Factors Affecting Small-Scale Fishers Adaptation toward the Impacts of Climate Change: Reflections from South Eastern Bangladeshi Fishers

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Abstract – *The main objective of this research is to understand fishers' perceptions of climate change and to identify factors that influence their expectations concerning adapting to change. Two coastal communities at Salimpur on the Sitakunda coast and Sarikait in Sandwip Island were selected as a case study to analyse fishers' perceptions of climate change in southeastern Bangladesh. This research involved a questionnaire survey to interview 135 male fishers in two areas, who are professional fishers. Exploratory factor analysis and a binary logistic regression were adopted for empirical analysis. From the fishers surveyed, 84% opined that they might adapt and continue the fishing profession in response to climate change. The results suggested that fishers, although they have experienced formal and institutional barriers to adaptation in response to climate change and pursued alternative livelihoods as adaptation strategies, may continue to a fishing profession in the future. On the contrary, the fishers who have generated a high fishing income and experienced extreme climate events may not continue to a fishing profession. Fishers also cited climatic factors along with non-climatic factors (fishing ban, no return on investment, low supply of caught fish) as the reasons hindering their adaptation strategies in response to climate change.*

Keywords – *adaptation, Bangladesh, climate change, fisheries management, fishers' perception.*

1. INTRODUCTION

The global climate is changing, and the effects are impacting both the ecosystem and human well-being [1], [2]. In the last century, the global average temperature has increased by 0.74°C, as reported in the Fourth Assessment Report. The Fifth Assessment (AR5) report of the Intergovernmental Panel on Climate Change (IPCC) revealed that between 1880 and 2020, the globally averaged combined land, and the ocean surface temperature was 0.85°C. Also, AR5 noted that global ocean warming is the greatest near the surface. Over the period 1971– 2010, ocean warming has increased by 0.11°C per decade [3]. The IPCC also stated that their simulation produced an average temperature rise by 1.8–4°C depending on various emission scenarios [4]. The AR5 reported that since about 1950, changes had been observed in extreme weather and climate events (warm temperature extremes, heavy precipitation and extremely high sea levels). The IPCC also reported in 2018 that anthropogenic global warming had reached about 1°C above global average temperatures between 1850–1900 and if it continues to rise by a current rate of 0.2°C per decade global warming is likely to reach 1.5°C between 2030 and 2052 [5]. This rate of warming indicates that climate change is inevitable and impacts on the future development of humans and the environment may be substantial, particularly in respect to the world's marine ecosystem functions [6]-[8]. Increased water temperature impacts aquatic organisms and the declining fish catch potential worldwide [9], [10].

Moreover, changes in fish distribution and abundance are likely to affect the fishing profession, fishery-based livelihoods, and associated industries [11]. In Bangladesh, the mean annual temperature, between 1958 and 2007, has increased by 0.10°C [12]. The global mean surface temperature increased by 0.12°C per decade [3]. Rahman, *et al*. [13] investigated temperature scenarios for Bangladesh for 2050 and indicated that the monthly mean surface air temperature could increase between 0.5 and 2.1°C. Simulation models suggest that climate change will lead to changes in primary productivity, shifting in distribution, and changes in the potential catch of marine resources, leading to global impacts on the fishing industry [14].

The fisheries sector in Bangladesh contributed 3.57 percent of the National Gross Domestic Product (GDP) in the fiscal year of 2018, and in 2017-2018 it accounted for one-fourth of agricultural GDP. In 2018, the contribution to GDP by agriculture and industry was 13.07% and 28.54%, respectively. Over 11 percent of the total population of Bangladesh is wholly or partially involved in this sector for their livelihoods [15]. In terms of food and nutrition supply, the population of Bangladesh receive 60 percent of animal protein from this sector. Furthermore, small-scale coastal fisheries support the livelihoods of half a million fishers and the members of their households [15]. Such fishers capture 82 percent of Bangladesh's overall marine catch [15].

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Despite this, the fisheries sector of Bangladesh is susceptible to climate change and global variability [16]. Various climatic variables, including tropical cyclones and temperature, salinity, sea-level rise, water temperature, precipitation, and drought, have adversely affected the sustainability of coastal fishing, thus affecting the livelihood and well-being of fishing communities [17], [18]. Climate change is expected to have a significant impact on fishery-based livelihoods [19]. Coastal communities in Bangladesh are consistently adopting instinctive survival strategies to live under changing climatic conditions [20]-[22].

Climate change and its related impacts are said to have significantly impacted coastal means of life, ecosystems, human settlement, and water resources. In the Bay of Bengal, Bangladesh's coastline and offshore islands such as Sandwip, Kutubdia, and Hatiya are subjected to frequent tropical cyclones. The increase in the height of storm surges caused by intense tropical cyclones could be magnified by low lying land on the coast of Bangladesh along with the rise in sea level in the northern Bay of Bengal [23], [24]. Haque [25] states that in Bangladesh, coastal regions are frequently affected by tidal flooding, floods, and storm surges. Biswas, *et al*. [26] reported that about 21 percent of the south and southeast coastal areas of Bangladesh were affected by high to very high storm and tidal surge. Chowdhury, *et al*. [27] reported that increasing temperature and pH variation due to climate change might affect the marine fish species and affect the distribution pattern of some fish species. The small-scale fishing communities of Bangladesh are less educated and live along the coast of the Bay of Bengal. Thus, the economic hardship of these fishers is likely to be impacted by climate change. Studies, [27], [28] which mentioned the effects of climate change on the marine fishery resources (hilsa and shrimp) and the distribution pattern of marine fish species in Bangladesh coastal areas, also state that increased temperature might cause some fish species to migrate to a higher latitude or towards the sea.

