshwater ecosystems, particularly *beel*s (floodplain wetlands), serving as essential foundations for food security and sustainable rural livelihoods (Sultana et al., 2022). These systems are increasingly threatened by climate change, as demonstrated by long-term trends of rising air and water temperatures, erratic precipitation, and more frequent extreme hydrological events (IPCC, 2014). *Beel* ecosystems are both ecologically significant, supporting high biodiversity, and economically vital for artisanal fishing communities. These wetlands are highly sensitive to cumulative anthropogenic and climatic stressors, including habitat loss, declines in native fish species, overexploitation, altered hydrological regimes, accelerated siltation, and the spread of invasive species. Collectively, these factors jeopardize both biodiversity conservation and the food security of Bangladesh's most vulnerable populations (Tikadar et al., 2022).

Although extensive research has examined climate change impacts on marine and large riverine fisheries (Limuwa et al., 2018; Badjeck et al., 2010), and vulnerability assessments focus on various resource-dependent communities (Poissant et al., 2023; Tregidgo et al., 2020), wetland-dependent artisanal fishing populations remain significantly understudied. This gap is notable given that beel-based fishers contribute up to 60% of rural animal protein intake in Bangladesh, yet are rarely addressed in climate adaptation literature (Hasan & Nursey-Bray, 2017). The limited empirical focus on freshwater artisanal fisheries represents a substantial knowledge gap, particularly in light of the pronounced vulnerability of these biodiverse wetlands to climatic disturbances threatening both ecological stability and socioeconomic well-being. As a result, key questions remain insufficiently explored: (1) how do beel fishers perceive climate-related risks and environmental changes affecting their livelihoods; (2) what adaptive capacities exist within these communities; and (3) what are the complex interrelationships between ecological transformation and livelihood security in these socio-ecological systems? The lack of empirical evidence undermines targeted policy interventions and climate-resilient management strategies tailored to the needs of wetland-dependent communities.

This study addresses these knowledge and policy gaps by systematically investigating climate change perceptions, vulnerabilities, and adaptive responses among artisanal fishers in *Beel Gajna*, a representative floodplain wetland ecosystem in Bangladesh. Using an integrated methodological approach that combines ecological assessment with socio-economic analysis, the research pursues three objectives: (1) to document fishers' perceptions of climate variability and related ecological changes; (2) to evaluate the multidimensional vulnerabilities faced by these communities; and (3) to characterize existing adaptive strategies and their determinants. This comprehensive approach clarifies the complex relationship between climate-driven environmental transformation and livelihood security in this wetland system.

The investigation produces several important insights. The findings indicate limited climate awareness among fishers, despite significant ecological and socioeconomic vulnerability to ongoing environmental changes. Where adaptation efforts exist, they are constrained by resource scarcity, limited institutional support, and insufficient access to climate information. These results have important implications for conservation policy and development practice. By providing robust empirical evidence from an understudied yet critical socio-ecological system, this study establishes a foundation for evidence-based conservation policies and locally tailored adaptation frameworks that can protect both biodiversity and food security for Bangladesh's most vulnerable wetland communities. The findings also contribute to broader academic discussions on climate adaptation in small-scale fisheries and offer transferable insights for wetland-dependent populations across the Global South facing similar challenges.

The remainder of this paper is organized as follows. Section 2 describes the study area and outlines the integrated methodological approach. Section 3 presents empirical findings on climate perceptions, vulnerability dimensions, and adaptive responses. Section 4 discusses these findings in relation to existing literature and policy implications. Section 5 concludes with key recommendations for research, policy, and management interventions.

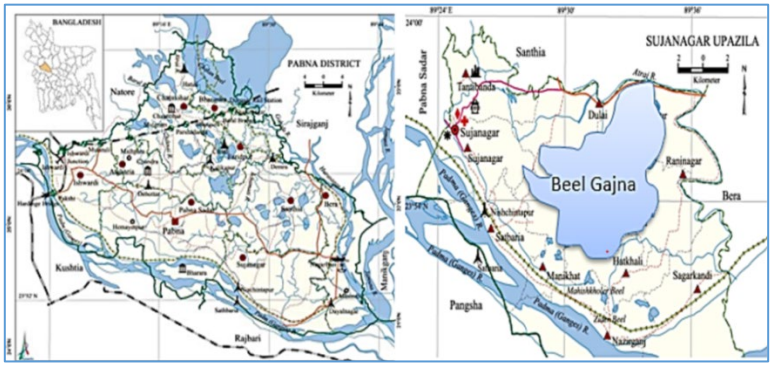
2. Research Method

2.1 Study Area

The study was conducted in *Beel Gajna*, an ecologically significant wetland in Sujanagar Thana, Pabna District, Bangladesh (Figure 1). As the second largest *beel* in Pabna District after *Chalan Beel*, *Beel Gajna* was selected as a representative case study due to its ecological importance and the diversity of wetland-dependent communities. Located approximately 30 kilometers from Pabna Sadar, the *beel* influences thirty-four adjacent villages within its hydrological catchment. The area is characterized by predominantly clay soils, with sandy deposits along the margins. *Beel Gajna* is hydrologically connected to the Padma River through sluice gates and experiences seasonal flooding, which introduces wild fish species into the

ecosystem. Although the central basin dries seasonally, the deepest depressions retain water throughout the year, serving as important aquatic refuges. Historically, *Beel Gajna* supported robust artisanal fisheries; however, local knowledge and recent observations indicate a significant decline in biodiversity. This decline is attributed to disrupted hydrological flows, siltation, temperature increases, irrigation demands, and altered fish migration routes. These combined anthropogenic and climatic pressures have shifted the ecosystem from a state of abundance to one experiencing considerable ecological stress.

Figure 1: Location of *Beel Gajna*



Source: Banglapedia

2.2 Study Design and Sample

Fieldwork in *Beel Gajna* from January to March 2022 used a mixed-methods design to evaluate climate change impacts on fish biodiversity and community livelihoods. Primary data collection included Focus Group Discussions (FGDs) with two stratified groups (fishers and non-fishers), Key Informant Interviews (KIIs) with local experts, and structured household surveys. Of the 34 surrounding villages, 12 were randomly selected, yielding a purposive sample of 195 households (124 artisanal fishers and 71 non-fishers). Structured questionnaires gathered perceptions of climatic variability (temperature, rainfall, siltation) and ecological impacts (fish populations, aquatic biodiversity, bird species). Observational checklists documented fish species status according to IUCN (2000) Red List criteria (Hilton-Taylor & Brackett, 2000). A dedicated module examined livelihood challenges among fisher households. Secondary sources, such as peer-reviewed publications, government reports, and climate databases, provided context and validation. Analytical frameworks from Paul et al. (2014) guided the assessment of climate perceptions and vulnerabilities. This triangulated methodology facilitated an evaluation of both ecological changes and socioeconomic vulnerabilities in *Beel Gajna.*

2.3 Data Analysis

Descriptive statistical analysis was performed to examine key variables and patterns within the dataset. The analysis commenced with profiling the socio-

economic and demographic characteristics of the 195 sampled households, thereby establishing a baseline for subsequent interpretation. Quantitative assessments of climate change awareness and knowledge were conducted, along with evaluations of perceptions of observable climate and ecological changes in the *Beel Gajna* ecosystem. Ecological data were analyzed by classifying fish species status according to the IUCN (2000) Red List criteria: Endangered, Critically Endangered, and Vulnerable. The analysis further investigated socio-economic dynamics and livelihood challenges specific to the fisher subpopulation, and systematically documented local adaptation practices in response to environmental changes.

