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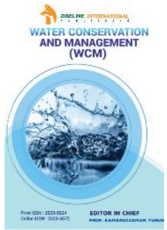

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RESEARCH ARTICLE

CLIMATE CHANGE VULNERABILITY AND RESPONSES OF FISHERFOLK COMMUNITIES IN THE SOUTH-EASTERN COAST OF BANGLADESH

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ABSTRACT

Climate change is an ongoing threat across the earth–especially those who depend on fishing. This study aims to understand how fishery-dependent communities in the South-Eastern coast of Bangladesh build resilience against environmental stresses, and in what ways their strategies sometimes fail. A composite index approach has been used to calculate livelihood vulnerability. Results reveal that exposure to floods and cyclones, sensitivity and lack of adaptive capacity concerning physical, natural, and financial capital and diverse livelihood strategies construe livelihood vulnerability in different ways depending on the context. The study reveals that over the last ten years, 20% household heads have changed their fishing profession, where dependency to non-fisheries livelihoods such as rickshaw pooling and small business is growing in the studied fishing villages. However, many of them are applying their traditional knowledge to cope with the changing climate stress and in conserving the biodiversity of the coast. In order to strengthen adaptive capacity and to build resilience, government and the external agencies need to facilitate the existing traditional knowledge and systems with which the fishermen communities have been historically responding to the environmental stresses.

KEYWORDS

Fisherfolk community, Composite index approach, Vulnerability, Adaptive capacity, Environmental stress.

1. INTRODUCTION

Worldwide, nearly half a billion people derive their income from fisheries and fisheries products provide about 15% of the animal protein and support the livelihoods of 10-12% of the world's population. Most people who depend on fisheries live in developing countries where incomes are low, food resources limited, and residents have few opportunities to substitute occupations and diets. In both cases large-scale environmental change can pose a serious threat to the lives and livelihoods of people who depend on marine resources (Islam et al., 2014).

The majority of the world's 200 million full and part-time fisherfolk (fishers, fish processors, traders and ancillary workers) and their dependents live in areas vulnerable to human-induced climate change, or depend for a major part of their livelihood on resources whose distribution and productivity are known to be influenced by climate variation. The impacts of biophysical changes on fisheries communities are varied as the changes themselves. Both negative and positive impacts could be foreseen, their strength depending on the vulnerability of each community, the combination of potential impacts (sensitivity and exposure) and adaptive capacity (Allison et al., 2009). Impacts would be felt through changes in capture, production and operation costs, changes in sales prices, and possible increases in risks of damage or loss of infrastructure, fishing crafts and gears. However, relationships between the biophysical impacts of climate change and the livelihood vulnerability of poor fishing communities have seldom been investigated. Information has been lacking on the areas and people that are likely to be most vulnerable to climate-induced changes in the fisheries. This information is required for the effective prioritisation of development interventions to reduce vulnerability to the impacts of adverse climate change on fisherfolk living in poverty. The fisheries sector makes important contributions to local development in coastal areas, through employment and multiplier effects. Maintaining or enhancing the benefits of fisheries in the context of a changing climate regime is an important development challenge. Moreover, the impact of long-term trends in climate change, in particular related to weather extreme events, is less well-understood in fisheries but is beginning to receive attention (Barua et al., 2017; Barua and Rahman, 2018; Barua and Rahman, 2019; Barua et al., 2019).

Bangladesh is one of the most vulnerable nations being in the receiving end of the impacts of global climate change in the coming decades. The frequency and intensity of natural calamities, e.g., tropical cyclones, river erosion, floods, landslides, and droughts have been increased, and creating significant impacts on agriculture, livelihood, economy and other sectors in Bangladesh (Agrawala et al., 2003; Bank 2003; IPCC 2007; Al-Amin et al., 2013; Barua et al., 2017; Barua 2018). The fishery-dependent people living in the coastal areas of Bangladesh are the most vulnerable community among those exposed to climate-change impacts (Agrawala

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et al., 2003; Barua et al., 2017). While their livelihoods are impacted by many climate shocks and stresses such as cyclones, floods and sea level rise, their fishing activities are impacted mainly by cyclones in the Bay of Bengal (Islam et al., 2014). Ahmed and Neelormi (2008) observed a reduction of fishing days in Bangladesh due to minor cyclones and greater fluctuation in fish production may occur due to climate change (Ahmed et al., 2002). Taken together, these effects may further increase livelihood vulnerability in Bangladeshi coastal fishing communities without adaptation.

Climate change has both direct and indirect impacts on fish stocks. Direct effects alter the physiology, growth, reproductive capacity, mortality, and distribution of fish, while indirect effects change the structure, and composition of the marine ecosystems and the fish food-chain. There are many other factors, including fishing, biological interactions, and non-climatic environmental factors. Fishers income and their livelihood are highly seasonal, and there is an acute scarcity of alternative livelihood in the coastal areas, which in turn diminishes the adaptive capacity of fishers against the adverse impacts of climate change. It has been reported that most of the fishers in the world are poverty-stricken and uneducated, and therefore, unable to take other occupation/vocations as adaptive measures (Koya et al., 2017).

Adaptation is widely recognised as a fundamental response to the threat of climate change (IPCC, 2007). Adaptation to climate change is a need and a challenge for ecosystems, for human beings, and for governance systems at all levels. Technical and societal adaptation is required to reduce the growing risk of vulnerability under climate change. National policies and programs as well as development interventions need to be designed so that adaptation is not hindered but enabled. Revised governance structures may support adaptation at multiple levels and layers (Brockhaus and Kambire, 2009). Local information in particular plays a key role (Agrawal, 2008) and identifying appropriate adaptation requires initial learning about the communities indigenous capacities, knowledge and practices of how to cope with climate hazards in the past (Reid and Huq, 2007). However, gaps are often observed between local adaptation realities and the global and national processes. Even though local adaptation frequently occurs autonomously and spontaneously, adaptation and the importance of fisheries sector have not yet been sufficiently mainstreamed into governance structures, policies, regulations, and development projects and programs (Locatelli et al., 2008).

Consequently, local adaptation to climate change for sustainable natural resource management lacks an appropriate political and institutional framework, or can even be counteracted by interventions that do not take account of existing local adaptive responses. Further efforts are needed to link local efforts to national and global approaches, and ensure planned and strategic adaptation to climate change. Autonomous adaptation to climate change needs to be seen as an integral part of a country's development planning, rather than as a separate issue, and adaptation measures that lead to better overall development outcomes are preferable to ones that focus exclusively on adapting to climate change impacts while ignoring other stresses (Berkes and Folke, 1998; Berkes et al., 2003; Adger et al., 2001, 2002, 2003; Adger, 2003; Tompkins, 2005). Technical and societal adaptation is required to reduce the growing risk of climate-change vulnerability. National policies and programs, as well as development interventions, need to be re-designed so that adaptation is not hindered but enabled (IPCC 2007; Adger et al. 2009; Brockhaus & Kambiré 2009; Barua 2018). Consequently, localized adaptation to climate change for sustainable natural resource management lacks an appropriate political and institutional framework, or can even be counteracted by interventions that do not take account of existing regional adaptive approaches (Allison et al. 2009; Islam et al. 2014; Barua 2017; Barua et al. 2017). Local-level autonomous adaptation to climate change needs to be seen as an integral part of a country's development planning, rather than as a separate issue, and adaptation measures that lead to better overall development outcomes are preferable to ones that focus exclusively on adapting to climate change impacts while ignoring other stresses (Tompkins, 2005; Sallu et al. 2010).