Marine fisheries account for 16.28 percent of National fish production [29]. Shamsuzzaman, *et al*. [30] suggest that marine fisheries' contributions to the total fish production in Bangladesh has declined from twenty-one percent to sixteen percent (21.30% to 16.18%) throughout 2000 to 2015. Other findings reinstated this when Barange, *et al*. [31] showed that the fish production in the marine waters of Bangladesh is likely to decrease to less than ten percent due to the impacts of climate change.

According to the IPCC, adaptation is "the process of adjustment to the actual or expected climate and its effects." In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. Natural environments and natural interventions may also facilitate adjustment to climate change and its effects [3]. However, there is a lack of grounded research in this area, namely, to identify local-level symptoms of climate change, its impacts, community-level adaptation and resilience [20]. Islam, *et al*. [11] analysed the vulnerability of fishery-based livelihoods to the impacts of climate variability and change in two coastal fishing communities in Bangladesh. Adaptation can be positive or negative, and the inability to recognise climate change can lead to maladaptation. Thus, awareness of climate change is needed to prevent maladaptation within the Bangladeshi fishing industry.

Vulnerabilities are those factors that compromise the capacity of a community to prepare and respond to natural hazards. Islam, *et al*. [11] identified that livelihood vulnerability includes exposure to floods and cyclones, sensitivity, and lack of adaptive capacity in terms of physical, natural, and financial capital, as well as diverse livelihood strategies that vary depending on location and context. Islam, *et al*. [32] also identified the restrictions of and barriers to climate change adaptation among the Bangladeshi fishing communities. The limits include physical characteristics of the climate and the sea, such as the frequency and duration of tropical cyclones, and hidden sandbars, which obstruct the safe return of the fishers to communities on the coast [32]. The barriers to climate change adaptation include technologically inferior boats, weak radio signals, low incomes, credit inaccessibility, unfavourable credit schemes, inaccurate weather forecasts, underestimation of cyclone occurrence, coercion of fishers by boat owners and captains, lack of education, skill and livelihood alternatives, lack of enforcement of fishing regulations and maritime laws, and the lack of access to fish markets.

Hasan and Nursey-Bray [33] studied fishers' perceptions in response to climate change, where the authors mentioned a few important determinants (geographic characteristics and disaster experiences) that shape the fishers' views about climate change. Jahan, *et al*. [34] investigated fishers' perceptions on the effect of climate change and anthropogenic impact on Hilsa fishery at lower Meghna river, where the authors reported that the stock of Hilsa is declining due to several adverse climatic conditions. Billah, *et al*. [35] studied fishers' perception of climate change on saltmarsh and seagrass ecosystems in the southeastern coast of Bangladesh, where the authors reported that fishers are helpless to face the effects of climate change due to their poverty especially less income source and food deficiency. Chen [36] identified factors that influence Taiwanese fishers' perception in response to climate change and developed an empirical model to predict the influences on fishers' willingness to adapt their fishing behaviours under climate change. However, studies related to identifying critical factors, in particular socio-economic factors and climate change perceptions, that influence fishers' eagerness to adapt to fishing activities under climate change is limited in Bangladesh.

Therefore, this research aimed to improve understanding of local-level climate change perceptions, adaptation constraints, and community-led adaptation strategies of the fishing communities in south-eastern Bangladesh. Subsequently, it determines the essential factors that influence the fishing behaviour of south-eastern Bangladeshi fishers in response to climate change. The findings intend to help government agencies, decision-makers, and fishery managers develop coherent and comprehensive strategies for enhancing fishing communities' resilience to climate change on the Bangladesh coast.

2. METHODS

2.1 Study Area

Sandwip Island and Sitakunda are located on the southeast Bangladesh coast (Figure 1). For this study, both offshore and mainland coastal households have been selected that carry out fishing activities in the Bay of Bengal. Also, the fishers' communities from the villages of Sarikait in Sandwip Island and Salimpur in Sitakunda mainland coast were consulted. These fishing communities are located on the shores of the Bay of Bengal, which makes these areas highly vulnerable to floods, cyclones, erosion, and storm surges. The monthly mean sea surface temperature (SST) was between 23.4°C (January) and 29.2°C (May) in the coastal waters of Sandwip and Sitakunda mainland coast area with the average SST throughout the year of 28°C. The total population of Sarikait is 24, 543, of which 900 people are coastal fishers, according to the last census conducted in 2011. Salimpur, located in the coastal belt of Sitakunda, has a total population of 54,797, of which 734 people are coastal/offshore fishers. In our study areas, two categories of marine fisheries were found. The first is industrial fishers, who go for deep-sea fishing involving high-level technology to participate in large scale fishing. The second is artisanal fishers, who go out approximately eight kilometres from the coast to participate in small-scale fishing.