Adaptation intensity was quantified using a livelihood adaptation index (LAI), calculated as the unweighted sum of nine binary adaptation practices: active cooperation, ignoring small fish, exploring new areas, saving money, generating extra family income, using different tools, holding multiple jobs, learning additional skills, and direct selling. This index produced a score ranging from 0 to 9 for each fisher household (see Table 1). An ordinary least squares (OLS) regression model was employed with LAI as the dependent variable to identify determinants of adaptation adoption, including climate awareness, education level, fishing experience, cooperative membership, household size, household income, land ownership, and perception of catch decline as independent variables. Model diagnostics included the Variance Inflation Factor (VIF) for multicollinearity and the Breusch-Pagan test for heteroscedasticity, with statistical significance evaluated at $\alpha = 0.05$, 0.01, and 0.10. Cross-tabulation and structured tabular presentation facilitated integrated assessment of community awareness, perceived and observed ecological changes, biodiversity status, socio-economic impacts, and adaptive responses. This analytical approach yielded critical insights into climate vulnerability and resilience strategies within the *Beel Gajna* wetland system.

2.4 Measurement of Livelihood Adaptation Strategy

2.4.1 Livelihood adaptation index

The livelihood adaptation index (LAI) quantified the adaptive capacity of fisher households, utilizing nine binary adaptation indicators presented in Table 1. The LAI serves as a composite measure of household-level adaptation intensity.

Table 1: Livelihood adaptation index (LAI) components

Component	Adaptation Practice	Code
L1	Active cooperation practices among fishermen	1=yes, 0=no
L2	Ignore catching small fishes (conservation practice)	1=yes, 0=no
L3	Explore new areas to increase fish catches	1=yes, 0=no
L4	Save money to cope with uncertain events	1=yes, 0=no
L5	Family members engaged in extra income	1=yes, 0=no
L6	Have different tools to increase fish catches	1=yes, 0=no
L7	Do more than one job to support family	1=yes, 0=no
L8	Learn additional skills to improve income	1=yes, 0=no
L9	Selling fish directly (ignore middleman)	1=yes, 0=no

Source: Authors' construction based on field survey, 2023

The LAI was calculated as the sum of adaptation practices adopted by each household:

$$LAI_i = \sum_{j=1}^{9} A_{ij} \quad (1)$$

Where, LAI_i = Livelihood adaptation index score for household (range: 0 to 9) and A_{ij} = binary indicator (1 or 0) for adaptation practice j of household i

Table 2: Interpretation categories

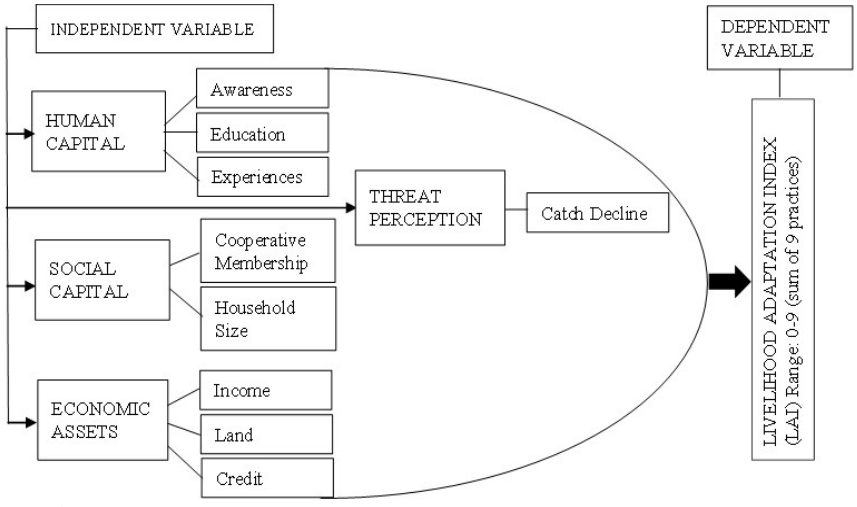
LAI Score	Adaptation Level	Description
0-2	Very Low	Minimal adaptation, highly vulnerable
3-4	Low	Below-average adaptive capacity
5-6	Moderate	Average adaptation intensity
7-8	High	Strong adaptive capacity
9	Very High	Comprehensive adaptation adoption

Source: Authors' construction based on field survey, 2023

2.4.2 Livelihood adaptation framework

The The Sustainable Livelihoods Approach (SLA) posits that households possess multiple forms of capital assets—human, social, natural, physical, and financial—which collectively determine their capacity to respond to external shocks and stressors (DFID, 1999; Scoones, 1998; Béné et al., 2019; Ellis & Freeman, 2023). Within climate-vulnerable artisanal fishing communities, adaptation behavior is conceptualized as a function of these asset endowments and cognitive perceptions of environmental change. The framework proposes that the livelihood adaptation index (LAI), which quantifies the number of adaptation practices adopted by households (ranging from 0 to 9, as shown in Table 1), is determined by three interconnected categories: human capital, social capital, and economic capital.

Figure 2: Conceptual model of the study



Source: Authors' construction

In this analysis, climate awareness, education level, and fishing experience are classified as human capital. Social capital encompasses cooperative membership, which facilitates resource pooling, information sharing, and mutual support through collective action. Household size is also included within the social capital dimension, as larger households provide opportunities for labor diversification. Economic capital comprises household income, land ownership, asset wealth, and access to credit, all of which provide economic security and serve as buffers against shocks. Financial inclusion further enables upfront investment in adaptation. Finally, perceived resource scarcity, such as declining catches, functions as a threat perception that triggers protection motivation and adaptive responses, and is therefore included in the model.