Fishers has extensive knowledge and expertise that can be applied in assessing community risk, selecting adaptation measures and mobilizing communities to manage the risk of climate change. The fishermen livelihoods are impacted by many climate shocks and stresses such as cyclones, floods, and sea level rise, while their fishing activities are affected mainly by cyclones in the Bay of Bengal (Islam et al., 2014). The extent to which local community and fisheries systems are affected by climate change (their vulnerability) has been determined by three factors: their exposure to specific change, their sensitivity to that change, and their ability to respond to impacts or take advantage of opportunities (Allison et al., 2009). Despite the importance, knowledge of climate-induced impacts and vulnerability on the local scale of fishery-based livelihoods remains limited. Fishery-dependent communities of Bangladesh are facing increased vulnerability regarding fewer stable livelihoods, in the availability of fish catch, and safety risks due to changing climate conditions.

Hence, the objective of the present study is to analyze the climate change impacts on fishers and fisheries resources, changing the climate parameters over the 10 years (2006-2016), socioeconomic status of the fishermen dependence of the river with local response strategies of coastal fishing communities to formulate an integrated adaptation framework in the South-Eastern coast of Bangladesh.

2. Materials and Methods

The Bakkhali river estuary is one of the largest estuarine river (20°85′40′′–20º46′ 92′′ N and 91º34′37′′–92º34′37′′ E) on the south-eastern coast of Bangladesh (Figure 1).

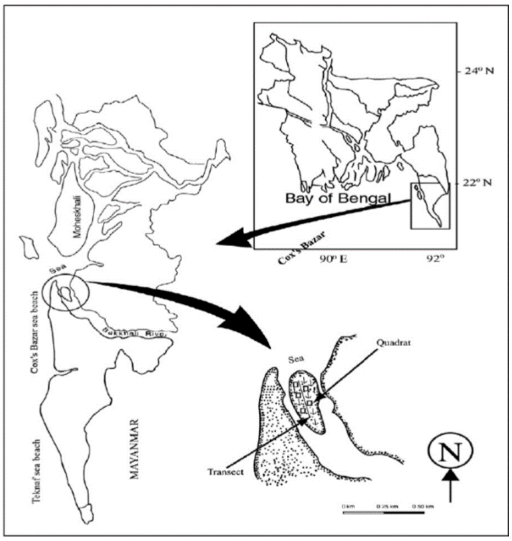

Figure 1: Geogrphical Location of Bakkhali river

A semidiurnal tide characterizes this river with a tidal range of 0.07–4.42 m during the neap and spring tide, respectively. Some small streams originating from the south-eastern hills of Mizoram (India) meet at the Naikhongchhari of Bandarban district and form the river Bakkhali. It flows through Naikhongchhari and Ramu of Cox's Bazar district and falls into the Moheshkhali channel of the Bay of Bengal. This river is relatively wide compared to other tributaries of the Cox's Bazar district and has a length of about 67 km (Figure 1).

The Bakkhali river estuary has a semi-diurnal tidal regime. Its hydrology is heavily influenced by monsoon wind. This estuary is home to 38 species (21 families) of fish, eight species (3 families) of shrimps, two species (2 families) of crabs and other coastal fishery resources (Rashed-Un-Nabi et al., 2011; Billah et al., 2016]. Four fishing villages namely, *Nazirartek*, *Choufaldandi*, *Khuruskul* and *Banglabazar* along the Bakkhali River of the Cox's Bazar Sadar Coast were selected for the study. A total of 1200 fishers engaged in the fishing in and around the study areas. The sample size was 120 taking 30 from each fishing village. Household head was the respondent, and a simple random sampling technique was applied to select the respondent from each village.

This study was undertaken from January to December 2016. The interviews cover the issues, including the fisher's experiences of fishing, perception on management regimes and climate change and its impact on the industry, and lastly fishers' perception and ideas about the possible adaptation strategies. In person interview and Guba's criteria of (i) credibility, (ii) transferability, (iii) dependability and (iv) conformability (Guba 1981) were used to evaluate the information obtained.

3. INDICATORS OF VULNERABILITY

The vulnerability is the extent to which people and systems are affected by climate change. The vulnerability is determined by three factors: their exposure to specific change, their sensitivity to that change, and their ability to respond to impacts or take advantage of opportunities (IPCC 2007, Allison et al., 2009).

Exposure in the context of this study is the nature and degree to which a fishery-based livelihood system is exposed to significant climatic variations (IPCC 2007). Exposure indicators selected for this area characterize the frequency of extreme events, the rate of land erosion and sea-level rise, and variations in temperature and rainfall (Table 1).

Table 1: Community exposure to climate shocks and stresses

Climate Shocks and Stresses	Fishermen community		Sources of Data
	Mean	Standard Deviation	
Number of past floods [a]	8	N/A	Focus Group Discussion (FGDs) [b]
Number of past cyclones [a]	7	N/A	FGDs[b]
Past land erosion (meter/year) [a]	18.80	N/A	FGDs[b]
Past sea-level changes (mm/year)	1.6	N/A	(Yu et al. 2012)
Variation in past maximum temperature (°C) [c]	1.70	0.50	BMD (2016)
Variation in past minimum temperature (°C) [c]	1.50	0.65	BMD(2016)
Variation in past rainfall (mm) [c]	15.65	15.80	BMD (2016)

[a] Period discussed with respondents 1985-2016; [b] Refer to data collection and analysis section [c]Mean change 1980-2016, Cox's Bazar Station; [s]standard deviations of daily maximum temperature (_C), daily minimum temperature (°C), and daily total rainfall (mm) by month, between January 1980-December 2016, averaged. Data from: Cox's Bazar station

Sensitivity is defined as the degree to which a fishery-based livelihood system is impacted by or responsive to climate stimuli (IPCC, 2007). In the study, only indicators of the dependence of livelihoods on climate-sensitive activities in the fisheries sector, for employment, income, and nutrition were used as sensitivity indicators (Allison et al., 2009) (Table 2).

