REVIEW ARTICLE

COPING PRACTICES OF COASTAL FISHERMEN IN RESPONSE TO CLIMATE CHANGE FOR SOUTHERN COASTAL BELT OF BANGLADESH

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ABSTRACT

Climate change impact over the fishermen of an coastal river that flowing over the southern coast of Bangladesh are suffering the increased vulnerability in terms of less stable livelihoods, decreases in the availability of fish catch, and safety risks due to fishing in harsher weather conditions. This study highlights the river-based livelihood and economies of local communities along the Sangu River basin inside Bangladesh in response to climate change induced problem. Adaptation practices by the fishermen of Sangu river was investigated by triangulating semi-structured interviews, household survey data, while the different environmental variables and their fluctuations at five year's time scales had been compared to detect the bio-physical changes. About 20% fisheries productivity reduced and the annual yield dropped to 162 MT from 850 MT in last fifteen years, which lead to BDT 280 million (80%) revenue loss. 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. Due to the low adaptive capacity, fishers tend to be poorer, more marginalized and losing their occupation.

KEYWORDS

Sangu River, climate change, fishers, fisheries productivity, adaptation

1. INTRODUCTION

Fundamentally, local communities in the coastal area of Bangladesh are dependent on fisheries and coastal resources. Their existence in harmony with these resources until the market economy and state interventions come into effect. Fisheries are considered open-access resources in early times when population pressure and use patterns were still minimal and subsistent. There was no restriction on access to these fisheries resources. The resources were abundant and open to all those who are capable of fishing. When population pressure together with the market and the cash economy entered. The fishing communities through the introduction of fishing engine, modern gears and ice storage, the types of ownership and resource-use rights took different forms (Gani et al., 2011).

Globally, almost half a billion populations derive their earning opportunities from fisheries resources that provide nearly 15% of the animal protein and assist the livelihood for 10-12% of the population in the present world. Maximum population that depends on fisheries resources are living in the developing countries where income generating options are limited, low availability of food resources and less opportunities to alternate occupations and diets. Climate change has direct and indirect effects on fish stocks. Direct impacts act on physiology and behaviour and reproductive capacity, mortality, distribution and alter the growth on fish species and on the other hand, indirect impacts found on altering the productivity, structure and composition of the marine ecosystems on which fish depend for food. However, many other factors, including fishing, biological interactions and non-climatic environmental factors can also have similar effects. When a change is ascribed to climate these other factors should also be evaluated and the degree of confidence in the ascription should be given. The fishery as a profession is extremely

seasonal in nature and there is a sensitive insufficiency of the alternative livelihood in the coastal areas, that is retreating the fishermen's adaptive capacity against adverse climate change impacts. Maximum fishermen of the world are illiterate due to unavailability of finding an alternate vocation as adaptive measures (Mohammed et al., 2017).

Climate Change Vulnerability and impact in Bangladesh is an extremely crucial issue, and Bangladesh is one of the most vulnerable nations to the impacts of Global Climate Change in the coming decades. The regular and severe natural hazards already batter the country like tropical cyclones, coastal and river erosion, flood, landslides and drought increase in strength and frequency as a consequence of climate change which problem creating noteworthy effects on livelihood, economy, agriculture and other sectors in Bangladesh (Barua and Rahman, 2018). However, fishery-dependent communities living in the coastal areas of Bangladesh with highly exposed to the impact of climate change (Barua and Rahman, 2020). Income generating activities and livelihood of coastal fisherfolk communities 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 adverse impacts of climate change (Koya et al., 2017). Fishermen of coastal Bangladesh are suffering at present due to increased vulnerability in terms of less stable livelihoods, declining the availability of fish catch as well as safety risks because of fishing in harsher weather conditions. The degree to which local community and fisheries resources are influenced by the climate change (their vulnerability) which is determined by three factors: their exposure to a specific change, their sensitivity to that change, and their ability to respond to impacts or take advantage of opportunities (Allison et al., 2009).

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The authors highlighted the impact of climate change induced natural disasters on socio-economic status of fishermen of an estuarine river of Bangladesh named Sangu river over the 16 years (2005 to 2020) with autonomous adaptation practices at south-eastern coast to formulate an integrated adaptation framework. The Sangu is a transboundary river is one of the maddening watercourses which is sometimes a river, often a torrent and mostly a stream, rising on the Indo-Burma border (North Arakan Hills of Myanmar: located at 21°13'N 92°37') which flows northwards through the Chittagong. Hill Tracts, bending West at Bandarban until it breaks into the Bay of Bengal to the west of Dohazari, Chittagong. The length of the river is 295 km (Figure 1).