2.2 Survey Methods

In terms of climate change, the fishers' perceptions of the impacts emanated from extreme weather events are important for fisheries-related decision making. This study aims to identify local fishing communities' perceptions of climate change and identify the significant factors which affect fishers' response to climate change. Only a few studies, to the best of our knowledge, have discussed the determinants on the practices of fishers regarding climate change; thus, there is still insufficient literature to identify these important factors. Hasan and Nursey-Bray [33] mentioned a few important determinants (geographic characteristics, disaster experiences, socio-economic status, and worldviews) that shape fishers' perceptions about climate change. Fishers' characteristics, socio-economic status, and experiences are critical factors in influencing fishers' perceptions and adaptation measures regarding climate change [37]. Before conducting the field survey, a list of fishers' households from the selected study areas was gathered from both the Salimpur and Sarikait union councils. The study was conducted on fishers who fish as a primary source of income and have continued this profession for generations. From the selected household list, the formal survey was conducted between August 2019 and September 2019 and 135 fishers were interviewed face-to-face using a structured questionnaire survey which consists of 23 questions.

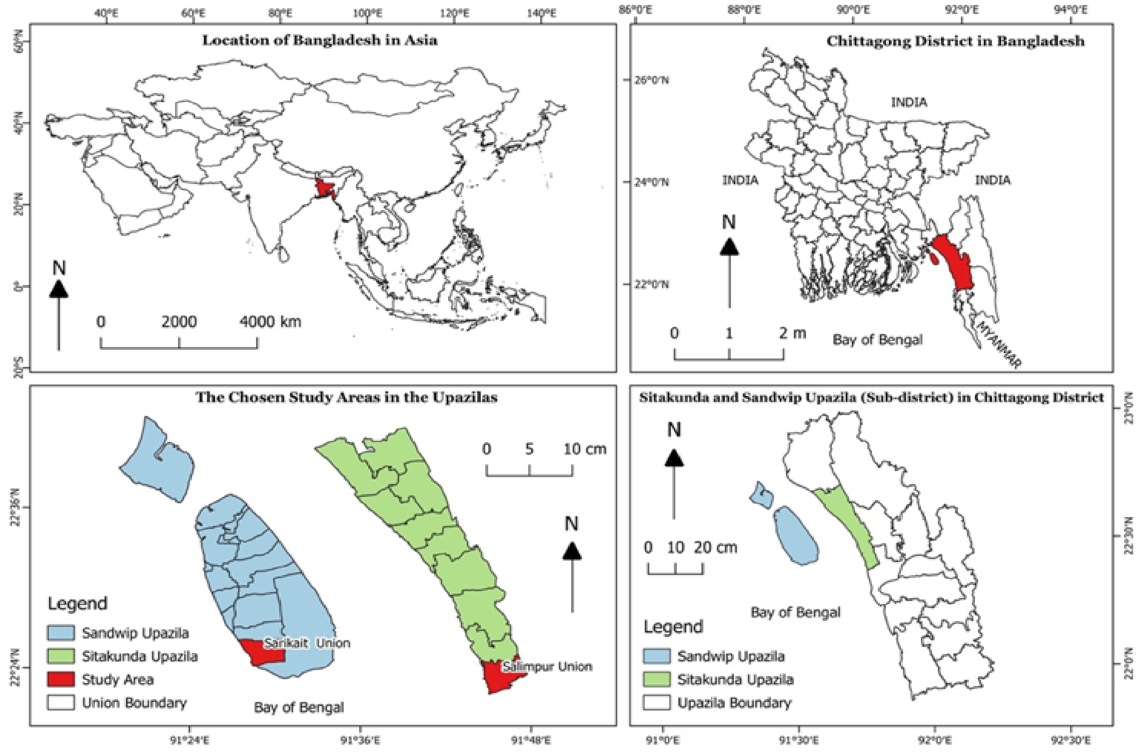

Fig. 1. Location of selected study areas.

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A simple random sampling technique was applied to select the participants. Of these 135 participants, 68 were from Sitakunda and 67 from Sandwip. The total fishers of these selected areas were 1634 (900 + 734), 135 responses can reach a sampling error level of 0.08. For further analysis in this study, a total of 135 samples are, therefore, admissible. A 5 Likert scale can perform a good measurement statistically [38]. In this research, the questions were set using a 5-point Likert scale, which ranged from 1 to 5 (strongly disagree, disagree, neutral, agree, and strongly agree).

2.3 Analysis

To find noticeable patterns among many variables or items, researchers often use the factor analysis method [36]. Factor analysis can be used to reduce many variables into a smaller and more manageable number of factors [52], [53]. Exploratory factor analysis reveals patterns among the inter-relationships of the items or variables [54].