Table 2: Indicators used to assess fishery-based livelihood vulnerability

Indicators	Explanation of Indicators	Sources of Data
Indicators of exposure	From Table 1	From Table 1
Indicators of sensitivity		
Employment from fisheries	Number of days a household is involved with fisheries in last year	Household questionnaires (HQs)
Income from fisheries	Percentage of household income from the fisheries sector in last year	HQs
Nutrients uptake from fisheries	Amount (per capita) of fish and seafood a household consumed in last year (kg/month)	HQs
Indicators of adaptive capacity		HQs
Number of adult workforce	Number of individuals aged 14-60 in household	HQs
Presence of non-elderly household head	Whether household head is <50 years old or not	HQs
Experience (years)	Experience of household head in the fisheries sector (year)	HQs
Health (days)	Number of days a year household head remains physically fit to carry out livelihood activities	HQs
Male-headed households*	Whether household head is male or not	HQs
Housing Condition ***	Aggregate index of household qualities of the house	HQs and FGDs
Fishing equipment availability**	Number of types of fisheries-related materials (boats, nets) of households	HQs
Technology application ***	Aggregate index of household use of technology	HQs
Distance from services**	Aggregate index of distance (time) of the household from the services	HQs and FGDs
Natural capital **	Aggregate index of natural capital	HQs
Financial capital excluding income***	Aggregate index of household financial capital excluding income	HQs
Per capita income (Taka)**	Per capita income of household (Taka/year) (Taka 80= US 1$)	HQs
Social capital ***	Aggregate index of household social capital	HQs
Number of income-generating activities**	Number of Income-generating activities per household	HQs

Adaptive capacity in the context of this study is the ability or capacity of the fishery-based livelihood systems to adjust to climate change (including variability and extremes), to take advantage of opportunities, or to cope with the consequences (IPCC, 2007).

3.1 Assessment of livelihood vulnerability index

A composite vulnerability index approach was applied in this study to find out the relative exposure, sensitivity and adaptive capacity. A composite index approach computed the vulnerability indices by aggregating data for a set of indicators. An indicator represents a parameter of a system (Cutter et al., 2008, Barua et al., 2017) and it is an empirical, observable measure of a concept (Siniscalco, 2005). The composite index approach can help to identify indicators or determinants for targeting interventions and programs (Eakin & Bojorquez-Tapia 2008, Czúcz et al., 2009, Barua et al., 2017).

Using the suite of indicators described in Tables 1 and Table 2, we quantitatively assessed the vulnerability of fishery-based livelihood systems using the combination of individual indicators and aggregate indices that measured on a different scale; they were normalized (rescaled from 0 to 1) by using Eq. 1.

$$\text{Index}_{S_i} = \frac{S_i - S_{min}}{S_{max} - S_{min}} \tag{1}$$

Where index S_i is a normalized value of an indicator of a household; S_i is the actual value of the same indicator, and S_{min} and S_{max} are the minimum and maximum values, respectively, of the same indicator.

After normalization, the finding values were averaged to yield the three sub-indices for exposure, sensitivity and adaptive capacity. A household scale exposure data were unavailable to the same exposure sub-index score, which was used to calculate intra-community livelihood vulnerability indices. The household-level sensitivity and adaptive capacity sub-indices were also normalized. The normalized adaptive capacity sub-index was inverted (1-index) for inclusion in the vulnerability index because the potential impact of climate variability and change may be offset, reduced or modified by adaptive capacity (IPCC 2007).

Sub-indices were combined to create a composite vulnerability index by using an additive (averaging) (Eq 2) or multiplicative (Eq 3) approach. This paper followed both procedures, but they produced highly correlated vulnerability scores (Spearman's q 0.97). This paper also highlights the results of the multiplicative approach because it better reflects low and high indicator and sub-index values (Hajkowicz, 2006).

$$V= (E+ S + (1-AC))/3 \tag{2}$$

$$V = E \times S \times (1-AC) \tag{3}$$

Where V, E, S, and AC represent vulnerability, exposure, sensitivity and adaptive capacity of a household, respectively.

Next steps were to quantify key relationships among changes in climate parameters such as average temperature, average precipitation, average salinity and storm surges and impacts on economic activities and livelihoods, measured through changes in fisheries productivity, and impacts on ecosystems functions, fishers health, and other fisheries resources. Monthly fisheries productivity and environmental data (viz., temperature, salinity, precipitation, and turbidity) were collected during investigation time, where meteorological data including storm surge were collected from Meteorological Observatory located in Cox's Bazar Sadar.

The analysis begins with an understanding of which climate/weather and hydrological variables are likely to affect a given economic sector. Thereafter, projected trends in the relevant climate variables, obtained through direct comparison with previous data (Barua, 2006; Gani *et al.,* 2011).

As part of the vulnerability assessment, a risk perception study was conducted to gain some understanding of commercial fishers' perceptions of the potential impact of climate change on the industry. The first step in the methodology thus consists of attempting to identify the physical assets which were exposed to various climate risks and their sensitivity to which they were affected. Finally, gross scenarios were drawn about the potential impact allowing for community-based adaptation (CBA). The authors applied several qualitative and quantitative technique for assessing the community-based adaptation that practiced by the fishermen. First, semi-structured interviews were conducted with key individuals, household heads and small (naturally formed 4) groups. Second, repeat focus groups discussion with village elders facilitated a mapping of social memory which is pertinent to the study of environmental change and the subsequent reactions of societies over time (McIntosh et al., 2000). Third, household survey data were collected using a Rapid Rural Assessment (Chambers 1980), specially adapted for the study of fishing communities (McGoodwin 2001). Lastly, data collected about the outbreak of two cyclonic storm surges in the south-eastern coast of Bangladesh on 2011 cyclone *Giri* and cyclone *Ruano* on 2016. The study focused the impacts on economic activities and livelihoods, measured through changes in fisheries productivity, and impacts on ecosystems functions, fisher's health, and other fisheries resources compare the ten years of the study.

The data set from the sampled households were divided into quartiles of vulnerability (very high, high, moderate, and low), each representing a fourth of the population sampled for each indicator and index (Table 3). Z-test and ANOVA were conducted to determine significant differences, respectively, between two and more than two data sets. ANOVA was also performed to investigate the significance of an indicator in distinguishing the vulnerability classes.

Table 3. Vulnerability classification of households in the study area (exposure index reflects community scale, while sensitivity and adaptive capacity indicators represent household scale)

Indicators	Very highly vulnerable	Highly vulnerable	Moderately vulnerable	Low vulnerable	Mean	Standard deviation
Number of households	30	30	30	30	30	
Sub-Index of exposure	0.30	0.30	0.30	0.30	0.30	0.50
Indicators of sensitivity						
Employment from fisheries (days/year)***	250	230	215	190	222	25
Income from fisheries (%)***	99	95	96	85	94	16
Nutrients uptake from fisheries (kg/month)**	3.50	2.59	2.40	2.70	2.95	1.40
Sub-Index of sensitivity***	0.75	0.65	0.55	0.42	0.55	0.20
Indicators of adaptive capacity						
Number of adult workforce***	2.80	3.20	3.35	4.95	3.57	1.90
Presence of non-elderly household head	0.80	0.80	0.82	0.95	0.85	0.28
Experience (years)	18.50	16.50	17.50	18.05	17.65	8.50
Education (years)***	4.25	5.30	7.25	8.50	7.02	3.25
Health (days)	325	330	340	335	330	30
Presence of male-headed household*	0.75	1.25	1.35	0.90	0.90	0.15
Quality of house***	1.25	1.75	1.90	3.25	2.09	1.45
Number of fishery materials**	0.05	0.30	0.42	0.49	0.36	0.45
Use of technology***	1.50	2.40	2.54	4.10	2.50	1.40
Distance from services**	4.90	5.35	6.90	6.40	5.90	2.40
Natural capital **	0.90	1.20	1.02	0.9	0.90	0.40
Financial capital excluding	1.30	1.50	1.65	2.35	1.65	0.68

income***						
Per capita income (Taka)**	18,200	18,000	38,257	55,452	32,300	43,230
Social capital ***	8.32	9.00	10.24	9.96	9.38	1.70
Number of income-generating activities**	1.55	1.45	1.50	2.29	1.70	0.90
Sub-index of adaptive capacity***	0.27	0.40	0.48	0.63	0.44	0.18
Index of livelihood vulnerability***	0.17	0.12	0.09	0.04	0.10	0.05