Figure 1: Geographical Location of the Sangu river basin

The major tributaries of the river are Chandkhali River and Dolu khal. Sangu river is also significant as a one of the major habitat of Indian major carps that migrate to the river Halda via Karnaphuli river for spawning during the time of breeding season. Azadi and Alam identified 127 finfish (109 finfish along with 3 exotics and 18 shell fish species) from the river Sangu. River-based livelihoods of communities surrounding by Sangu river have involved a combination of many various linkages and relationships between people and their rivers (Azadi and Alam, 2014). This is clear that Sangu River is closely interlinked with the livelihood of local people. The people of the area depend on the Sangu river for irrigation, transportation, drinking water, sanitation as well as for practicing religious, ethnic and cultural rituals and traditions. While it is obvious that Sangu River is providing hugely to the sustainable livelihood of the people specially fishermen it is equally important to find out alternatives to decline this categories of high dependency on the river. Too much reliance on Sangu River is creating conflict of resource and in the long run, might diminish the potential of Sangu River to serve the communities due to overexploitation.

2. MATERIALS AND METHODS

As part of the vulnerability assessment for the fishermen of Sangu river, a risk perception study was conducted to gain some understanding of commercial fishers' perceptions of the potential impact of climate change in the industry. This is differentiated from what is scientifically or formally known, since what is identified as an actual risk and how industry stakeholders perceive it can differ. 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 effected. Finally, gross scenarios were drawn about the potential impact, allowing for autonomous adaptation. Autonomous adaptation to the climate change impacts on Sangu river fishery was investigated by triangulating several qualitative and quantitative techniques. First, semi-structured interviews were conducted with key individuals, household heads and smaller (naturally formed 4) groups. Second, repeat focus group discussion with village elders facilitated a mapping of social memory. Social memory is pertinent to the study of environmental change and the subsequent reactions of societies over time.

Third, household survey data were collected by means of a Rapid Rural Assessment, especially adapted for the study of fishing communities. This study was undertaken over a twelve month period between January and December 2020. Seventy five semi-structured interviews were undertaken. Additional information from a range of stakeholder participants was gathered via six participatory workshops and some focus group work using PRA techniques. All respondents were male, with an average of 10–15 years experience in the industry. Many of those interviewed fished all around Sangu river, so their feedback includes all possible experiences. Subjects of focus for the interviews included: (i) the fisher's experiences of fishing; (ii) the fisher's perception on management regimes; (iii) the fisher's perception of climate change and its impact on the industry; and (iv) the fisher's perception of and ideas for adaptation. Face-to-face validity and Guba's criteria of (i) credibility, (ii) transferability, (iii) dependability and (iv) conformability (Guba, 1981) were used to evaluate the information obtained.

Second 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 Chattogram. 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. Having assessed "who needs to adapt and to what," the next step in the analysis was to learn from existing experiences in dealing with past and current climate variability, including extreme weather event like a storm surge. Finally, whole findings were discussed and evaluated again in a workshop focused on participatory scenario development to develop a robust understanding of feasible adaptation measures and pathways and their relevance for vulnerable fishers groups.

3. RESULTS AND DISCUSSION

During the present investigation, about 1390 fishers were engaged in fishing throughout the Sangu. All fishers indicated extensive experience of fishing. Of those interviewed, about 40% did not perceive that climate change was a problem at all. Another 30–40% felt that there was currently no consensus about the reality of climate change. These fishers noted that changes in climate did seem to be occurring, but were not convinced that it was human-induced, and that even if it was, considered it would not have a great impact on the fishery. Some of these fishers felt that they had observed changes in the fishery, and areas they fished, but were not convinced that the cause was climate change. Some fishers added that their main concern was the very low egg production, and wondered whether or not that was due to climate change. In this context, a key discourse about climate change was the view that environmental change was cyclical, and that it was therefore uncertain whether or not changes were simply a natural climatic variation. In any case, all fishers added, in this part of the discussion, that while they may not believe in climate change, they did believe in sustainability and making the industry as sustainable as possible. 20% of fishers did express concern about climate change. Of those that indicated they were concerned about socioeconomic and biophysical changes in terms of potential impact on the Sangu river fishery.