2.3.1 Factor analysis

Factor analysis is used to determine the underlying factors or latent variables among questionnaires' items or observed variables. In exploratory factor analysis, the associations between latent and observed variables are called factor loadings. Exploratory factor analysis with the principal components method and varimax rotation has been used to minimise the many variables and examine the underlying dimensions of risk perceptions, adaptation constraints, and adaptation strategies. The principal component method can be used to solve high-dimensional multicollinearity issues of questionnaire data for estimating logistic models [39]. Before performing factor analysis, the Kaiser-Meyer-Olkin Measure of sampling adequacy (KMO) and Bartlett's Test of Sphericity were employed to check whether the variables are suitable to run factor analysis. KMO tests the proportion of variance in the data and how data is suited for factor analysis; the value range between 0 and 1 with test results greater than 0.6 are acceptable for factor analysis. Bartlett's Test of Sphericity is another evaluation of the factorability in data. Bartlett's test checks whether observed variables inter-correlate to the identity matrix. If the test is statistically significant, factor analysis is admissible. Also, factors with an eigenvalue greater than one are acknowledged for extracted factors.

The extracted items with factor loadings less than 0.5 should not be considered for factor analysis [40]. Thus, items of those factors with factor loading values less than 0.5 were dismissed.

2.3.2 Test of Internal Reliability

Internal reliability is a measure that checks whether different items on the same test produce a similar score based on the correlations between given items. Cronbach's alpha measure to test internal reliability was employed in this present study. The Cronbach's alpha ($\propto$) ranges between 0 and 1. High values are desirable but very high reliabilities (0.95 or higher) are not; since it indicates that items may be redundant [41]. An alpha score higher than 0.7 is acceptable [42].

2.3.3 Model

OLS (Ordinary Least Square) with dichotomous dependent variables leads to statistical problems (homoskedasticity or heteroskedasticity). Heteroskedasticity often leads to erroneous conclusions in hypothesis testing; thus, this study used binary logistic regression, as empirical modelling estimates the relationship between independent variables to a dichotomous variable. In addition, Maximum Likelihood Estimation (MLE) estimates the parameters of a logistic regression; thus, avoiding such statistical problems. A binary logistic regression with the MLE approach is considered for this study. This study aims at identifying the influencing factors in the fishers' decisions to adapt their fishing activities in response to climate change.

The eagerness of fishers to adapt their fishing activities is the dependent variable (Y), as follows:

$$Y = 1, 0 \tag{1}$$

where 1(yes) indicates that in response to climate change, a respondent may adapt fishing activities and 0 (no) indicates that the respondent may not adapt fishing activities in response to climate change. In the empirical model, p is the expected value of Y,

$$p = P(y = 1|x_1, x_2, \dots\dots, x_p) \tag{2}$$

where $P(y = 1|x_1, x_2, \dots\dots, x_p)$ is the probability of changing fishing activities when the given independent variables are $(X_1 = x_1, X_2 = x_2, X_K = x_K)$. Thus, the significant independent variables $(X_1, X_2, \dots\dots, X_K)$ that influence p were found; the nonlinear logistic model used is represented by Equation 3:

$$p = \frac{e^{\beta_0+\beta_1 x_1+\beta_2 x_2+..+\beta_p x_p}}{1+e^{\beta_0+\beta_1 x_1+\beta_2 x_2+..+\beta_p x_p}} \tag{3}$$

where β is the parameter to be estimated. According to the estimation procedure, the logistic model can be transformed into Equation 4:

$$ln\frac{p}{1-p} = \beta_0 + \sum_{i=1}^{k} \beta ixi \tag{4}$$

where $ln\frac{p}{1-p}$ is log odds, p is the probability that Y for cases equals 1, $1 - p$ is the probability that Y for cases equals 0, β_0 is intercept term, β_i are the coefficients associated with each explanatory variables x_i. The coefficients in the logistic regression were estimated using the maximum likelihood estimation method.

3. RESULTS

3.1 Profile of Respondents

The demographic characteristics of the respondents are shown in Table 1. From the total sample of the respondents, all of them are male; 50.4% lived in Salimpur, 49.6% lived in Sarikatpur. Most respondents had less than five years of education (53.3%), with 43% having primary education and 3.7% had completed secondary education. Of the total respondents, most were under 50 years of age (40.0%); 14.8% were between the ages of 51–55. Additionally, about 42.22% had 30-40 years of fishing experience. Furthermore, 28.9% of respondents reported that their monthly income from fishing occupation is between BDT 15000 to 20000.

Table 1. Summary statistics of the respondents.