* Indicates significant difference (normalized values were used) between vulnerability classes in ANOVA test; * p\0.05, ** p\0.01, *** p < 0.001

4. Results

During the household survey with fishermen communities regarding the vulnerability of climate change in their profession, they responded that they observed changes in the climate and in extreme events over time (Table 4). In regards to the annual mean temperature and rainfall, 85% of the respondents believed that the former had increased and 85% believed that the latter had decreased. No respondent perceived an increase in rainfall and a decrease in temperature. The respondents observed abnormalities in rainfall timing and distribution, which have severe consequences for their production plans. They affected a household's ability to produce seasonally and to grow diversified crops throughout the year. Some fishermen added that their main concern was deficient egg production, and wondered whether or not that was due to climate change. All the responses above express their concerns about the socio-economic and biophysical changes that have the potential impact on the Bakkhali River fishery. Figure 2 illustrates a wide range of potential indirect biophysical, direct and indirect socio-economic impacts. This investigation focused on the consequences of climate change at the point, which impacts on fishers, fishing activities, and fisheries productivity.

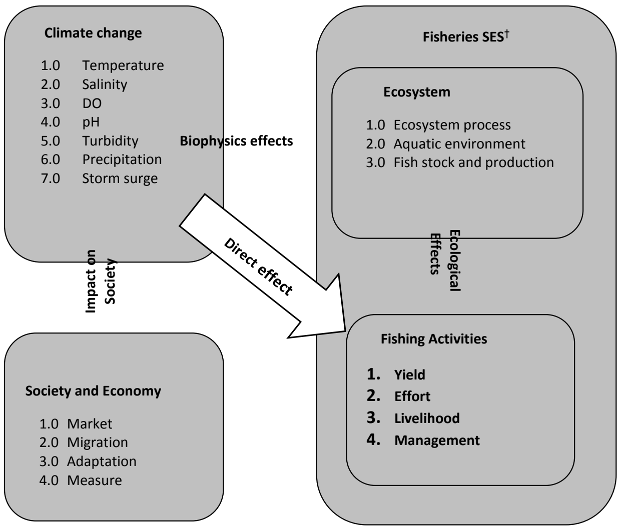

Figure 2: Possible Impacts of climate change on Bakkhali River Fisheries

Table 4. Fishers and their physical assets engaged in fishing in the Bakkhali River					
S.L	Physical Assets		Comparative the Quantity within 10 years		
			2006	2011	2016
1	Fisher		2299	1538	1010
2	Gears				
	i	ESBN	157	150	140
	ii	Beach Seine	15	12	10
	iii	Gill Net	10	8	6
	iv	Push Net	221	210	190
3	Crafts				
	i	Raw boat	113	105	95
	ii	Medium boat	166	145	130
	iii	Engine boat	25	20	15

It is widely acknowledge that many interacting biophysical factors influence the occurrence, distribution, abundance and diversity of fisheries species. Among the environmental variables, water salinity, temperature, turbidity, dissolved oxygen, water pH and their fluctuations at five years' time scales (2006, 2011 and 2016) had been compared to detect the changes. During this period, a significant variation of above water parameters were observed (Figure 3), which shows that 0.38°C water temperature increased during this period where the salinity of the Bakkhali River water showed increasing trends (+3.85‰) as well. In addition, water transparency increased (+3.09). Moreover, Dissolved oxygen level reduced significantly, which was dropped to 4.10 mg/l from 4.86 mg/l and decreased pH content (-0.62) indicated the acidification of the Bakkhali River as it's dominated by the adjacent Bay of Bengal.

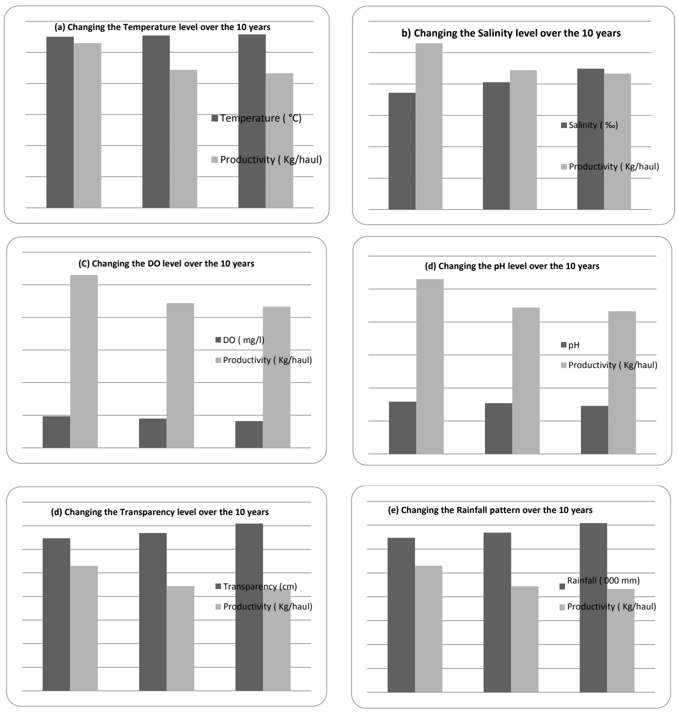

Figure 3: Change in major environmental variables (a) Surface water temperature (b) Water salinity (c) Dissolve Oxygen (D.O); (d) Water pH; (e) Transparency ; and (f) annual rainfall at 5 years time frame in the Bakkhali River (Barua, 2006; Gani et al., 2011 and Present Study, 2016).

Fishing operation in the Bakkhali River used to be carried out by traditional craft until the mid 1960s. Two organization namely, the Bangladesh Fisheries Development corporation (BFDC) and the Bangladesh Jatiya Matshyajibi Samabay Samity (BJMSS) started the process of mechanization of the fishing boats by importing introducing marine engines during late 1970s. Craft and gears used in the Bakkhali River were mostly indigenous and locally built. Three types of wooden craft viz., dingi or chuto nao (small row boat, 5m length), bor-nao (medium boat, 5-7m length) and large engine boat (7-10m length, draft of 0.70-1.0m) with 16-22HP were used for fishing in the Bakkhali River. Large engine boat and small boat were used for catch collection where the medium boats always fixed with the fishing gear (ESBN) to look after the nets and catch as well as resting, recreation, net repairing, cooking and dining space for the fishers. Fishing gears in the Bakkhali River are of various types (Table 3). It is found that, number of fishers reduced to 1010 from while 2299 fishers were engaged in fishing during 2006 to 2016.

Nets, the main gears were made of cotton yarns, hemp or other special yarns and prepared by the fishermen themselves. Estuarine Set Bag Net (ESBN) was the dominant fishing gear and widely operated throughout the all places of the Bakkhali River about 25 km from the down, while other gears a rarely used. Fishing Gears and Crafts number also reducing significantly compare to the quantity within 10 years of timeline (2006 to 2016) (Table 3).

