Barriers to Climate Change Adaptation: Insights from the Sundarbans Mangrove-based Fisheries of Bangladesh

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Abstract

Adaptation to climate change in mangrove-based fisheries is confronted by multiple barriers on which studies are limited. This study identified barriers to climate change adaptation faced by fishing communities dependent on the Sundarbans mangroves. The study also explored the possible linkages among the different barriers for the adaptation to climate change and ways to overcome them. Using both quantitative and qualitative approaches data were collected from September to December 2018 from two fishing communities dependent on the Sundarbans mangroves in Shyamnagar Upazila of Satkhira district. This study identified six categories of barriers: natural (cyclones, floods, riverbank erosions and salinity intrusion with increased frequencies and magnitudes), social (lack of education and awareness, insecurity at the cyclone shelters and during fishing), institutional (weak enforcement of fisheries regulations and fishing bans), financial (unfavourable credit systems, low income from fishing, and commissions for harvesting natural resources), technological (shortcomings of the weather forecast, lack of safety equipment, and low-grade boats and engines) and informational (lack of training on climatic hazards management and lack of livelihoods alternatives). Some of these barriers are inter-related and overlapped with one another directly or indirectly and hampered the climate change adaptation in complex ways. This research provides a range of measures to help mitigate and overcome the barriers including mitigation of climate change, proper education and awareness-raising, enforcement of fisheries rules and regulations, reconsideration of fishing ban in the Sundarbans, favourable credit systems, reduction of fees for collecting natural resources from the Sundarbans and technological development.

Introduction

Globally climate change has created unprecedented impacts on coastal ecosystems, including fisheries and fisheries dependent communities, as they are exposed to multiple climate-related hazards and disasters such as cyclones, floods, sea-level rise, riverbank erosion and salinity intrusion (IPCC, 2014). According to the projection of the climatic models, the frequencies and magnitudes of the climatic hazards will be exacerbated in future which might create adverse impacts on the mangrove ecosystems and its dependent fisheries communities especially in vulnerable developing countries (IPCC, 2018). Bangladesh is considered as one of the hotspots of climate change, especially its coastal and mangrove systems (IPCC, 2014). Several hundred thousand of coastal Bangladeshis, many of whom were fisheries dependent had died due to climatic hazards over the past few decades (IFRC, 2010).

People have been adapting over the millennium to minimise the adverse impacts of climate change, and ecosystems (Ahmed et al., 2019) which has been successful or unsuccessful. Globally many studies done on climate change vulnerability and its impacts on the marine ecosystem, fisheries or human, and they tried to find ways (strategies) to overcome the impacts (e.g., Miller et al., 2018; Ahmed et al., 2019; Woodson et al., 2019). The long-term sustainable

strategies are known as adaptation strategy, which can minimise or overcome the adverse impacts of climatic hazards. Similarly, some studies have also been conducted on the same topics in the fisheries sector in Bangladesh as well (Ahmed et al., 2013; Islam et al., 2014a, b, c; Hossain et al., 2015; Khan et al., 2018; Islam et al., 2019a, b). These adaptation strategies might be interrupted or become unsuccessful in some cases to cope with climate change impacts because of some barriers.

Several structures and methodologies have been evolved to demonstrate the barriers to climate change adaptations (Dow et al., 2013). In this study, barriers include limits, constraints and obstacles to climate change adaptation. Limits to climate change adaptation are not only endogenous, but also absolute, and therefore, they are unsurpassable (Dow et al., 2013). Factors which engendered adaptation capacity ineffective as a response to climate change are known as limits. They are widely insurmountable and there has no way forward to minimise or overcome the adverse impacts of climate change (Klein et al., 2014).

Constraints or obstacles are defined as factors or conditions that lessen the effectiveness of any adaptation strategy or make it more difficult to plan and implement adaptation strategies (Klein et al., 2014). Usually, limits to climate change are challenging to overcome, whereas, constraints or obstacles can be overcome through some interventions or concerted efforts with stakeholders, governmental and non-governmental organisations (GOs and NGOs) (Moser and Ekstrom, 2010). In many cases, these limits and constraints or obstacles might overlap and hereafter are referred to as barriers.

Some studies have reviewed the barriers to climate change adaptation around the world (e.g., Moser and Ekstrom, 2010; Klein et al., 2014; Nalau et al., 2018). The study by Islam et al. (2014a) on barriers to climate change adaptation in coastal Bangladesh was specific to cyclones. As yet, there has been no study focused on barriers to climate change adaptation in the mangrove-based fisheries in Bangladesh. As such, the objective of this study aimed to identify the barriers to climate change adaptation in the mangrove-based fisheries dependent communities of Bangladesh and find possible links among the barriers and suggest the way forward to overcome them.