Fishing operation in the Sangu 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 Sangu 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 Sangu 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 Sangu River are of various types (Table 1). It is found that, number of fishers reduced to 1010 from while 2500 fishers were engaged in fishing during 2005 to 2020 (Hasan and Rashid, 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 Sangu 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 15 years of timeline (2005 to 2020) (Hossan et al., 2019).

Table 1: Fishers and their physical assets engaged in fishing in the Sangu River				
S.L	Physical Assets	Comparative the Quantity within 15 years		
		2005	2015	2020
1	Fisher	2500	1538	1010
2	Gears			
	i ESBN	157	145	130
	ii Beach Seine	15	10	7
	iii Gill Net	10	6	4
	iv Push Net	221	205	180
3	Crafts			
	i Raw boat	113	105	95
	ii Medium boat	166	145	130
	iii Engine boat	25	20	15

3.1 Exposure and Sensitivity

In this book chapter, 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. These assets include socioeconomic assets (fisher, fishing accessories, and cash income), and biophysical assets (fisheries productivity). Relating the relative risk on above assets, 30% respondents believe that the productivity of the Sangu River were in top risk, while 27% and 16% respondent focused on fishing gears and their boats respectively. 15% 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 2).

Figure 2: Fishermen perception for about the vulnerability of fishing sectors

Based on the fishermen perception and their involvement with the industry, a dimension of sensitivity was drawn (Table 2) to explain the issues relating to potential impacts.

Table 2: Exposed fishers' assets and factors of sensitivity

Grouping	Exposed Assets	Fishery	Dimension of Sensitivity
Socio-economic	Fishers, fishing accessories, market price		1000 Fisher, 74% fishing gears, entire fishing boats, Market price fall due to bad weather
Biophysical	Finfish, shrimps and prawns, crabs, molluscs, echinoderms		Existing condition and health of ecosystem, abundance and variety of aquatic species

3.2 Impact of Climate Change

Climate change impact on Sangu River fisheries was observed through a diverse range of pathways and drivers. Figure 4 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 3).

Figure 3: Impact of Climate Change on Sangu river fishermen

It is widely acknowledge that many interacting biophysical factors influence the occurrence, distribution, abundance and diversity of fisheries species. In comparison with the previous socioeconomic data the result shows that about 20% household heads changed their fishing profession, where dependency to non-fisheries livelihoods (example, rickshaw pooling, other business) were growing in the fishing villages (Mahmood, 2006; Zaman et al., 2020 ; Adnan et al., 2019). In addition, overall fishing efforts declined in last 15 years. During the questionnaire survey, a common question was asked to understand key climate variable that directly influences such socioeconomic changes. The result shows, 72% fisher believed that this changed was occurring due to the storm surge effect where they 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.

The local fishers reported that the intensity and frequency of storm surge increased and posing a threat to the fishermen's livelihood directly. They did not able to operate their fishing gears when the river becomes rough due to harsh weather and storm surge effects. During this investigation (December 30, 2020) the fishers of the Sangu River faced a category V types cyclone Named Amphan that hit the southern Bangladesh on May, 2020 which responsible to displace 50,000 peoples lost their home, land and housing from the southern coastal area of Bangladesh. This cyclone destroys the Banskali and Anwara coastal area This was created the economic loss of 5 crore BDT and vanishing 20,000 houses of Banskali

and Anwara coastal inhabitants including fishermen. Fishermen of Sangu river also greatly affected by cyclone Komen during the month of July 28, 215 and cyclone Giri which was crossed the southern coast of Myanmar on October 22, 2010 having peripheral effect on Banskhal coast. As an effect of the cyclone Amphan on May, 2020, storms raged through all investigated fishing villages.

With tidal surges hitting seven to eight meters above normal water level, 78% fishers of Banskhal moved to safer shelters, but it was not possible to put the fishing boats and gears in safe place for shelter. Meanwhile, it caused severe damage on fishing boats and stationary fishing gear (ESBN). 186 fishers were injured during the cyclone while during the cyclone 250 fishers got injured and cyclone 350 people become injured (Giri, 2010; Kome, 2015; Amphan, 2020). Besides, the authors found that farmers lost 276 MT catch of fish due to damage of fishing gears which economically found 1.1 million BDT, while after 5 years cyclone Komen outbreak farmers lost 520 MT catch because of damaged fishing crafts and gears which become 2.5 million BDT loss for fishermen. The rate of loss of fishermen increased significantly during cyclone Amphan incidence on May, 2020 while fishermen lost 700 MT fish harvest which financially turn the loss of 5 million BDT. The annual yield of the Sangu River was declined to 162 MT from 658 MT in last 15 years (2005 to 2020), which resulted to 72% revenue loss (Figure 9, 10, 11). Though, the price of the catch increased 48%, but the monthly income from ESNB operation was not increased due to the reduction of yield and 90% increasing of operational cost.