Total					
Age		Experience		Income	
Age group	Frequency (%)	Fishing experience (years)	Frequency (%)	Income (BDT)	Frequency (%)
≤50	54 (40)	10-20	7 (5.19)	5001-10000	4 (3)
51-55	20 (14.8)	21-30	27 (20.0)	10001-15000	26 (19.3)
56-60	18 (13.3)	31-40	57 (42.22)	15001-20000	39 (28.9)
61-65	16 (11.9)	41-50	28 (20.74)	20001-25000	32 (23.7)
66-70	19 (14.1)	51-60	13 (9.63)	25001-30000	24 (17.8)
>70	8 (5.9)	60+	3 (2.22)	>30000	10 (7.4)
Total	135 (N=100)				
Sitakunda					
Age		Experience		Income	
Age group	Frequency (%)	Fishing experience (years)	Frequency (%)	Income (BDT)	Frequency (%)
≤50	27 (39.70)	10-20	6 (8.82)	5001-10000	4 (5.88)
51-55	12 (17.65)	21-30	13 (19.11)	10001-15000	13 (19.11)
56-60	11	31-40	28 (41.17)	15001-20000	22 (32.35)
61-65	8	41-50	15 (22.05)	20001-25000	16 (23.52)
66-70	8	51-60	5 (7.35)	25001-30000	10 (14.70)
>70	2	60+	1(1.47)	>30000	3(4.41)
Total	68 (N=100)				
Sandwip					
Age		Experience		Income	
Age group	Frequency (%)	Fishing experience (years)	Frequency (%)	Income (BDT)	Frequency (%)
≤50	27 (40.29)	10-20	1 (1.49)	5001-10000	63 (94.03)
51-55	12 (17.91)	21-30	14 (20.89)	10001-15000	2 (2.98)
56-60	7 (10.44)	31-40	27(40.29)	15001-20000	-
61-65	8 (11.94)	41-50	13 (19.40)	20001-25000	-
66-70	7 (10.4)	51-60	8(11.94)	25001-30000	1 (1.49)
>70	6 (8.95)	60+	2(8.95)	>30000	1(1.49)
Total	67 (N=100)				

Note: Number in parenthesis indicates per cent distribution. BDT=Bangladeshi Taka (currency unit in Bangladesh).

3.2 Factor Analysis Results

An exploratory factor analysis on the raw data was employed to explore the latent structure of the items and identify the factors that can influence fishers' perception to adapt concerning climate change. Three exploratory factor analyses were employed on three dimensions as "dimension of risk perception", "dimension of adaptation constraints", and "dimension of adaptation strategies".

The selected variables of each dimension were shown in Tables 3 to 5. Before performing exploratory factor analysis, the KMO test was employed to check whether the variables are suitable to run factor analysis. The analysis results showed that all KMO assessments were admissible (0.877, 0.7133, and 0.704). Also, Bartlett's Test of Sphericity is found significant for factor analysis. KMO test and Bartlett's test results suggested these variables are eligible for further analysis. Furthermore, the Cronbach's α of these extracted factors were α=0.826, 0.816, and 0.707, which are above the acceptable level 0.7. Additionally, all the item's communality score was higher than the cut-off value 0.3 (Table 2).

In this study, factor loading values less than 0.5 were deleted as suggested by [40]. Factors with an eigenvalue greater than one have been considered.

In the dimension of risk perception, two factors evolved with the eigenvalues that were greater than one were extracted. The factors are as follows: (1) IPE (eigenvalue=7.446, proportion=43.494); (2) OI (eigenvalue=2.317, proportion= 43.494). In adaptation constraints dimension, two factors were extracted. The factors are as follows: (1) NT (eigenvalue=7.446, proportion=43.494); (2) FI (eigenvalue=2.317, proportion= 43.494). Then, two factors were also considered in terms of the dimension of adaptation strategies; (1) AL (eigenvalue=3.352, proportion=35.48); (2) NO (eigenvalue=1.191, proportion=33.68).

Table 2. Values of communality for all variables.

Risk Perception		Adaptation constraints		Adaptation Strategies	
Variable	Communality	Variable	Communality	Variable	Communality
Increased high rainfall	0.805	Poor quality of boats increases the risk during inclement weather	0.551	Women forced to work outside	0.871
Increased height of storm surge	0.636	Inaccurate information about the weather	0.726	Engaged with alternative income sources	0.942
Increased intensity of wind speed of tropical cyclones	0.889	Increased frequency of tropical cyclones	0.532	Temporary displacement to elsewhere	0.512
Increased frequency of tropical cyclones	0.858	Unfavourable credit schemes sometimes put more pressure during extreme weather events	0.850	Involved in fish drying and processing instead of catching	0.767
Increased sea level	0.680	Lack of access to fish markets	0.602	Engaged in more farming activities compared to fishing	0.995
Decreased sea level	0.876	Lack of enforcement of fishing regulations and maritime laws	0.936	Women forced to work outside	0.871
Decreased cool days/nights	0.585	-	-	Engaged with alternative income sources	0.942
Decreased in total rainfall in the wet season	0.849	-	-	-	-
Number of annual rainy days decreased	0.898	-	-	-	-
More areas inundated by salinity	0.838	-	-	-	-
Decreased fish	0.815	-	-	-	-

Communality = The proportion of each variable's variance that can be explained by the *factors*.

3.3 Binary Logistic Model

Logistic regression is a regression model where the response variable is categorical. When there is a binary response variable, it is called a binary logistic regression model [55]. In this study, a binary logistic regression model was employed to determine the significant factors that might influence the fishers' decision to adapt fishing activities in response to climate change.

3.3.1 The Model and Variables

$$ln \frac{p}{1-p} = \beta_0 + \sum \beta_i \times SE_i + \sum \beta_j \times PER_j \quad (5)$$

where SE is the socio-economic variable including (1) AGE: age of the respondents, (2) EXP: fishing experience (years), (3) EDU: education level of the respondents (years), and (4) monthly income of the respondents. Also, PER are the perception variables, and six variables were extracted via a factor analysis that includes: (1) IPE: extreme climate events and impacts on physical environment; (2) OI: observed impacts, (3) NT: natural and technological (4) FI: formal and institutional (5) AL: alternative livelihoods (6) NO: new opportunities. All variable descriptions are shown in Table 6.