2.4.3 Empirical specification

Based on the theoretical framework, the econometric model is specified as:

$$LAI_i = \beta_0 + \beta_1(CAi) + \beta_2(EDUi) + \beta_3(EXPi) + \beta_4(COOPi) + \beta_5(HHSi) + \beta_6(INCi) + \beta_7(LANDi) + \beta_8(CDPi) + \varepsilon_i \quad (2)$$

where, LAI_i = Livelihood adaptation index (0-9) for household i
CAi = Climate awareness (1=aware, 0=unaware)
$EDUi$ = Education level (1-5 scale)
$EXPi$ = Fishing experience (years)
$COOPi$ = Cooperative membership (1=yes, 0=no)
$HHSi$ = Household size (number of members)
$INCi$ = Household income (BDT/month, log-transformed)
$LANDi$ = Land ownership (1=>33 decimals, 0=otherwise)
$CDPi$ = Catch decline perception (1=yes, 0=no)
ε_i = Random error term

3. Results and Discussion

3.1 Socioeconomic Profile

This study investigates local perceptions of climate change impacts on fisheries in *Beel Gajna*, acknowledging that respondents' interpretations of temperature changes, rainfall variability, siltation, and biodiversity loss may not align with scientific definitions of climate change. The research identifies key socio-demographic characteristics that contextualize these perceptions. As indicated in Table 3, the sample (n=195) was predominantly composed of middle-aged and older individuals, with 51.6% aged 31–45 years and 30.5% over 45 years. The majority (72.6%) identified as Muslim, while 27.4% were Hindu. Educational attainment was generally low; 55.8% had only primary education and 12.6% were illiterate, which may affect understanding of climate change. The occupational profile demonstrates a strong reliance on aquatic resources, with 70.2% engaged in artisanal fishing as their main livelihood. Land ownership data show that 6.3% were landless, while most

respondents (71.6%) owned more than 33 decimals of land, indicating relatively stable housing despite climate-related vulnerabilities.

Table 3: Socio-economic and demographic information of the sample population (n=195)

	(n)	(%)
Age		
Below 30	35	17.9%
31-45	101	51.6%
Above 45	59	30.5%
Religion		
Muslim	142	72.6%
Hindu	53	27.4%
Education		
Illiterate	25	12.6%
Primary	109	55.8%
Secondary	35	17.9%
Higher secondary	20	10.5%
Graduation	06	3.2%
Occupation		
Artisanal Fisher	124	63.58%
Farmer	26	13.33%
Tenant Farmer	32	16.4%
Small Business	08	4.1%
Service Holder	05	2.56%
Land Ownership		
Landless	12	6.3%
0-33 decimals	43	22.1%
Land>33 decimals	140	71.6%

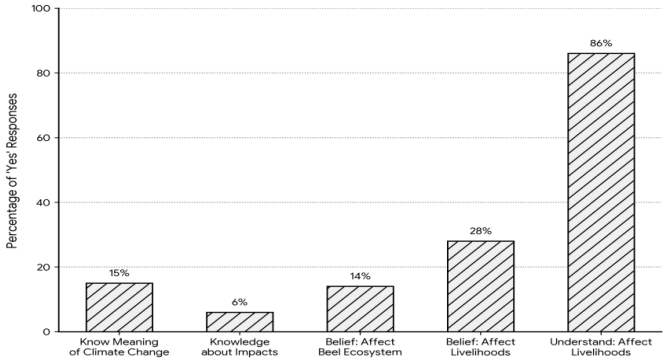
Source: Authors' calculations based on field survey, 2023

3.2 Climate Awareness

Figure 3 presents community perceptions of climate change and its impacts in *Beel Gajna*. The results reveal a significant disparity between scientific knowledge and local experience. Only 14.7 percent of respondents reported understanding the concept of climate change, and just 6.3 percent were aware of its specific impacts, indicating low levels of formal climate literacy. A minority of respondents (13.6 percent) believed that climate change could affect the *beel* ecosystem, and less than one-third (28.4 percent) perceived direct impacts on their livelihoods. When questions were framed in practical terms, however, 86.8 percent recognized that climate change could threaten their ability to earn a living. These findings indicate that, although scientific terminology is often unfamiliar, community members are highly aware of environmental disruptions through daily experience. Their understanding is shaped primarily by observable changes rather than abstract definitions. Consequently, policy and adaptation initiatives should focus on bridging this knowledge gap by translating scientific concepts into accessible language and

locally relevant examples. Such strategies are likely to strengthen community resilience and promote the protection of the wetland ecosystem.

Figure 2: Awareness level about the climate change and its impacts



Source: Field survey of the authors, 2023

3.3 Perceptions of Climate Change

Table 4 summarizes climate change impact perceptions in the *Beel Gajna* area, comparing fishermen and non-fishermen. Most respondents noted rising temperatures (56.45% fishermen vs. 53.52% non-fishermen), though roughly a third saw no variation. Declining rainfall was reported by 50.81% of fishermen and 57.75% of non-fishermen, while 29.84% of fishermen observed no change compared to just 9.86% of non-fishermen. Perceptions on increasing siltation differed sharply (73.39% fishermen vs. 35.21% non-fishermen), while 22.58% and 38.03% respectively felt it was decreasing. Regarding biodiversity, majorities reported significant declines across fish species (64.52% vs. 53.52%), bird populations (67.74% vs. 71.83%), and general aquatic life (79.03% vs. 64.79%). Additionally, 60.48% of fishermen observed altered fish growth and taste.

Table 3: The respondents' perceptions on the effects of climate change in the *Beel Gajna*

Perceived Effects	Fishermen (n=124)		Non-Fishermen (n=71)	
	(n)	(%)	(n)	(%)
Temperature Changes				
Increased	70	56.45%	38	53.52%
Decreased	14	11.29%	6	8.45%
No Change	40	32.26%	27	38.03%
Rainfall Changes				
Increased	24	19.35%	23	32.39%
Decreased	63	50.81%	41	57.75%
No change	37	29.84%	7	9.86%
Siltation				
Increased	91	73.39%	25	35.21%
Decreased	28	22.58%	27	38.03%
Not Known	5	4.03%	19	26.76%

Perceived Effects	Fishermen (n=124)		Non-Fishermen (n=71)	
	(n)	(%)	(n)	(%)
Fish Species Variety				
Increased	44	35.48%	33	46.48%
Decreased	80	64.52%	38	53.52%
Fish Growth Status and Taste				
Changed	75	60.48%	37	52.11%
No Changed	49	39.52%	34	47.89%
Aquatic Biodiversity				
Increased	26	20.97%	25	35.21%
Decreased	98	79.03%	46	64.79%
Not Known	0	0.00%	0	0.00%
Bird Species Growth				
Decreased	84	67.74%	51	71.83%
No Changed	9	7.26%	13	18.31%
Not Known	31	25.00%	7	9.86%

Source: Authors' calculations based on field survey, 2023

3.4 Biodiversity of Beel Gajna

Due to the limited research on climate change impacts in *Beel* ecosystems, particularly in *Beel Gajna*, this study establishes essential baseline data regarding fish biodiversity. Data validation was conducted in collaboration with local fisheries experts and stakeholders through Focus Group Discussions. Applying the IUCN (2000) Red List criteria, the survey identified 64 distinct fish species in *Beel Gajna*. Of these, 48.4 percent, or 31 species, are classified as threatened, as detailed in Table 5, indicating significant ecosystem degradation. Among the threatened species, 15 are endangered, including the ecologically significant Ghonia (*Labeo gonius*) and Chital (*Chitala chitala*). Six species, such as the culturally important Kakila (*Xenentodon cancila*), are critically endangered, while 10 species, including the commercially valuable Boal (*Wallago attu*), are considered vulnerable. The high proportion of threatened species underscores the urgent conservation challenges in *Beel Gajna*. Ecologically sensitive, culturally significant, and economically important fish species are experiencing substantial population declines, likely due to ongoing climate change, habitat modification, and overexploitation within this wetland ecosystem.