Methods

Socio-demographic background of the study sites

In this study, two fishing communities dependent on the Sundarbans mangrove-based coastal fisheries, in Mathurapur and Datinakhali in Shyamnagar Upazila (sub-district), Satkhira district, Bangladesh, were selected (Fig. 1). Sundarbans mangroves are one of the valuable functional ecosystems which provide
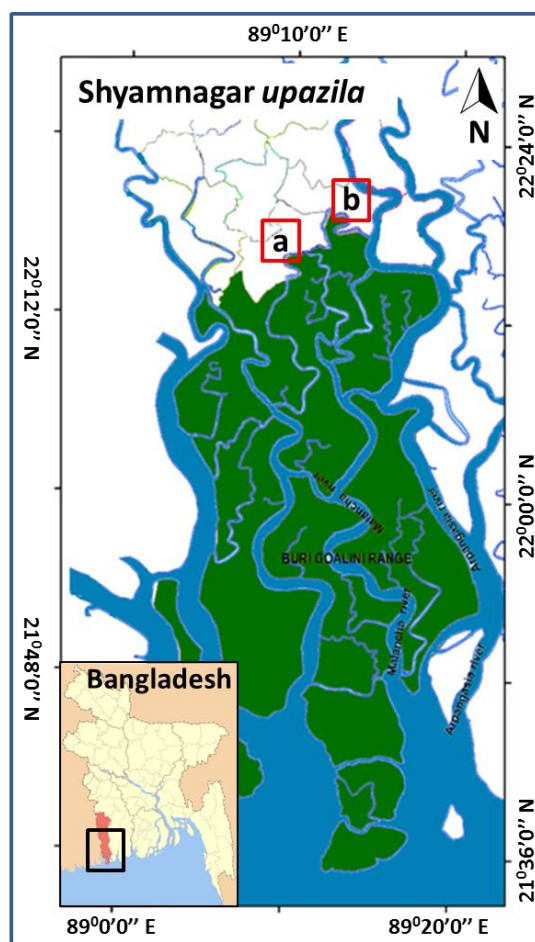

Fig. 1. Map of the study sites (a) Mathurapur and (b) Datinakhali, adjacent to the Sundarbans mangroves in Shyamnagar Upazila, Satkhira district, Bangladesh.

benefits to coastal communities and help the national economy through multiple ecosystem services. In the study sites, fisheries are the primary activity for the majority of the households. Almost 80–90 % households depend directly or partially on fisheries and agriculture, in different seasons for their livelihoods. These two coastal sites were selected as they are highly vulnerable to climatic hazards such as cyclones, floods and salinity intrusion (Islam et al., 2015). A brief description of the study sites is below:

Mathurapur is located on the bank of Malancha River which separates the community from the main Sundarbans mangroves. It has a total of 2,147 populations in 480 households (BBS, 2014). Two-thirds of the people are Hindu. According to key informant interviews (KIIs), around 200 households in Mathurapur depend on the Sundarbans mainly for fishing. Rest of the households are involved in fish farming, crab fattening, agriculture, honey collection, woodcutting, day labouring. In this community, women are involved in multiple fisheries-related activities like direct fishing, fish drying and net mending. It is one of the highly vulnerable fishing communities to natural climatic hazards such as cyclones, floods, riverbank erosions and salinity intrusions within the Shyamnagar Upazila.

Datinakhali is located at the edge of the Sundarbans which is separated by the Kholpetua River. It has a total of 2,220 population in 513 households (BBS, 2014). More than 95 % of the people are Muslim. In this community, the majority of the people are involved in agriculture, shrimp farming, crab fattening, small business, and day labouring. Most of the fishers here depend on the Sundarbans and catch crab and small fish, and collect honey. This community is also highly vulnerable to climatic hazards such as cyclones, riverbank erosions and salinity intrusions. A comparative description of the two study areas is shown in Table 1.

Data collection

The quantitative and qualitative data were collected from primary and secondary sources between September to December 2018. Primary and secondary data were collected in a mixed-method approach, including semi-structured interviews, focus group discussions (FGDs) and key informant interviews (KIIs).

Semi-structured interviews

An initial scoping study was conducted to finalise the target group for semi-structured interviews. Lists of

fishers in Mathurapur and Datinakhali were collected from Shyamnagar upazila fisheries office, Satkhira district. The sample size for semi-structured interviews was determined according to Bartlett et al. (2001):

$$n_0 = \frac{z^2 p (1-p)}{d^2}$$

Here, n_0 = sample size, z = standard normal deviation at 95 % of confidence level, p = percentage of picking a choice or response (92.2 %) and d = confidence interval (5 %).

Using the formula, the estimated sample size was 110 (65 in Mathurapur and 45 in Datinakhali). From the list of the fishers, 110 participants for semi-structured interviews were selected using simple random sampling. The interviews were conducted to collect data to identify barriers to climate change adaptations. Most of the household heads were interviewed as they have practical experience on their households' vulnerability, adaptation strategies and barriers to their adaptation strategies. Every question was asked in a similar manner which empowered the accumulation of equivalent answers as much as possible on which factual investigation could be performed.