3.3.2 Results of the Logistic Model

An empirical model was adopted to understand the factors that influence fishers' decisions to adapt their fishing activities in response to climate change. The empirical results are shown in Table 7. The goodness of fits of the models are Cox and Snell R^2 is 0.177, and Nagelkere $R^2 R^2$ is 0.301, the predicted probability is 84.4%, and the P-value of the Hosmer and Lemeshow test is 0.962 (where > 0.1 is considered as acceptable); therefore, all indicators of the goodness of the fit of this model are well addressed.

Table 3. Factor analysis of the risk perception dimension.

Variable	Factor loading	Eigenvalue	Proportion	Cronbach's α
Factor 1: Extreme climate events and impacts on the physical environment (IPE)				
Increased high rainfall	0.816	7.446	43.494	0.946
Increased height of storm surge	0.794			
Increased intensity of wind speed of tropical cyclones	0.923			
Increased frequency of tropical cyclones	0.912			
Increased sea level	0.647			
Decreased sea level	0.902			
No change in sea level	0.730			
Decreased fish	0.827			
Factor 2: Observed impacts (OI)				
Variable	Factor loading	Eigenvalue	Proportion	Cronbach's α
Decreased cool days/nights	0.752	2.317	28.185	-
Decreased in total rainfall in the wet season	0.902			
Number of annual rainy days decreased	0.911			
More area being inundated by salinity	0.862			

Kaiser–Meyer–Olkin measure of sampling adequacy = 0.877
Bartlett's test of sphericity (significant) = 0.000

Table 4. Factor analysis of the adaptation constraints dimension.

Variable	Factor loading	Eigenvalue	Proportion	Cronbach's α
Factor 1: Natural and technological (NT)				
Poor quality of boats increases the risk during inclement weather	0.740	3.288	41.344	0.816
Inaccurate information about the weather	0.816			
Increased frequency of tropical cyclones	0.613			
Unfavourable credit schemes sometimes put more pressure during extreme weather events	0.918			
Factor 2: Formal and institutional (FI)				
Variable	Factor loading	Eigenvalue	Proportion	Cronbach's α
Lack of access to fish markets	0.766	2.317	28.185	-
Lack of enforcement of fishing regulations and maritime laws	0.952			

Kaiser–Meyer–Olkin measure of sampling adequacy = 0.713
Bartlett's test of sphericity (significant) = 0.00

Table 5. Factor analysis of the adaptation strategies dimension.

Factor 1: Alternative livelihoods (AL)				
Variable	Factor loading	Eigenvalue	Proportion	Cronbach's α
Engaged with alternative income sources	0.816	3.352	35.48	0.707
Temporary displacement to elsewhere	0.794			
Involved in fish drying and processing instead of catching	0.923			
Factor 2: New Opportunities (NO)				
Variable	Factor loading	Eigenvalue	Proportion	Cronbach's α
Women forced to work outside	0.752	1.191	33.68	
Engaged in more farming activities compare to fishing	0.902			

Kaiser–Meyer–Olkin measure of sampling adequacy = 0. 707
Bartlett's test of sphericity (significant) = 0.000

Table 6. Explanatory variables in the binary logistic regression model.

Dependent variable				
Variable	Description	Type	Mean	SD
Y	Will you adapt to fishing activities in response to climate change	Dummy variable 1 = Yes 0 = No	0.83	0.37
Independent variable				
Variable	Description	Type	Mean	SD
Personal variable (PV)				
AGE	Age of the respondent	Numeric variable	56.77	7.33
EDU	Education level of the respondent (years)	Numeric variable	1.48	1.93
FE	Fishing experience (years)	Numeric variable	38.98	11.79
Income	Monthly income of the respondent	Numeric variable	20018.98	5988.86
Risk perception variable (RP)				
IPE	Extreme climate events and impacts on the physical environment	Numeric variable	-	-
OI	Observed impacts	Numeric variable	-	-
Adaptation constrains variable (AC)				
NT	Natural and technological	Numeric variable	-	-
FI	Formal and institutional	Numeric variable	-	-
Adaptation strategies variable (AS)				
AL	Alternative livelihoods	Numeric variable	-	-
NO	New opportunities	Numeric variable	-	-

The empirical results suggest that the estimated coefficient of the variables Income, IPE, FI, and AL are statistically significant. Moreover, the variables FI and AL are seen to positively affect fisher's eagerness to adapt their fishing activities to the threat of climate change. Thus, the respondents who faced formal and institutional barriers as their stated constraints to adaptation and pursued alternative livelihoods may adapt to fishing behaviours in response to climate change. Also, Income and IPE negatively affect fishers' decisions to adapt fishing activities under climate change. Thus, respondents who generate a low fishing income are more likely to adapt to the fishing activities in response to climate change than those who generate a high income. Furthermore, respondents who experienced extreme weather events might not adapt to new fishing activities under climate change. Relating to empirical results, the following sections discuss various factors in the understanding of the importance of the personal backgrounds and perceptions of fishers regarding adaptation barriers and adaptation strategies associated with extreme climatic risks.