Table 4: IUCN classification of threatened fish species in *Beel Gajna*

Category	Total	Example Species	Scientific name
Endangered	15	Ghonia	*Labeo gonius*
		Kalbaush	*Labeo calbasu*
		Bata	*Labeo bata*
		Putul mach	*Botia Dario*
		Papta	*Ompok bimaculatus*
		Lati paibda	*Ompok pabda*
		Kala pabda	*Ompok pabo*
		Desi pungas	*Pangasius pangasius*
		Bacha	*Eutropiichthys vacha*
		Ayer	*Aorichthys seenghala*

Category	Total	Example Species	Scientific name
		Gang tengra	*Gagata chenia*
		Chital	*Chitala chitala*
		Sarpunti	*Puntius sarana*
		Bagha Ayer	*Bagarius yarrellii*
		Gazar	*Channa marulius*
Critically endangered	6	Nameshwar tengra	*Mystus cavasius*
		Raik	*Cirrhinus reba*
		Teen kanta	*Pseudeutropius atherinoides*
		Kakila	*Xenentodon cancila*
		Chaipla	*Gudusia chapra*
		Bansh pata	*Ailia coila*
Variable	10	Meni	*Nandus nandus*
		Lomba Chanda	*Chanda nama*
		Gol Chanda	*Parambasis ranga*
		Tita punti	*Puntius ticto*
		Foli	*Notopterus notopterus*
		Tara baim	*Macrognathus aral*
		Khorshola	*Rhinomugil corsula*
		Boal	*Wallago attu*
		koi	*Anabas testudineus*
		Magur	*Clarias batrachus*

Source: Authors' construction based on field survey, 2023

3.5 Socio-economic dynamics in the context of climate change

A semi-structured questionnaire was employed to assess the socioeconomic impacts of climate change on households reliant on *Beel Gajna* for their livelihoods. Informed by literature reviews and focus group discussions, the survey examined the effects of changing climatic conditions on fish production, household incomes, and the broader local economy. The results presented in Table 6 demonstrate that climate change has substantially altered the socio-economic conditions of households dependent on *Beel Gajna*. Most respondents reported declines in fish-related resources, livelihood opportunities, and ecological conditions, alongside increased economic pressure and competition. The most prominent impact is the reduction in fish availability: 75.00% of respondents indicated a decrease in the quantity of fish captured, while only 16.94% observed an increase. Additionally, 81.45% reported that fish size has diminished over time, indicating significant pressure on fish stocks and the aquatic ecosystem. The ecological condition of the *beel* has also deteriorated. A majority of respondents (86.29%) noted declining vegetation and biodiversity, and 87.10% observed a reduction in the area available for fishing.

These environmental changes have reduced the productivity of the *beel* and limited access to fishing grounds. Fishing activities have become less frequent and productive, with 60.48% of respondents reporting fewer fishing days per week and 66.13% noting a decline in household-based crafting of fishing gear and nets. This trend reflects the weakening of traditional fishing practices and the diminishing role of fishing in the local economy. Concurrently, economic pressure has intensified:

58.87% of respondents reported increased fishing costs, and 52.42% observed higher fish prices over the past year, likely reflecting reduced fish supply in local markets. Furthermore, 54.84% reported increasing economic hardship. The data indicate that fishing is becoming a less sustainable livelihood option. Approximately 79.03% of respondents reported a decline in fishing-based livelihoods, and 47.58% indicated a change in their primary occupation. Although 42.74% reported no change in occupation, the substantial proportion shifting away from fishing suggests growing livelihood instability and increased reliance on alternative income sources. Resource competition has also intensified, with 70.16% of respondents reporting increased competition with other resource users. This trend may result from the shrinking availability of fish, water, and other wetland resources, compelling more individuals to compete for limited opportunities. Responses regarding group fish catching practices were mixed: 37.90% reported an increase, 36.29% reported a decrease, and 25.81% observed no change. This variation suggests that while some fishers may cooperate more to cope with declining resources, others may abandon collective practices due to heightened competition and reduced catches. In sum, climate-induced ecological degradation in Beel Gajna is closely coupled with dwindling fish production, rising operational costs, and occupational displacement. These findings indicate that the traditional fishing economy is under critical stress, forcing local households to diversify their livelihoods to mitigate economic hardship.

Table 6: Socio-economic dynamics under changing climate in *Beel Gajna* (n=124)

Item	Increased		Decreased		No Change	
	(n)	(%)	(n)	(%)	(n)	(%)
Quantity of fish captured	21	16.94%	93	75.00%	10	8.06%
Cost of fish captured	73	58.87%	51	41.13%	0	0.00%
Size of fish captured	19	15.32%	101	81.45%	4	3.23%
Price of fish captured over the last year	65	52.42%	45	36.29%	14	11.29%
Number of fishing days per week	5	4.03%	75	60.48%	44	35.48%
Group fish catching practice	47	37.90%	45	36.29%	32	25.81%
Crafting fishing gears and nets at home	7	5.65%	82	66.13%	35	28.23%
Competition with other resource users	87	70.16%	30	24.19%	7	5.65%
Area for catching fish	5	4.03%	108	87.10%	11	8.87%
Fishing based livelihood	10	8.06%	98	79.03%	16	12.90%
Economic hardship	68	54.84%	21	16.94%	35	28.23%
Change occupation from main livelihood	59	47.58%	12	9.68%	53	42.74%
Beel vegetation and biodiversity	12	9.68%	107	86.29%	5	4.03%

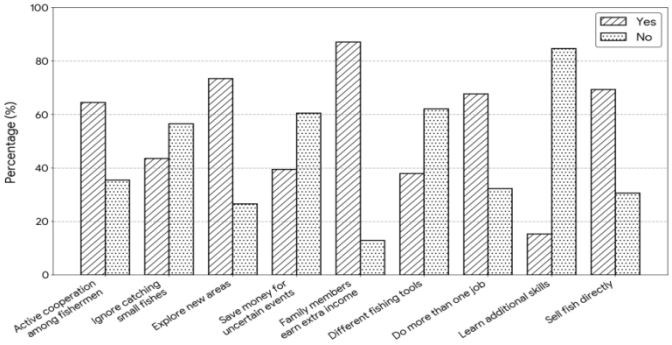
Source: Authors' calculations based on field survey, 2023