From the study, the authors found that financial condition of the fishermen of Sangu river basin, their costing and income opportunities have been changing significantly since 2005 to 2020. During the year of 2005, fishermen monthly costing assess 17,419 BDT which increasing as 32,670 BDT during 2010. After cyclone Komen outbreak in 2015, fishermen monthly costing increased as 40,975 BDT and during the year 2020 while cyclone Amphan fishermen costing become 55,000 BDT. The authors found that due to increasing rate of fishermen monthly costing per month that reflect the monthly net income of them. Their monthly net income during 2005 was 50,191 BDT which reducing continuously as 47,121 BDT on 2015 and 40,500 BDT during 2020. The income also depend on fishing season of the coastal areas of Bangladesh.

3.3 Autonomous adaptations and other adaptive capacity

The field research underlined the fact that fishers along the Sangu River are used to these kinds of challenges and have adapted to the impact of naturally occurring changes and other natural hazards for decades. They have experienced periods of scarcity in the past and they are well accustomed to employing coping mechanisms. However, as climate change is increasing the frequency and intensity of naturally occurring hazards these coping mechanisms are coming under increasing strain, with the potential to cause conflict in the future. Focus group participants from source locations provided examples of the types of autonomous adaptations that have been familiar by the fishermen. During focused group discussion, 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 Sangu 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-laws, 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 Shahporir Island, Mr. Bashir said *"Fish production is decreasing day by day. No fish is available in the Sangu 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 Sangu 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 Shahporir dip jalia para 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 Shahporirdip area through mangrove plantation with the support of local NGO"*. Fisher Mr. Rahim Sheik, most senior participants in a focus group discussion 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 ESNB fisher shared a horrible experience about the strong surge which was hit on 22 October, 2010 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, 2010, most of the ESNB fishers were struggled to reinstall their net in the Sangu River till November, where the monthly yield was dropped on the following months (Fig. 10). Mr Nazibul another participants in the focus group discussion 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"*. Mr. Jolil Mia another fisher said, *"I was unemployed when my employer lost his boat and fishing gear during the cyclone which was hit on 26 May, 2020 and it was being quite difficult for me to maintain my family expenses as it was my only earning source. Then I had to borrow BDT 30,000 from a local NGOs with high interest, where I was bounded to pay BDT 800 per week. Then I had to work as daily labour in salt bed, earth filling works, where they paid BDT 180 per day and resulted to change my previous profession"*.

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 ESNB 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 ESNB 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 Premasia of Khankhanabad 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 Chanua of Banskhal 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 led 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 TekSangu 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 ESNB gears and had to migrate in TekSangu Sadar, 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.

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 suggest that migration was increasing in response to the severity of naturally occurring storm surges and that this migration 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 a number of 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 tends to be seen as the solution only after all alternative coping mechanisms had been 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 10,000-15,000 to migrate the short distance from Banskhal 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. Mr. Abul Monsur, an old fisherman stated *"The majority of fishers living in areas affected by storm surge on this fishing village are 'potential migrants'. For now, they are trying to cope through finding temporary employment and shelter, but most are trying to save up the money needed to migrate."* From the overall discussion in the workshops, it was revealed that fishers in the investigated areas had low adaptive capacity and was likely to be less resilient to recover from stressful climate change events and conditions. 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.

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. The impacts of climate change on Sangu 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 Sangu River was a function of the annual rainfall pattern in the catchment area and also intrusion of more saline water from the Bay. Sangu 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. Precipitation, salinity and turbidity were found as key environmental variables and played significant role fisheries productivity in the Sangu 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. 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 15 years.

In fact, fishers along the Sangu 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 Banskhal. 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.

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 and what adaptive measures are taken over both short- and long-terms. Therefore, local observations and perceptions were taken into account in efforts to understand climate change, its impacts, adaptation to it, and mitigation of it (Figure 4).