Table 7. Results of the binary logistic regression model.

Variable	Coefficient	SE
AGE	0.057	0.054
EDU	0.100	0.134
FE	-0.039	0.033
Income	-0.001 *	0.000
IPE	-1.703 ***	0.621
OI	0.055	0.296
NT	0.548	0.570
FI	3.825 **	1.511
AL	3.486 ***	1.258
NO	13.237	8681.311
Constant	-0.388	-
Predicted probability	84.4%	-
Cox and Snell R^2	0.177	-
Nagelkere R^2	0.301	-
Hosmer and Lemeshow test	$X^2 = 2.488$	-
	P-value = 0.962	-

*Significance at the 10% level, **significance at the 5% level, ***significance at the 1% level

4. DISCUSSION

Understanding fishers' perception of climate change is vital to their adoption and success of adaptation and mitigation strategies to climate change. Some critical information about the fishers' risk perception of climate change is important for fisheries-related policy-making in Bangladesh. Such policy-making in terms of climate change is limited; therefore, this study attempted to identify such critical factors via factor analysis and empirical modelling that might help to make fisheries-related policy. Climate change risk management needs to be considered for marine fishers' adaptive capacity [43], [44]. Therefore, the results concerning the fisher's perception of risk and adaptation constraints of climate change can improve fisheries' management strategies in response to climate change. In the risk management process, risk identification and risk assessment are essential [36], [45], [46]. In this present study, findings suggest that under the risk perception dimension, perception of extreme climate events and impacts on the physical environment (increased high rainfall, increased height of storm surge, increased intensity of wind speed of tropical cyclones, increased frequency of tropical cyclones, increased sea level, decreased sea level, and no change in sea level) have the highest variability and the highest eigenvalue (7.446) and proportion (43.494); thus, the findings indicate that the risk of extreme climate events is more important than other risks in the fishers' view. Islam, *et al*. [32] mentioned the type of limits and barriers to the adaptation of fishing activities to climate change.

In terms of adaptation constraint dimension, the fishers identified natural and technological barriers (NT) as more critical elements than formal institutional barriers (FI). For example, NTs poor quality of boats increases the risk during inclement weather, inaccurate weather information, increased frequency of tropical cyclones, and unfavourable credit schemes may put more pressure on fishers during extreme weather events. The effects of these constraints may have an indirect and direct impact on the income and economic activities of fishers.

Fishers' perception of adaptation strategies is also addressed in this study. Alternative livelihoods (eigenvalue=3.352 and proportion=35.48) and new opportunities (eigenvalue= 1.191 and proportion =33.68) are two major adaptation strategies undertaken by fishers. These two adaptation factors include the items of engagement with alternative income sources, temporary displacement to elsewhere and involvement in fish drying and processing instead of catching, women forced to work outside, and engaged in more farming activities compared to fishing. Thereby, these items are essential factors for fishers to be included in climate change risk management.

Furthermore, 84 percent of the respondents opined that they would continue their fishing activities; thus, they may adapt in response to climate change. The empirical model found factors affecting the eagerness of fishers to adapt their fishing activities to climate change and the identified factors that might be important to implement relevant fishery-management policies in Bangladesh. In the empirical models, fishers' demographic characteristics and perceptions are considered. In response to climate change, the empirical results suggest that a few variables significantly influence fishers' fishing activities. Two variables significantly and positively affect fishers' eagerness to adapt fishing action: formal and institutional (FI) and alternative livelihoods (AL). Therefore, the respondents who perceived FI and pursued AL might adapt their fishing activities in response to climate change. Fisher's

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communities frequently undertake adaptation strategies to cope with climate event losses.

Alternatively, Income and IPE significantly and negatively affected fisher's decisions; thus, respondents who generate high fishing income and are experiencing extreme climate events might not adopt fishing activities in response to climate change. In summary, fishers who may adapt their fishing activities in response to climate change are likely to have some of the following characteristics: (1) they are facing barriers in terms of access to fish markets and the enforcement of fishing regulations and maritime laws during adverse climatic conditions and events, (2) they already have undertaken some adaptation strategies such as engaging with alternative income sources, temporary displacement to elsewhere or are involved in fish drying and processing instead of catching to survive in adverse climatic conditions, and (3) they are generating low fishing incomes. These findings coincided with the earlier studies in the area following the April 1991 tropical cyclone that demonstrated that the members of the fishing community changed their profession temporarily to cope with the devastation of the storm before returning to their previous work [47], [48].

In addition, fishers' income and experience of extreme climate events are the two most significant factors that influence the fishers' eagerness to adapt fishing activities in response to climate change. Income is a significant socio-economic factor in terms of adaptation as more income makes it possible to prepare against the impacts of climate change and to speed up the recovery process [49]. Salik, *et al*. [49] also mentioned that small-scale fishers, who had low, diversified and intervallic income, had lower climate change adaptation levels. Income deficiencies increase the vulnerability of livelihoods through coping and adaptive capacity reduction [11]. However, based on the empirical results of this study, fishers who generated a low fishing income are more likely to adapt in response to climate change than those with higher fishing incomes.