3.6 Adaptation Practices

The bar chart indicates that fishers in Beel Gajna predominantly employ a combination of livelihood diversification, mobility, and market-oriented strategies to address environmental and economic uncertainty. The most prevalent adaptation involves engaging family members in supplementary income-generating activities (87.10%), demonstrating a strong reliance on multiple household earners to stabilize

income. Additionally, a substantial proportion of fishers reported exploring new fishing areas (73.39%), selling fish directly to consumers without intermediaries (69.35%), and participating in more than one occupation (67.74%). Cooperation among fishers is also notable, with 64.52% indicating active collaboration, which underscores the significance of social networks and collective action. In contrast, long-term adaptive strategies are less frequently adopted: only 39.52% save money for unforeseen events, 37.90% use different fishing tools, and just 15.32% acquire additional skills to enhance income. These patterns suggest that while fishers prioritize short-term, immediate coping mechanisms, engagement in sustainable, long-term capacity-building strategies remains limited. Furthermore, the chart reveals that 56.45% of respondents do not refrain from catching small fish, highlighting the persistence of unsustainable fishing practices with potential ecological consequences. In summary, the findings indicate that fishers primarily rely on immediate income diversification and catch-enhancing measures rather than savings, training, or sustainable resource management practices.

Figure 4: Adaptation practices by fishing households

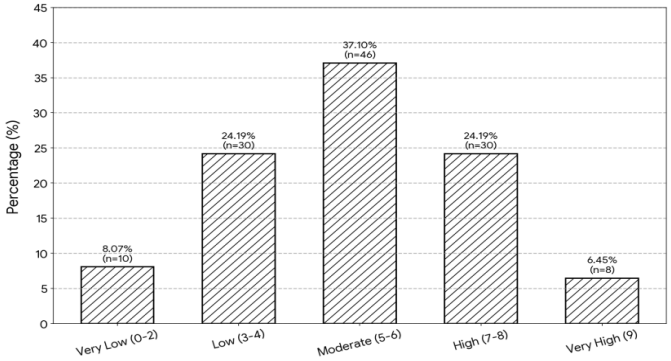


Source: Authors' calculations based on field survey, 2023

3.6.1 Livelihood adaptation index

The Livelihood adaptation index (LAI) measures how many adaptation practices each fisher household adopts, based on nine possible actions (range: 0-9). Figure 5 shows, in Beel Gajna, most fishers scored in the moderate adaptation range, with 37.10% achieving an LAI of 5 or 6. This indicates they have taken several steps to cope with climate risks, though they face ongoing challenges. Both low and high adaptation categories include 24.19% of respondents, showing some fishers are just starting to adapt while others have advanced further. Very low adaptation (few or no coping measures) was found in 8.07% of households, highlighting a vulnerable group. Only 6.45% of fishers reached the highest adaptation level, indicating that few have implemented comprehensive adaptation strategies. The majority operate at an intermediate stage—leaving them neither acutely vulnerable nor fully resilient. Strengthening their climate resilience requires targeted support for livelihood diversification, enhanced financial resources, and expanded climate awareness.

Figure 5: LAI adaptation level



Source: Authors' calculations based on field survey, 2023

3.7 Determinants of Adaptation Adoption

Table 7 presents the ordinary least squares (OLS) regression results identifying factors associated with the Livelihood adaptation index (LAI) among *beel*-dependent households (n=195). The model is statistically significant ($F=12.34$, $p<0.001$) and explains 37.5% of the variance in adaptation scores ($R^2=0.375$). The adjusted R^2 of 0.345 suggests the model generalizes effectively beyond the sample.

Table 7: Determinants of livelihood adaption

Variable	Coefficient (β)	Standard Error	t-value	p-value
Fisher status (1=fisher, 0=non-fisher)	1.187	0.276	4.301	0.000**
Climate awareness (1=aware)	1.089	0.234	4.654	0.000**
Education level (1-5 scale)	0.234	0.089	2.629	0.009**
Household income (log)	0.356	0.108	3.296	0.001**
Cooperative membership (1=yes)	0.678	0.287	2.362	0.019*
Household size (members)	0.067	0.071	0.944	0.347
Land ownership (>33 decimals)	0.423	0.298	1.419	0.158
Catch decline perception (1=yes)	0.734	0.312	2.353	0.020*
Age (years)	0.012	0.008	1.500	0.135
Constant	1.234	0.456	2.706	0.007**
$F=12.34$ ($p<0.001$)				
$R^2=0.375$				
Adjusted $R^2=0.345$*				

Source: Authors' estimation based on field survey, 2023
*Note: *p<0.05, **p<0.01*

Table 7 shows that being a fisher is the strongest factor in predicting livelihood adaptation ($\beta=1.187$, $p<0.001$). Artisanal fishers score 1.19 points higher on the livelihood adaptation index (LAI) than non-fishers, which is a 27.6% increase over the average LAI of non-fishers (3.87). This result matches recent research on vulnerability (Béné et al., 2019), which finds that people who depend on natural resources tend to adapt more because they face more environmental changes.

Climate awareness is also strongly linked to adaptation (β=1.089, $p<0.001$). People who understand climate change use 1.09 more adaptation strategies than those who do not. This supports Protection Motivation Theory (van Valkengoed & Steg, 2019) and suggests that improving climate literacy—since only 23% of respondents showed awareness—could lead to more adaptation. Household income has a significant positive effect (β=0.356, $p<0.01$). A 10% increase in monthly income leads to a 0.036 point rise in LAI. Households in the highest income group score about 1.42 points higher than those in the lowest group, showing that money is a key factor in adaptation, as described by the Sustainable Livelihoods Framework (Ellis & Freeman, 2023).

A decline in fish catch is also associated with higher LAI (β=0.734, $p<0.05$), supporting the idea in Protection Motivation Theory that noticing environmental problems encourages people to adapt. Being a member of a cooperative also predicts higher LAI scores ($\beta = 0.678$, $p < 0.05$). Cooperative members use 0.68 more strategies than non-members, which fits with recent studies on social capital and resilience (Aldrich & Meyer, 2015) and shows that social connections help communities adapt. Education level matters too (β=0.234, $p<0.01$). Each step up in education raises LAI by 0.23 points, confirming that education helps people solve problems and find information about adaptation. Household size (p=0.347), land ownership (p=0.158), and age (p=0.135) are not significant, though their effects are positive. The model explains about 35% of the differences in LAI scores (Adjusted R^2=0.345), which is reasonable for this type of survey (Menard, 2022). The rest of the variation may be due to factors such as personality, broader social networks, or access to climate information.

The results also have practical meaning. For example, a fisher household with climate awareness, cooperative membership, secondary education, and higher income is expected to have an LAI of about 6.8 (high adaptation), while a non-fisher household without these traits is expected to have an LAI of about 2.5 (low adaptation). This 4.3-point gap is almost half the total LAI range. Five main points stand out: (1) being a fisher and having climate awareness are the top predictors, showing that both direct experience and understanding matter; (2) income and cooperative membership are important, suggesting that reducing poverty and supporting institutions can help; (3) seeing threats motivates action, so learning from experience works; (4) education supports adaptation, so investing in rural education is important; and (5) the model explains 35% of the variation, so future research should look at psychological, cultural, and governance factors not covered here.