Mangrove plantation along the bank of the Sangu 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, where Set distance from a coastal feature within which all or specific types of development (examples: 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 Sangu River habitats and ecosystems.

Figure 4: Climate change adaptation goals and their relative measures being identified by the local resource users group in Banskhali-Anwara

Fisheries management seeks equity to organize and empower the weak or less privilege groups of fisher to allow them to freely participate in and collaborative management. Diverse fisheries management related options were identified by the participants for the Sangu 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 ESNB 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 shell fish during different stages of handling, transportation, processing and preservation are some of the immediate needs for the development of the fisheries management of the Sangu River.

In addition, coastal aquaculture could be one of the potential alternative livelihood options, where 4,675 ha area suitable for coastal aquaculture in the area. In this regard, largely 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. Moreover, cruising across the Sangu River was identified as another rising 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 etc., through training and demonstration with necessary inputs and institutional supports. 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 (Chowdhury et al., 2005).

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 Banskhalī. 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

These benefits included protection from storms; controlling erosion; and retaining and assimilating nutrients, sediments. In addition to these benefits, functional ecosystems were critical to maintaining biodiversity and to fishers and other resource users whose livelihoods rely on the condition of natural systems. These approaches provide a departure for the next generation of adaptation briefs. Using a single, stand-alone measure was usually not the best approach. To respond effectively to a wide array of climate change impacts requires combining complementary measures. In selecting the best combination, it helps to look for measures that have interdependencies, contribute to good fisheries resources management, and bring additional benefits in terms of climate change adaptation. For example, if the management goal is to maintain and restore fisheries productivity, a variety of adaptation measures can apply: coastal development setbacks, coastal zoning, ecologically critical area management, integrated fisheries and other coastal resources management.

Most of the fishermen along the Sangu River were not educated enough to have a basic understanding of the long-term management goals and therefore, it appears difficult to implement even a well formulated plan which necessitates extension works and awareness building at different levels. 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.

By the above discussion, climate changes in the Sangu River is thus a prime example of what has been called a “social ecological system” with factors from different domains interacting on different scales. How people in any given area like Banskhalī coast are affected by climate change is therefore not only depend on the climatic changes themselves in that area but also on ecological, social, and economic factors. People’s ability to adapt likewise depends on a variety of factors including availability of resources (both community and individual) for adaptation, motivation, and information about the changing state of the environment and the links between human decisions and the environment. This local knowledge can promote the understanding of climate change impacts and adaptation in local scale.

4. CONCLUSIONS

This research gives an account of adaptation to environmental change in the context of the Sangu River Fishery. This fishery provides particularly useful settings in which to study adaptation. Their environments are typically dynamic, affected by a mix of geomorphologic process, seasonality, and shifting patterns of ecology and productivity. Fishers along the Sangu River are also susceptible to environmental shocks through natural events such as cyclones. The Sangu river fisheries host a society which has a wide experience of living with dynamic change and unpredictable events. The study of Sangu River fisheries can thus provide a wealth of information about how people live with environmental change which often presents itself in extreme forms.

During this research, no model based analysis was done due to the

unavailability of biophysical data for long time comparison. However, climate change is not a purely physical or even solely an environmental phenomenon, but also has social, cultural, economic aspects. To understand these phenomena local actors and their accounts are directly relevant. Only local people can explain how climate change becomes manifest locally and how it is evaluated, interpreted and handled by the affected people. While local observations cannot substitute for scientific measurements and models, they are important supplements, detailing local phenomena and perceptions and giving insight into local concerns. Local observations can inform scientists by directing attention to overlooked aspects and can aid in the formulation of new hypotheses and research questions.

Furthermore, people's perceptions and interpretations influence the way they respond to phenomena such as climate change and which options are regarded as appropriate. Our study also showed that this may differ significantly, even within a small geographic area, depending on factors such as local climatic differences and subsistence activities. Policies and projects aiming at promoting adaptation will only be relevant to local people if such differences are taken into account. Perceptions and concerns of local people have sometimes been dismissed as irrelevant and superstitious by scientists and policy makers because they do not fit with their own world view. The fishers along the Sangu River in this study were able to accept different explanatory models. It is our hope that scientists and policy makers equally will be able to accept the knowledge of the fishers along the Sangu River and other local peoples. Mutual respect is indispensable to gain a better understanding of climate change and to tackle its many-faceted impacts.

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