Moreover, empirical results also suggest that people who perceived extreme climate impacts might not pursue fishing as a profession. In addition, fishers with low fishing incomes might be able to adapt; since low-income increases the likelihood of fishers adapting to climate change as fishing is their primary activity, and they lack the skills to switch to other jobs. Low-income may be associated with unstable climate and a decrease of fish-catch. On the other hand, a higher fishing income might decrease the likelihood of fishers adapting in response to climate change. In other reports, higher fishing incomes led to a greater awareness of climate change [50], [51]; thus, it might encourage fishers to continue with the fishing profession in response to adverse climate change.

About 94 per cent of Sandwip fishers generate less than 10,000 taka monthly (Table 1) from fishing activities. Among these, 86 per cent of the respondents want to continue their fishing profession in response to climate change. The main reason for continuing the fishing profession is to maintain the current earning by the inherited fishing professional. They also expressed that, due to lack of experience in any other profession, they are at risk of even forfeiting their current income. The fishers reported that they face climatic and non-climatic challenges that hinder income from fishing activities. Events such as the recent government ban to catch in the Bay of Bengal, lack of return on investments, and housing changes due to erosion-induced landlessness have all led to fishers not having enough money for fishing.

Furthermore, in the adaptation constraints dimension, 84 per cent of the fishers state they may continue in the fishing profession despite the perceived formal and institutional barriers such as lack of enforcement of fishing regulations and maritime laws and less access to the fish market during climate change. Thus, the findings indicated that fishing is the primary occupation of respondents; however, they also pursue alternative livelihoods for increasing income, this may serve as adaptation strategy to climate change. The 49 per cent of respondents reported that they face barriers such as lack of access to the fish markets, while 62% opined that fishing ban regulations are inadequate as the implementation does not consider fishing communities welfare. Despite experiencing and recognising such barriers, the overwhelming majority opined they will continue to fishing activities. The fishers identified managing an alternative income source, temporary displacement to elsewhere, fish drying, and processing other adaptation strategies.

Overall, based on the empirical findings of this study, the following recommendations for policy implications are offered:

a. Incentive programs for younger fishers

From the empirical results, fishers with a higher fishing income might not adapt their fishing behaviours in response to climate change. In this study, most of the respondents were older and lacked other skills; thus, younger fishers with better incentives might adapt their fishing behaviours to climate change. The Government of Bangladesh (GoB) should attract younger fishers to the coastal fisheries sector with better incentive programs.

b. Accurate weather information and warning dissemination

Based on the findings of the empirical results, fishers who experienced extreme climate events might not adapt their fishing activities in response to climate change. Based on the factor analysis, natural and technological barriers to adaptation are important perceived factors for fishers. However, this is not a factor that influences the decisions of fishers to change fishing behaviours in response to climate change. When this factor is coupled with inaccurate weather information and poor-quality boats, the vulnerability and risk to climate change and inclement weather increases.

Extreme weather events such as storm surges and cyclones are common in coastal areas of Bangladesh; thus, government agencies should try to increase awareness related to current conditions and disseminate timely warning signals to all fishing communities.

c. Remove formal and institutional barriers:

Despite facing formal and institutional barriers to adaptation, fishers still want to adapt their fishing activities in response to climate change. This implies that fishing is the primary activity of the respondents. Thus, removing formal and institutional barriers such as making markets more accessible for fishers and making fishing regulation favourable to fishers may help continue fishing activities in response to climate change.

d. Diversifying income sources

The adaptation strategies such as alternative income sources, temporary displacement to elsewhere, fish drying, and fish preservation techniques during the extreme weather events are significantly and positively affecting fishers' ability to continue fishing activities in response to climate change. Small-scale fishers are undertaking such strategies to reduce their vulnerability to climate change impacts. Thus, several government programs and non-governmental organisations (NGOs) may introduce new opportunities such as vocational and entrepreneurial-related jobs that will help fishers cope with the impacts of climate change.

5. CONCLUSION

This study contributes to the understanding of the factors that affect fishers' decisions to adapt to climate change. The results indicated, of the fishers surveyed, 84 percent opined that they might adapt and continue the fishing profession in response to climate change. This result indicated that fishers have the perception of climate change impacts and adaptation constraints in response to climate change. The empirical results also indicated that higher fishing incomes and perception of climate change impacts negatively affect their adaptation decisions. While on the other hand, the perception of adaptation constraints such as lack of access to fish markets, lack of enforcement of fishing regulations, and maritime laws significantly and positively affected their adapting decisions. The findings of this study may provide some insights to develop coherent and comprehensive strategies for improving the fishing community's resilience to climate change on the Bangladesh coasts.

Information about fishers' perceptions of climate change in other coastal regions of Bangladesh should be collated in the future for comprehensive and long-term community-led climate change adaptation research. The additional research could help policy-makers understand factors that influence fishers' adaptation decisions under climate change in a greater context and develop and integrate adaptation policies according to the community's needs.

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