The vulnerability of Bakkhali river based fisherfolk communities expressed in Table 4. Fishery-based livelihoods in households have high exposure to climate-related shocks and stresses, especially floods and cyclones, because the communities are located near the coastline and livelihoods are dependent upon marine fishing from small vessels. Vulnerability also differs significantly ($p < 0.01$) between the household classes (very high, high, moderate and low) within each community. The findings indicate that the highest livelihood vulnerability to climate variability and change does not coincide with the highest sensitivity and lowest adaptive capacity. However, when looking into the classes of differently vulnerable households within a community (where all households are similarly exposed), higher sensitivity and lower adaptive capacity typically combine to create higher livelihood vulnerability.

Although it was not possible to distinguish exposure between the classes of households in a community, vulnerability matrices include flood and cyclone as the main determinants of livelihood vulnerability in the fishermen communities, while the impact of exposure on the livelihood vulnerability depends on the context of the community (Table 4). According to most respondents, the cyclone was the most critical determinant of vulnerability in the study rather than flood and erosion. In the communities, cyclones are typically followed by surges (floods), and together they cause vastly adverse impacts on household livelihood assets, strategies, and outcomes.

Sensitivity to climate variability and changes are influenced by conditions at the community and household level. FGDs reveal that increasing access to facilities over the past two and half decades have enabled the level of involvement of the households in fisheries in the study area. Some of the households had expanded their livelihood strategies by fishing and drying fish outside the regular seasons when climatic stresses and shocks were more pronounced in the study area. All three indicators of sensitivity are significant ($p < 0.001$ for most indicators) in distinguishing vulnerability classes for fishermen communities (Table 4).

In this study, exposure was defined as the types of valued assets of the fishers that were at risk of being impacted by changes in the climate system. Relating the relative risk on above assets, 30% respondents believe that the productivity of the Bakkhali River was in top risk, while 27% and 16% respondent focused on fishing gears and their boats, respectively. About 15% of respondents felt that their lives were in risk during fishing due to bad weather, while 12% respondents believed that their cash incomes were reducing (Figure 4).

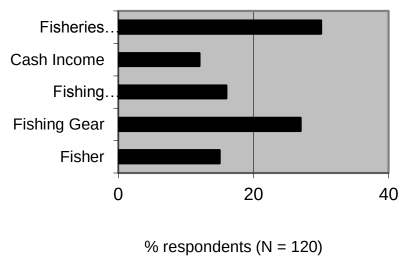

Figure 4: Fishermen perception about the risk on different assets

Adaptive capacity depends on the context of each household and community, but some indicators appear to be general determinants of livelihood vulnerability in the Bakkhali river fishermen communities. Unlike sensitivity, the sub-index of adaptive capacity does not differ significantly ($p < 0.05$) for the community of study area (Table 4).

It was found that a range of indicators such as the number of adult workforce, quality of house, number of fishery materials, natural capital, financial capital excluding income, per capita income, social capital, and number of income-generating activities were significant ($p < 0.001$ to $p < 0.05$) in distinguishing vulnerability classes of households in the fishermen of Bakkhali river.

Among the six human capital indicators, it was found that only the ''number of adult workforce'' in a household was significant. The ''quality of house'' was identified as an essential adaptive capacity indicator in the vulnerability matrices. From the study, it has been found that quality of house improved as the level of vulnerability decreased (Table 4).

The livelihood options in the fishing villages were not diverse, most of the households heads (48%) were directly involved in fishing, and 7% households heads are indirectly depend on fishing, while other business, agriculture, salt production, and aquaculture also contribute as the source of income generation. In comparison with the previous socioeconomic data (Barua & and Zamal 2006; Gani et al. 2011), the result shows that about 20% household heads had changed their fishing profession, where dependency to non-fisheries livelihoods such as rickshaw pooling, other small business were growing in the fishing villages. Also, overall fishing efforts declined in the last ten years (Table 5).

Table 5: Changes in livelihood options (%) to household heads in the study areas

S.L. No	Occupation of the household head in the study area	Year of Changing		
		2006	2011	2016
01	Fishers	70	60	48
02	Rikshaw Polar	4	7	10
03	Fish Traders	4	2	2
04	Net Makers	3	2	1
05	Boat Makers	3	3	2
06	Agriculture	2	3	3
07	Aquaculture	3	5	7
08	Salt Producer	3	4	7
09	Buisness	3	5	6
10	Others	3	4	5

During the questionnaire survey, a common question was asked to understand key climate variable that directly influences such socioeconomic changes. Table 5 shows that 72% of the fishers believe that this change has been occurred due to the storm surge effect where they had lost their physical assets like fishing gears and crafts and made the sector unstable; and remaining number of fishers focused on low income due to low productivity which showed indirect effects of climate variables.

During FGD, most of the fishermen reported that they were exhausted in fulfilling their social responsibilities for their families. They used to go fishing in the Bakkhali River but could not earn as much as their family needs. Most of the fishermen were fisherman by heredity, who maintained the joint family consisting of his wife, sons, sisters-in-law, grandsons, and granddaughters. Most of the fishermen said the fishermen caught fish during the full moon or new moon times but did not have any work during the rest of the time. Also, most of the fishermen pointed that the number of fishing days was reduced due to a low number of fishes being caught, and thus depended on the earnings of earlier months. The fishermen-leader blamed the changes of weather patterns for the decrease in fish in the Bakkhali River. He observed that the increase of frequent cyclone attack in the coastal areas posed as a significant threat to the lives and livelihood of the fishermen.

Temporary migration was a traditional mechanism for sustaining livelihoods during periods of environmental insecurity. It usually comprises the short-term movement of one or two members of a family to a different location in order to find employment. Temporary migrant fishers moved to urban areas of *Cox's Bazar* to seek employment in the informal sector (such as rickshaw-pulling) or to rural areas to take up employment as labor on salt farms, grocery shops, earthworks, and so forth. Moreover, the field research shows that the number of fishers was migrating temporarily from fishing villages that were vulnerable to natural hazards had significantly increased over recent years, as localized coping strategies had become more difficult to sustain. Although various factors determined the decision to migrate temporarily, the frequency and intensity of naturally occurring hazards had increased the pressure on fishers to relocate both temporarily and on a more permanent basis.

Although temporary migration was well observed in the fishing villages, it appears that there had been a significant increase in permanent migration from investigated areas. The findings from the field research suggested that migration was increasing in response to the severity of naturally occurring storm surges and it was becoming more permanent. In two fishing villages, for example, it was found that over 10 percent of families had made a deliberate and permanent move to Chittagong city, while an additional 20–30 percent of people had not returned after migrating temporarily. Although some factors may have contributed to this increase in levels of permanent migration, climate change appears to have accelerated the process because of the reduction in opportunities in affected fishing villages. Permanent migration was usually preceded by temporary migration and was seen as the solution only after all alternative coping mechanisms were exhausted. Certain factors prevent people from permanently migrating, particularly the costs involved in relocating. Focus group participants in workshops stated that it costs the equivalent of BDT 5,000-10,000 to migrate the short distance from *Ramu-Chakaria* to *Chittagong*, and would cost a lot more to relocate longer distances. However, as the situation continues to worsen, the number of permanent migrants was set to rise as more fishers save money to move away. Moreover, the exposure and sensitivity indicated high vulnerability of the fishermen community, where such low adaptive capacity showed less ability to manage and reduce this vulnerability.