3.8 Discussion

The ecological degradation of *Beel Gajna* provides compelling evidence of climate change impacts on freshwater ecosystems, resulting in cascading socioeconomic consequences for dependent communities. Approximately 15 fish species have become locally extinct (Table 5), corroborating IUCN's (2008) warnings regarding declining wetland biodiversity in Bangladesh. This species loss

indicates severe ecosystem stress, as 74.65% of fishers report deteriorating environmental conditions (Table 5) and 81.69% observe smaller fish sizes, recognized indicators of nutritional stress in climate-affected fisheries worldwide (Cheung et al., 2013). The crisis extends beyond ecological dimensions, disrupting local economies through reduced fish availability (reported by 59.15% of respondents) and subsequent price increases, consistent with basic supply-demand principles (52.11%). These changes have led to a collapse in livelihoods, evidenced by obsolete fishing gear (70.42%), shrinking fishing areas (87.32%), and unsustainable incomes (78.87%), resulting in 47.89% of fishers partially or completely abandoning their profession. The ensuing economic hardship affects 54.93% of households, while only 28.17% maintain stable living conditions, demonstrating how climate change functions as a threat multiplier in vulnerable ecosystems. The combined effects of siltation and habitat loss, intensified by anthropogenic pressures such as agricultural expansion (Dasgupta et al., 2022), have produced an adaptation crisis in which nearly half the community is unable to improve their socioeconomic status, remaining trapped in a cycle of ecological decline and climate-induced poverty.

Ecological decline has triggered significant economic repercussions for dependent communities. The supply-demand imbalance has increased fish prices, as reported by 59.15% of respondents, aligning with global observations of climate impacts on small-scale fisheries (Lam et al., 2020). With 78.87% reporting decreased fishing-based livelihoods and 54.93% experiencing heightened economic hardship, these findings support Béné and Friend's (2011) concept of "distress diversification," whereby 67.61% now rely on multiple jobs. Value chain disruptions are particularly severe; although 69.01% recognize benefits from direct sales (Bush et al., 2011), most lack alternative market access, in contrast to Pacific communities studied by Bell et al. (2018) and Hanich (2018). The 16.90% of households reporting lifestyle deterioration, with only 28.17% maintaining stability, reflects a widening climate-induced poverty gap, consistent with findings in other deltaic regions (Townhill, 2023).

Fishing communities have adopted various coping mechanisms, though these have proven only partially effective. The portfolio approach (Badjeck et al., 2010) is evident in strategies such as cooperative fishing (64.79%), alternative livelihoods (87.32%), and tool diversification. However, these measures are less effective compared to global examples: only 15% pursue skill development, compared to 42% in Philippine communities (Fabinyi et al., 2024), and fewer than 50% possess adequate fishing gear, compared to 65% in coastal Bangladesh (Islam et al., 2021). The continued practice of immature fish harvesting by 43.66% of fishers exemplifies the poverty trap described by Béné and Friend (2011), in contrast to successful juvenile protection programs in Belize (Richmond et al., 2023). This implementation gap underscores the limitations of autonomous adaptation in the absence of institutional support (Ostrom, 2009), particularly as 60% lack emergency savings, unlike supported communities in Costa Rica (Alpízar et al., 2020).

The study identifies systemic barriers to effective climate adaptation. With only 11 of 124 respondents possessing non-fishing skills (Ahmed & Khan, 2023), the human capital deficit surpasses that observed in comparable Asian fisheries (Srinivasan et al., 2020). This knowledge gap perpetuates unsustainable practices despite 73.24% awareness of necessary innovations, a paradox consistent with Malloy and Ashcraft's (2020) framework. The predominant focus on short-term coping strategies rather than long-term adaptation reflects both limited institutional support and insufficient climate literacy, in contrast to more successful community-based management in Cambodia's Tonle Sap (Teh et al., 2019). Without addressing these structural barriers, even well-designed adaptation policies may not reach vulnerable fishers. The *Beel Gajna* case presents important contrasts with other climate-affected fisheries. While patterns of biodiversity loss are similar to those in West African wetlands (Nunoo et al., 2014), the economic impacts appear more severe than in the Bengal region of India (Baruah et al., 2020). The 70.42% reduction in fishing tools indicates greater resource constraints than those faced by Madagascar's coastal communities, although adaptation awareness levels are comparable to those of Indonesian fishers (Satria et al., 2021). The lack of middleman elimination, despite recognized benefits, contrasts with successful value chain reforms in Vietnam's Mekong Delta (Nguyen et al., 2023), suggesting unique institutional barriers in Bangladeshi wetlands (Islam et al., 2019).

4. Conclusion

The rural economy of Bangladesh remains highly dependent on climate-sensitive agriculture and fisheries (Arif et al., 2024). This study demonstrates that rising temperatures, erratic rainfall, and extreme weather events have significantly disrupted fisheries production in *Gajner Beel*. Ecological impacts include accelerated siltation, as reported by 82% of respondents, and biodiversity loss, with 15 species now extinct. These changes have led to direct livelihood consequences: 78% of fishers report reduced catches and 63% experience income declines. This situation presents a paradox: although 73% of respondents recognize climate change impacts, only 15% have adopted adaptive measures, primarily due to financial and knowledge constraints. This finding aligns with Mortreux et al. (2023) and the 'climate poverty trap' theory. The study is subject to several limitations, including its focus on a single *Beel* ecosystem, which restricts generalizability, short-term data collection that may not capture seasonal variations, limited gender-disaggregated analysis, and reliance on self-reported data without biological verification. Future research should prioritize longitudinal studies across multiple *Beels*, gender-sensitive adaptation assessments, cost-benefit analyses of restoration techniques, and evaluations of the integration of indigenous knowledge into climate planning.

The findings highlight three critical policy priorities. First, ecological restoration through re-excavation and habitat protection could reverse siltation trends, as demonstrated in Cambodia's Tonle Sap (Arias, 2021), with 87% of fishers supporting such measures. Second, livelihood diversification programs must address the

significant skills gap; only 15% of respondents possessed alternative income skills, compared to 42% in comparable Philippine communities (Fabinyi, 2022). Vocational training in sustainable aquaculture and ecotourism is recommended. Third, institutional strengthening is necessary, particularly through community-based monitoring systems modeled after successful programs in Costa Rica (Alpízar, 2020), since 65% of respondents identified lack of government support as a key barrier. Without immediate intervention, Bangladesh faces the risk of irreversible wetland degradation, threatening both biodiversity and the livelihoods of millions. Integrated policies that combine ecological management, socioeconomic support, and community-led adaptation are urgently required to build resilience against escalating climate impacts and to ensure equitable benefits for vulnerable fishing communities.