Table 6. Adaptation measures and their management framework being identified in the companion case studies through anticipatory scenario workshops

Adaptation Measures	Management approaches	Relevance to Climate Change
Functioning and healthy estuarine ecosystems as a primary goal		
Mangrove plantation along the bank of the Bakkhali River	1. Zoning • Area allocation • Time-sharing 2. Mangrove afforestation programme through an integrated and participatory approach	Acts as a buffer against extreme weather events, storm surge, and erosion; limits saltwater intrusion
Implementation of ECA in Taknaf Peninsula including Bakkhali River (declared in 1999)	1. Critical area identification 2. Restoration programme through a participatory approach	Maintains healthy and resilient coastal habitats and fisheries productivity; improves the resilience of coastal ecosystems to climate change and improves the economic and social conditions of coastal communities.
Payment for environmental services	1. Beneficiary group identification 2. Compensation scale determination for environmental insurance 3. Use the fund for environmental policies and actions	Provides incentives to protect critical habitats that defend against damages from storm surges or other climate change effects.
Built environment is less exposed as a primary goal		
Coastal development setbacks	1. Code of conduct for coastal development 2. Zoning for developmental activities like navigational jetty, shrimp farms and coastal embankments 3. EIA for developmental activities	Reduces the infrastructure and other resource losses and human safety risks of storm surge.
Diversified livelihoods as a primary goal		
Fisheries sector good practices	1. Zoning • Area allocation • Depth zone restriction • Carrying capacity 2. Gear specification 3. Craft modification 4. Limiting fishing days 5. Facilitating escape of bycatch and small size fish and shellfishes 6. Licensing 7. Code of conduct	Contributes to the protection of rural livelihoods, food security and fisheries biodiversity against the impacts of extreme climate events, precipitation change, and other climate variables changes.
Aquaculture best management practices	1. Zoning • Area allocation • Depth zone restriction • Carrying capacity 2. Improving culture system 3. Preventive and curative measures of diseases 4. Quality fish and shrimp hatchery development for quality fry 5. On-farm feed production 6. Licensing 7. Code of conduct	Integration of climate change considerations helps safeguard against extreme climate events, precipitation, and other climate change variables.
Eco-tourism best management practices	1. Code of conduct • Area allocation • Infrastructure development 2. Tourist facility development • Accommodation • Restaurant • Easy transportation • Recreation (site seeing, safety, and security) 3. Community participation	Integration of climate change concerns helps promote the sector's sustainability as well as safeguard against extreme climate events and other climate change variables.
Institutional supports and credit facilities	1. Enhancement • Education • Infrastructure • Service and trade business 2. Capacity building through training and demonstration • Livestock rearing (Poultry and Dairy) • Tailoring • Handicraft 3. Financial Input	Integration of climate change concerns helps promote the sector's sustainability as well as safeguard against extreme climate events and other climate change variables.

Fishermen safety and safety enhanced as a primary goal		
Community-based disaster risk reduction	1. Structural measure • Cyclone shelters • Safe fish harbor 2. Sea safety • Use of safety gears during fishing • Surveillance and rescuing during harsh environment 3. Community participation 4. Awareness campaign	By proactive planning and capacity building that addresses the specific needs of local communities, increases their resilience and ability to respond to the effects of extreme climate events like storm surges.
Early weather warning system	1. Set up 2. Mass broadcasting when depression appears in the sea	Increase the resilience and ability to respond to the effects of extreme climate events like storm surges.
Overarching planning and governance as a primary goal		
Bakkhali River watershed management	1. Conservation of aquatic resources 2. Sustainable exploitation and utilization of aquatic resources	Preserves estuaries, which act as a source of aquatic resources and also storm buffers.
Integrated coastal management	Integration among: 1. different coastal resource users groups 2. local communities, fishers, researchers, investors, traders, processors, GoB, NGOs 3. Sectors (fisheries, agriculture, environment, forestry, tourism, and land revenue) 4. Different levels of governments (national, district, local) 5. Disciplines (Natural sciences, social science, and engineering) 6. Integration of valuable resources (personal, fund, materials and equipment) 7. Integration of responsibilities	Provides a comprehensive process that defines goals, priorities, and actions to address coastal and estuarine issues, including the effects of climate change.

5. Discussion

It is widely acknowledged that many interacting physical and biological factors influence the occurrence, distribution, abundance and diversity of fishes. Among the environmental variables, water salinity, temperature, turbidity, dissolved oxygen, and their regular or irregular fluctuations at different time scales, have been identified as determinants in fisheries productivity (Blaber, 2000). The impacts of climate change on Bakkhali River fisheries occurred through changes in temperature, precipitation, salinity, pH, dissolved oxygen and turbidity, where these changes induced losses of fisheries productivity. Salinity distribution in the Bakkhali River was a function of the annual rainfall pattern in the catchment area and also intrusion of more saline water from the Bay. Bakkhali River was dominated by euryhaline marine teleosts . The most essential adaptation by fish and other organisms, which enters estuarine systems, is an ability to adjust to changes in salinity . Most estuarine fishes are able to cope with salinity fluctuation but their ability to do so varies from species to species and hence influences their distribution (Blaber, 2000).

Precipitation, salinity and turbidity were found as key environmental variables and played significant role fisheries productivity in the Bakkhali River. Turbidity affects the fishes in three main ways: it may afford greater protection for juvenile fish from predators; it is generally associated with areas where there is an abundance of food; and it may provide an orientation mechanism for migration to and from the estuary . However, excessive high water turbidity showed negative affect on fish egg survival, hatching success, feeding efficiency (mainly on filter feeders), and growth rate and population size (Whitfield, 1996).

Socioeconomic impacts were felt through changes in capture, production and over all income, and possible increases in risks of damage or loss of fishing gears and crafts. Fishery-dependent communities also faced increased vulnerability in terms of less stable livelihoods, decreases in availability or quality of catch, and safety risks due to fishing in harsher weather conditions over the 10 years. In fact, fishers along the Bakkhali River were affected differently by the impacts of climate change and climate vulnerability. Due to the low adaptive capacity, fishers tend to be poorer, more marginalized and much more likely to be afflicted by natural hazards like storm surge. Fishers were vulnerable because of their social roles, inequalities in the access and control of other resources, lower education, and their low participation in decision-making.

Climate change magnified existing inequities among the fishers and other communities in Cox's Bazar Sadar. Employed autonomous adaptations in the investigated areas were not effective to reduce the vulnerability and all the participants in the participatory workshops ask for participatory based planned adaptations to combat the climate change impacts, where they believed, adaptive capacity can be strengthened through policies that enhance social and economic equity, reduce poverty, improve fisheries resources and coastal management, increase community participation, generate useful and actionable information, and strengthen institutions.

During the Focus Group Discussion with fishermen, most of the fishermen reported that they were exhausted to carry their social responsibilities to their families. They used to go for fishing in the Bakkhali River but could not earn as much as their family needs. One of the participants, Mr Polin Das reported "*We are compelled to lead a miserable life. With limited earnings, we are surviving somehow. We try to ensure meals and clothes for our family members first but we cannot bear our medical and educational expenses*". Most of the fishers were by-born fisherman, who maintained the joint family consisting of his wife, sons, sister-in-law, grandsons and granddaughters lamented. Mr. Polin Das, a symbol of distressed fishermen, said the fishermen were to catch fish during the full moon or new moon times but during the rest of the time they did not have any work. In addition, most of the fishermen pointed that number of fishing days were reducing due to low catch and were to depend on the earnings of earlier months. "*Fishermen cannot change their professions as they are not so educated and do not have experience of other jobs*" he observed.

A fishermen leader of Choufaldandi area, Mr. Bashir said "*Fish production is decreasing day by day. No fish is available in the Bakkhali River in abundance as before. Fishermen were moving to deep sea to catch fish*", while all other participants echoed the opinion of Mr. Bashir. The fishermen-leader blamed the changes of weather patterns for decrease of fish in the Bakkhali River. He observed that the rising of frequent attack of cyclone in the costal areas are posing threat to the lives and livelihood of the fishermen. Mr. Monsur a young fisher delivered interesting information. He said "*In recent years, there is growing tendency to reduce the mesh size of the net to increase the catch rate*". During social survey, this information was evaluated and found that the mesh size of the cod ends were reduced to below 5 mm. Mr. Jafar Ahmed, a fish businessman, called *bahaddar* of Choaufaldandi area had to incur loss of BDT 100,000 in this season, where his 3 fishing boats were damaged due to the strong surge, though he put his boats in a narrow small canal for shelter place. He added "*if we could able to create a green belt with the mangrove forest, it could reduce the intensity of wind power and could reduce the storm surge effects*".

He also said, "*We are trying to develop a safety green belt in the Chaufaldandi area through mangrove plantation with the support of local NGO*". Fisher Mr. Rahim Sheik, added, "*This mangrove forest is favoring the* *fishes, where fishes come in the mangrove swamps for eating those leafs and litter falls. During my fishing, I always found high abundance of fish in adjacent areas of mangrove swamps rather than other places*". Mr. Kokon Kanti, an ESBN fisher shared a horrible experience about the strong surge which was hit on 22 October, 2016 and said "*I saw a big surge raged on my boat and it was broken. Then I felt so dark around me, some how I grab a plastic drum with my hand as float, fortunately it made me alive and then I was rescued by other fishermen*". After the storm surge at 22 October, 2016, most of the ESBN fishers were struggled to reinstall their net in the Bakkhali River till November, where the monthly yield was dropped on the following months.

Mr Nazibul another participants in the workshop reported "*My fishing gear (ESBN) was almost damaged through strong water current during storm surge, which needed BDT 50,000 for necessary repairing but I didn't able to arrange such fund immediately. For these reasons, I had to borrow money from local money lenders with high interest and it also took 20 days to repair my net, where I was undone to continue fishing during this time and also did not have any alternative works for financial recovery*". Like Mr. Jolil Mia, most of the fishers borrowed from neighbors, relatives, local rich people, NGOs to cope with such crisis. Unless, they had to sale their land and other assets, and rarely using up previous saving, where all the participants reported that access to institutional sources of credit were very limited. Under these circumstances, significant number of fishers changed their profession as they couldn't maintain their family.

Numerous ESBN fishers changed their fishing activities in wild shrimp fry collection which had adverse effect on aquatic biodiversity. One of the participants Mr. Porimal Das who was a wild shrimp fry collector said "*I was an ESBN fisher, when my nets damaged in ruinous storm surge, I did not have money to repair it and there was no other options for earning except to engage with wild fry collection where I did not have to invest so much to buy the push net*". Moreover, livelihood of fish workers involved in selling, repairing nets fish processing and other supporting jobs were also being affected as their works depends on production of fish.

Mr. Kolim, active participants who worked in ice-factory located in Khuruskul area said "*My income is decreasing as I have not sufficient work of loading and unloading ice from fishing boats*". Mrs. Chemon Ara, a mother of five sons and four daughters, works at a dry fish processing at Choaufaldani Jalia Para said "*Now fish landings are interrupted and reduced due to the bad weather. I get only small amount of trash fishes after shorting dry fish and its being very difficult to sustain my livelihood, where I get only BDT 50-75 per day by selling those trash fish*". Those who had lost their livelihoods in fishing had been forced to search for alternative work as labourers for others, or to migrate temporarily or permanently in search of alternative employment.

However, due to increasingly high demand for employment both at source and destination locations, there were not enough jobs available. This leaded to tension that could result in conflict. Temporary migration was a traditional mechanism for sustaining livelihoods during periods of environmental insecurity. It usually comprises the short-term movement of one or two members of a family to a different location in order to find employment. Temporary migrant fishers moved to urban areas of Cox's Bazar Sadar to seek employment in the informal sector (such as rickshaw driving) or to rural areas to take up employment as labour on salt farms, grosser shop business, earth works. Mrs. Bilkis Banu wife of a fisher stated "*My husband was unemployed for last few months as he lost his job in operating ESBN gears and had to migrate in Cox's Bazar Municipality, where he now pooled rickshaw*".

Moreover, the field research shows that the number of fisher were migrating temporarily from fishing villages that were vulnerable to natural hazards had significantly increased over recent years, as localised coping strategies had become more difficult to sustain. Although the decision to migrate temporarily was determined by a number of differing factors, the frequency and intensity of naturally occurring hazards had increased the pressure on fishers to relocate both temporarily and on a more permanent basis.

From the study, it has been found that fishery-based livelihoods in households of Bakkhali riverside area were highly exposed to climate-related shocks and stresses, especially floods and cyclones than other area fishermen communities, because the communities were located near the coastline and livelihoods were dependent o the marine fishing from small vessels (Islam et al. 2014). The sensitivity of livelihoods to climate variability and change was determined by dependency on fisheries for livelihood due to lack of alternative livelihoods, lack of financial capital to invest in alternative livelihoods, lack of institutional support for livelihood diversification, and lack of human capital to engage in alternative livelihood strategies. Adaptive capacity was limited due to the lack of physical, natural, and financial capital and limited diversification of alternative livelihoods. Because of the lack of financial capital (i.e., income or access to credit), households were unable to augment their physical capital (i.e., boats or nets) or diversify their alternative livelihoods. These results resonate with research that found that the most vulnerable households and communities were usually poverty-stricken (Paavola 2008, Deressa et al. 2009, Black et al., 2011).

Fishers were not only the primary victims of climate change, but they can also be effective change agents, managing both mitigation and adaptation. Fishers have extensive knowledge and expertise that can be applied in assessing community risk, selecting adaptation measures and mobilizing communities to manage risk. In participatory workshops, all the participants from different stakeholders felt the necessity of an integrated approach to formulate the climate change adaptation strategies which aims to address the full range of coastal climate change hazards in ways that meet societal objectives.