The study identifies several urgent policy interventions. First, ecosystem-based management should prioritize habitat restoration and protection of breeding areas, drawing on lessons from Belize's juvenile fish programs (Richmond et al., 2023). Second, skill development initiatives must address the human capital deficit, potentially modeled after Thailand's successful vocational training programs (Chuenpagdee & Juntarashote, 2011). Third, microfinance programs could help break the poverty trap by providing emergency funds and gear loans, as demonstrated in Costa Rica (Alpízar et al., 2020). Finally, climate literacy campaigns should accompany all interventions to address the awareness-action gap noted by 73.24% of respondents (Westlund, 2007). Future research should evaluate gender-differentiated impacts and pilot community-based adaptation programs to identify scalable solutions.

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Reference

Ahmed, S. & Khan, M. A. (2023). Spatial overview of climate change impacts in Bangladesh: a systematic review. *Climate and Development, 15*(2), 132–147. https://doi.org/10.1080/17565529.2022.2062284

Aldrich, D. P., & Meyer, M. A. (2015). Social capital and community resilience. *American Behavioral Scientist*, 59(2), 254–269. https://doi.org/10.1177/0002764214550299

Alpízar, F., Saborío-Rodríguez, M., Martínez-Rodríguez, M. R., Viguera, B., Vignola, R., Capitán, T., & Harvey, C. A. (2020). Determinants of food insecurity among smallholder farmer households in Central America: recurrent versus extreme

weather-driven events. *Regional Environmental Change, 20*, 22, 1–16. https://doi.org/10.1007/s10113-020-01592-y

Arif, K. M., Islam, S. R., & Islam, A. (2024). Challenges and opportunities of growth centres in Bangladesh: rural development perspective. *Frontiers of Urban and Rural Planning*, 2, 1. https://doi.org/10.1007/s44243-023-00026-7

Badjeck, M. C., Allison, E. H., Halls, A. S., & Dulvy, N. K. (2010). Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy*, 34(3), 375–383. https://doi.org/10.1016/j.marpol.2009.08.007

Banglapedia. National Encyclopedia of Bangladesh. https://banglapedia.org/

Barua, P., Rahman, S. H., Barua, S., & Rahman, I. M. (2020). Climate change vulnerability and responses of fisherfolk communities in the south-eastern coast of Bangladesh. *Water Conservation and Management*, *4*(1), 20–31. http://doi.org/10.26480/wcm.01.2020.20.31

Bell, J. D., Cisneros-Montemayor, A., Hanich, Q., Johnson, J. E., Lehodey, P., Moore, B. R., & Wabnitz, C. C. (2018). Adaptations to maintain the contributions of small-scale fisheries to food security in the Pacific Islands. *Marine Policy*, 88, 303–314. https://doi.org/10.1016/j.marpol.2017.05.019

Béné, C., & Friend, R. M. (2011). Poverty in small-scale fisheries: old issue, new analysis. *Progress in Development Studies*, *11*(2), 119–144. https://doi.org/10.1177/146499341001100203

Béné, C., Headey, D., Haddad, L., & von Grebmer, K. (2019). Is resilience a useful concept in the context of food security and nutrition programmes? Some conceptual and practical considerations. *Food Security*, *11*(4), 785–803. https://doi.org/10.1007/s12571-015-0526-x

Brander, K. (2010). Impacts of climate change on fisheries. *Journal of Marine Systems*, *79*(3-4), 389–402. https://doi.org/10.1016/j.jmarsys.2008.12.015

Bush, E. R., Short, R. E., Milner-Gulland, E. J., Lennox, K., Samoilys, M., & Hill, N. (2017). Mosquito net use in an artisanal East African fishery. *Conservation Letters*, *10*(4), 451–459. https://doi.org/10.1111/conl.12286

Cheung, W. W., Watson, R., & Pauly, D. (2013). Signature of ocean warming in global fisheries catch. *Nature*, 497, 365–368. https://doi.org/10.1038/nature12156

Chuenpagdee, R., Juntarashote, K. (2011). Learning from the experts: attaining sufficiency in small-scale fishing communities in Thailand. In Jentoft, S. & Eide, A. (Eds.): *Poverty Mosaics: Realities and Prospects in Small-Scale Fisheries*, pp. 309–331. Dordrecht: Springer. https://doi.org/10.1007/978-94-007-1582-0_14

Dasgupta, S., Wheeler, D., Bandyopadhyay, S., Ghosh, S., & Roy, U. (2022). Coastal dilemma: climate change, public assistance and population displacement. *World Development*, *150*, 105707. https://doi.org/10.1016/j.worlddev.2021.105707

DFID. (1999). *Sustainable Livelihoods Guidance Sheets*. London: Department for International Development.

Ellis, F., & Freeman, H. A. (2023). *Rural Livelihoods and Poverty Reduction Policies: Who Suffers Most from the Extreme Weather Events?* Bonn: Germanwatch.

Fabinyi, M. (2024). Small-scale fisheries, large-scale fisheries and fisheries governance in the Philippines. *Journal of Environmental Policy & Planning*, *26*(2), 159–172. https://doi.org/10.1080/1523908X.2024.2314451

Ficke, A. D., Myrick, C. A., & Hansen, L. J. (2007). Potential impacts of global climate change on freshwater fisheries. *Reviews in Fish Biology and Fisheries*, *17*, 581–613. https://doi.org/10.1007/s11160-007-9059-5

Gaines, S., Cabral, R., Free, C. M., Golbuu, Y., Arnason, R., Battista, W., & Turley, C. (2023). The expected impacts of climate change on the ocean economy. In Lubchenco, J. & Haugan, P.M. (Eds.): *The Blue Compendium: From Knowledge to Action for a Sustainable Ocean Economy*, pp. 15–50. Cham: Springer International Publishing.

Galappaththi, E. K., Susarla, V. B., Loutet, S. J., Ichien, S. T., Hyman, A. A., & Ford, J. D. (2022). Climate change adaptation in fisheries. *Fish and Fisheries*, *23*(1), 4–21. https://doi.org/10.1111%2Ffaf.12595

Hanich, Q., Wabnitz, C. C., Ota, Y., Amos, M., Donato-Hunt, C., & Hunt, A. (2018). Small-scale fisheries under climate change in the Pacific Islands region. *Marine Policy*, *88*, 279–284. https://doi.org/10.1016/j.marpol.2017.11.011

Hasan, Z., & Nursey-Bray, M. (2018). Artisan fishers' perception of climate change and disasters in coastal Bangladesh. *Journal of Environmental Planning and Management*, *61*(7), 1204–1223. https://doi.org/10.1080/09640568.2017.1339026

Hilton-Taylor, C., & Brackett, D. (2000). 2000 IUCN red list of threatened species. The IUCN Species Survival Commission. Available from https://portals.iucn.org/library/sites/library/files/documents/RL-2000-001.pdf. [23 December 2023].