All the findings of the present investigation were discussed in a full pleasure workshop at the end of the study to select the potential adaptation measures, where fishers, fish traders, processors, net menders, boat makers, government officials, concerns NGOs and other fisheries resource users groups were actively participated and gave their valued opinions. Finally, fisheries adaptation measures and strategies were developed with the assistance of all stakeholders. Local knowledge and perceptions influence people's decisions both in deciding whether to act or not (Alessa *et al.,* 2008) and what adaptive measures are taken over both short- and long-terms (Berkes and Jolly, 2001).

Exposure, sensitivity, and adaptive capacity affect the vulnerability of fishermen livelihoods in varied ways. Those who were most exposed not necessarily the most sensitive or the least able to adapt. It means that climatic stresses and shocks had unequal impacts in the fishermen communities of the study area. Socio-economic impacts were felt through changes in the capture, production and overall income, and possible increases in risks of damage or loss of fishing gears and crafts. Fishery-dependent communities also faced increased vulnerability in terms of less stable livelihoods, decreases in availability or quality of catch, and safety risks due to fishing in harsher weather conditions over the ten years.

Fishers along the Bakkhali River were affected differently by the impacts of climate change and climate vulnerability. Due to the low adaptive capacity, fishers tend to be more impoverished, more marginalized and much more likely to be afflicted by natural hazards like a storm surge. Fishers were vulnerable because of their social roles, inequalities in the access and control of other resources, lower education, and their low participation in decision-making. Climate change magnified existing inequities among the fishers and other communities in Cox's Bazar Sadar.

Some adaptations practices employed by the fishermen in the study areas were not adequate to reduce the vulnerability. All the participants in the FGDSs were asked for participatory based planned adaptations to combat the climate change impacts, where they believed that adaptive capacity could be strengthened through policies that enhance social and economic equity, reduce poverty, improve fisheries resources and coastal management, increase community participation, generate useful and actionable information, and strengthen institutions (Table 5).

Mangrove plantation along the bank of the Bakkhali River was identified as one of the potential climate change restoration, mitigation and adaptation measure, which provides feeding, breeding and nursery habitats for fisheries, ecosystems services for communities and their protection and livelihoods; serves as a natural water filter, buffer against coastal ecosystems. To meet the functioning and healthy ecosystem goals, financial instruments under which beneficiaries of ecosystem services can compensate the suppliers as a means to fund sustainable environmental management policies and actions.

Coastal development setbacks protocol can be developed to set a distance from the coastal feature within which all or specific types of development (e.g., navigational jetty, coastal aquaculture pond in intertidal zone) need to be prohibited. Fishers feel to develop fisheries co-management for livelihood sustainability and also strengthening their capacity to deal with long-term climate-related effects on Bakkhali River habitats and ecosystems. Fisheries management seeks equity to organize and empower the weak or fewer privilege groups of fisher to allow them to participate actively in collaborative management. Diverse fisheries management related options were identified by the participants for the Bakkhali River focusing fishing, fishers and the productivity, which include various management issues and their potential implementations at different management levels. Biological conservation should incorporate that will enhance the ecosystem and livelihood security as well.

As regulatory approaches fishing gear or mesh size restriction, area allocation, fishing season prohibition, i.e. closure of fishing during the peak recruitment periods (July to September and February to April in selected areas) can be introduced for ESBN on the assumption that the juveniles would escape. Development technique for processing by-catch and non-traditional fishery items for the preparation of improved quality value-added products; development of post-harvest technology to prevent deteriorative changes occurring in fish and shellfish during different stages of handling, transportation, processing, and preservation are some of the immediate needs for the development of the fisheries management of the Bakkhali River. Furthermore, coastal aquaculture could be one of the potential alternative livelihood options, where 2,675 ha area suitable for coastal aquaculture in the area. In this regard, mostly self-enforced measures need to take to better efficiency and cost in the aquaculture sector in order to increase the derived benefits and promote development.

Maintaining fishing communities and involving them in the management process depends on the existence of appropriate institutions relating education, training and demonstration and also creating alternative livelihood options. But the people of fishing villages were poorly organized above the level of households. They don't have a history of associations and institutions, and hence little cultural background in collective action. A major challenge of capacity building is to reverse the effects of centralized resource management over many generations, which tends to suffocate the ability of fishing communities for self governance. Top-down resource management over a long period of time can result in the loss of civic institutions and local mechanism for consensus building, rule making, enforcement and monitoring.

Moreover, cruising across the Bakkhali River was identified as another growing sector in the area. Actions need to take that enable the tourism sector to improve services and business while minimizing the adverse effects on the environment and local communities. Besides, initiatives should take that enable capacity building for other alternate income generations viz., livestock rearing, tailoring, handy crafts making for tourist, and so forth, through training and demonstration with necessary inputs and institutional supports. The mechanism for community-based disaster risk reduction and early weather warning system should develop in the area to ensure the safety against natural fury. Personal and fishing accessories safety, disaster preparedness will reinforce the equity. Moreover, to bundle a series of measures, an overarching integrated management approach or strategy involving planning and decision-making could be geared to improve economic opportunities and environmental conditions for coastal people of Cox's Bazar.

Many of these adaptation measures were not "new" to those involved in autonomous adaptations. They included strategies and actions familiar to fishers as part of responding to episodes of natural hazards and shocks. They were also familiar as part of everyday efforts to implement sustainable development—including sound environmental management, planned development, wise resource use, and poverty reduction. Adopting these measures with a climate lens provides an opportunity to be strategic in the face of future changes. There were also new approaches and tools being developed, such as nature-based approaches to coastal adaptation. Nature-based approaches include new tools for managing fisheries resources and approaches to conserve biodiversity in the face of shifting geographies. They focused on helping fishers and communities deal with climate change impacts by protecting mangroves, estuaries, and other systems on or near shorelines and the benefits they provided. These benefits included protection from storms, controlling erosion, and retaining and assimilating nutrients, sediments.

6. Conclusions and Recommendations

This study analyzed the vulnerability of fishery-based livelihoods to climate variability and change using a composite index. The findings suggest that different components of vulnerability affect livelihoods in varied ways. Because of the different levels of exposure, the highest sensitivity does not always lead to the highest livelihood vulnerability, and the highest adaptive capacity does not always result in the lowest livelihood vulnerability. It is found that exposure, sensitivity, and adaptive capacity are highly context dependent. A large number of factors influence livelihood vulnerability in the fishermen communities.

The most critical climate-related elements of exposure for the fishermen communities of the study area are floods and cyclones, while the key factor determining the sensitivity of an individual household is the dependence on coastal fisheries for livelihoods. Adaptive capacity is underpinned by the combination of physical, natural, and financial capital and is influenced by the diversity of livelihood strategies.

While community participation is crucial for capacity building, however, fishing villages are found to be poorly organized. Their traditional knowledge system has contributed significantly to conserving the biodiversity of the south-eastern coast of Bangladesh over countless generations. Hence, to strengthen their adaptive capacity and to build their resilience to climate changes, government and the external agencies need to strengthen and take advantage of already existing traditional knowledge systems with which the fishermen communities have been historically responding to the environmental stresses.

This research provides an important starting point for directing future research into the vulnerability of fishery-based livelihood systems to climate variability and change. Further work is needed in order to move towards an improved characterization of fishery-based livelihood vulnerability and to identify most suitable means for households and communities to cope with and adapt to the impacts of climate change.

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