Islam, M. A., Ahmad, S. A., & Islam, R. (2019). Water quality perceptions and willingness to pay: valuing river water quality using contingent valuation method. *Journal of Advanced Research in Dynamical and Control Systems*, *11*(special issue 5), 1011–1022.

Islam, M. M., Begum, P., Begum, A., & Herbeck, J. (2021). When hazards become disasters: coastal fishing communities in Bangladesh. *Environmental Hazards*, *20*(5), 533–549. https://doi.org/10.1080/17477891.2021.1887799

Lam, V. W., Allison, E. H., Bell, J. D., Blythe, J., Cheung, W. W., Frölicher, T. L., & Sumaila, U. R. (2020). Climate change, tropical fisheries and prospects for sustainable development. *Nature Reviews Earth & Environment*, *1*(9), 440–454. https://doi.org/10.1038/s43017-020-0071-9

Limuwa, M. M., Sitaula, B. K., Njaya, F., & Storebakken, T. (2018). Evaluation of small-scale fishers' perceptions on climate change and their coping strategies: Insights from Lake Malawi. *Climate*, *6*(2), 34. https://doi.org/10.3390/cli6020034

Malloy, J. T., & Ashcraft, C. M. (2020). A framework for implementing socially just climate adaptation. *Climatic Change*, *160*(1), 1–14. https://doi.org/10.1007/s10584-020-02705-6

Menard, S. (2022). Applied Logistic Regression Analysis (4th edition). SAGE.

Nguyen, T. (2024). Challenges and strategies for sustainable fisheries in Vietnam. Master's Thesis, LUT University, Finland.

Nunoo, F. K. E., Asiedu, B., Amador, K., Belhabib, D., Lam, V., Sumaila, R., & Pauly, D. (2014). Marine fisheries catches in Ghana: historic reconstruction for 1950 to 2010 and current economic impacts. *Reviews in Fisheries Science & Aquaculture*, *22*(4), 274–283. https://doi.org/10.1080/23308249.2014.962687

Nyboer, E. A., & Chapman, L. J. (2017). Elevated temperature and acclimation time affect metabolic performance in the heavily exploited Nile perch of Lake Victoria. *Journal of Experimental Biology*, *220*(20), 3782–3793. https://doi.org/10.1242/jeb.163022

Ojea, E., Lester, S. E., & Salgueiro-Otero, D. (2020). Adaptation of fishing communities to climate-driven shifts in target species. *One Earth*, *2*(6), 544–556. https://doi.org/10.1016/j.oneear.2020.05.012

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, *325*(5939), 419–422. https://doi.org/10.1126/science.1172133

Paul, B., Faruque, M. H., & Ahsan, D. A. (2014). Consequences of climate change on fish biodiversity in the river Turag, Bangladesh: a community perception study. *World Journal of Fish and Marine Sciences*, *6*(2), 136–141. https://doi.org/10.5829/idosi.wjfms.2014.06.02.76194

Poissant, D., Coomes, O. T., Robinson, B. E., & Vargas Dávila, G. (2024). Fishers' ecological knowledge points to fishing-induced changes in the Peruvian Amazon. *Ecological Applications*, *34*(5), e2964. https://doi.org/10.1002/eap.2964

Rahman, M. S., Toiba, H., & Huang, W. C. (2021). The impact of climate change adaptation strategies on income and food security: empirical evidence from small-scale fishers in Indonesia. *Sustainability*, *13*(14), 7905. https://doi.org/10.3390/su13147905

Richmond, J. Q., Kingston, J., Ewing, B. A., Bear, W., Hathaway, S. A., Lee, C., & Fisher, R. N. (2023). Prioritizing the risk and management of introduced species in a landscape with high indigenous biodiversity. *Bulletin, Southern California Academy of Sciences*, *122*(2), 101–121. https://doi.org/10.3160/0038-3872-122.2.101

Rogers, L. A., Griffin, R., Young, T., Fuller, E., St. Martin, K., & Pinsky, M. L. (2019). Shifting habitats expose fishing communities to risk under climate change. *Nature Climate Change*, *9*(7), 512–516. https://doi.org/10.1038/s41558-019-0503-z

Scoones, I. (1998). Sustainable rural livelihoods: a framework for analysis. *IDS Working Paper 72*. Institute of Development Studies, University of Sussex, UK.

Shamsuzzaman, M. M., Islam, M. M., Tania, N. J., Al-Mamun, M. A., Barman, P. P., & Xu, X. (2017). Fisheries resources of Bangladesh: Present status and future direction. *Aquaculture and Fisheries*, 2(4), 145–156. https://doi.org/10.1016/j.aaf.2017.03.006

Sultana, M. A., Pandit, D., Barman, S. K., Tikadar, K. K., Tasnim, N., Fagun, I. A., & Kunda, M. (2022). A review of fish diversity, decline drivers, and management of the Tanguar Haor ecosystem: A globally recognized Ramsar site in Bangladesh. *Heliyon, 8*(11). https://doi.org/10.1016/j.heliyon.2022.e11875

Teh, L. S., Bond, N., Fraser, E., Seng, R., & Sumaila, U. R. (2019). The economic impact of global change on fishing and non-fishing households in the Tonle Sap ecosystem, Pursat, Cambodia. *Fisheries Research*, 210, 71–80. https://doi.org/10.1016/j.fishres.2018.10.005

Tikadar, K. K., Islam, M. J., Saha, S. M., Alam, M. M., Barman, S. K., & Rahman, M. A. (2022). Livelihood status of small-scale fishermen and determinants of their income: Insights from north-eastern floodplains of Bangladesh. *Geography and Sustainability*, 3(3), 204–213. https://doi.org/10.1016/j.geosus.2022.06.002

Townhill, B., Harrod, O., Painting, S., Acheampong, E., Bell, J., Nyarko, B. K., & Engelhard, G. (2023). Climate change risk and adaptation for fisher communities in Ghana. *Journal of Coastal Conservation*, 27(5), 45. https://doi.org/10.1038/s41558-019-0503-z

Tregidgo, D., Campbell, A. J., Rivero, S., Freitas, M. A. B., & Almeida, O. (2020). Vulnerability of the Açaí palm to climate change. *Human Ecology*, 48, 505–514. https://doi.org/10.1007/s10745-020-00172-2

van Valkengoed, A. M., & Steg, L. (2019). Meta-analyses of factors motivating climate change adaptation behaviour. *Nature Climate Change*, *9*(2), 158–163. https://doi.org/10.1038/s41558-018-0371-y

Welcomme, R. L., Cowx, I. G., Coates, D., Béné, C., Funge-Smith, S., Halls, A., & Lorenzen, K. (2010). Inland capture fisheries. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1554), 2881–2896. https://doi.org/10.1098/rstb.2010.0168

Westlund, L. (2007). Disaster response and risk management in the fisheries sector *FAO Fisheries Technical Paper. No. 479*. Rome: Food & Agriculture Organization.