Table 1. Comparison of Mathurapur and Datinakhali fishing communities of the Sundarbans, Satkhira, Bangladesh; recorded during semi-structured interviews and Bangladesh Bureau of Statistics (BBS, 2014).

Variables	Mathurapur (n = 65)	Datinakhali (n = 45)
Fisheries dependency in terms of income (%)	95	90
Family size (mean ± SD)	5.1 ± 1.4	6.2 ± 1.3
Literacy rate (up to 5 years of education) (%)	40.2	32.7
Housing condition (%)		
Earthen	88.9	92.8
Semi-building	7.1	5.8
Concrete building	4.0	1.2
Access to training facilities (%)	6	57.8
Access to drinking water facilities (tube-well) (%)	70	54
Transportation system	Poor	Poor
Access to medical facilities	Poor	Poor
Access to sanitary toilet facilities	66.6	90.3
Access to electricity facilities	33.9	23.7
Access to solar energy facilities	A few	A few
Women participation in fisheries (%)	21	<2
Mean monthly income (USD*)	54	64

*USD1 = BDT84.45 (Date: 14 April 2020).

Focus group discussions (FGDs)

The FGDs were conducted in two stages: i) scoping study to develop the research objectives and methodology, and ii) main data collection period on various barriers to climate change adaptations which impede fishers' capability to minimise the adverse

impacts of climatic hazards. During the selection of FGD participants, the age, gender and economic-condition were considered to ensure a fair representation of fishers from the community. The household participants, who had gone through central phenomena or were thought to have the ability to express the key concepts, were selected. At least one

FGD was conducted in each fishing community to ensure participation of women-headed households. In total, 6 FGDs (3 in each fishing community) were conducted and each FGD consisted of 7–8 homogenous household heads and continued for about 2.5–3 h. The FGD participants were asked to discuss how barriers confronted their adaptation strategies. The discussion was moderated, where further clarifications were required. More emphasis was given to clarifying unclear issues from semi-structured interviews. Finally, the participants were requested to draw critical linkages among various barriers to find ways to minimise or overcome the barriers.

Key informant interviews (KIIs)

Similar to KIIs, the KIIs were also conducted in two phases. KIIs were conducted to get in-depth information about the barriers to climate change adaptation which hinder fishers adaptation strategy and how they respond to overcome the barriers to minimise the adverse climatic impacts. Individuals within the community (e.g., head of the community) and outside the communities (e.g. upazila fisheries officer, representatives of GOs and NGOs) who have adequate knowledge on the impacts of climatic hazards, fishers adaptation strategies and barriers to climate change adaptation were chosen for KIIs. In total 10 KIIs (5 in each fishing community) were conducted and each lasted between forty minutes and one-and-a-half hours.

Data analysis

After collecting data, qualitative and quantitative data were analysed as follows:

Qualitative data analysis

During the semi-structured interviews, the answers of open-ended questions were handwritten on the question papers. The responses of FGDs and KIIs were audio-recorded with the permission of the participants. Two key informants' responses were handwritten as they refused voice recording. All the audio clips were listened carefully before transcribing into Bengali, which reduced confusions and increased reliability of the data. The results were rechecked with the original transcript to increase further reliability of the data. Qualitative data were analysed in three steps: data processing, data coding based on different objectives, and data representing in the form of tables or graphs.

Quantitative data analysis

The quantitative data for descriptive statistics were coded and analysed using Microsoft Excel (Version 13) and presented in tabular forms and graphs.

Results

Fisheries and ecosystem services in the study areas

More than 90 % of the people of Mathurapur and Datinakhali depend on fishing for their household's income. According to scoping study, 60 % of fishers in Mathurapur go fishing in the rivers inside the Sundarbans for 15 days per month and stay in boats leaving their family behind. About 40 % go fishing in the Malancha River daily and return home. They use small boats which are operated by two persons usually, the husband and wife. In Bangladesh, often only men are involved in direct fishing and women perform post-harvest and ancillary activities of fisheries. However, fishing in these areas is an exception as a large proportion of women are directly involved in fishing on boats. Around 21 % of women catch shrimp fingerlings using push nets near the bank of the Malancha River. Shrimp – *Penaeus monodon* Fabricius, 1798, *P. indicus* H. Milne Edwards, 1837, crab – *Scylla serrata* (Forskål, 1775), sea bass – *Lates calcarifer* Bloch, 1790, mullet – *Liza parsia* (Hamilton, 1822) are commercially important species in the area.

On the other hand, fishers of Datinakhali catch mainly crab (*S. serrata)* along with shrimp (*Penaeus* sp.*)* and finfish. They mainly use hooks and lines to catch the crabs. According to scoping study, 70 % of the fishers go for fishing in the rivers inside the Sundarbans for 15 days per month leaving their family behind and 30 % of them go for fishing daily and return home. Ecosystem services and fisheries dependency of the Mathurapur and Datinakhali fishers on the Sundarbans are given in Table 2 and Table 3, respectively. The Sundarbans are very important to them. According to a participant from Mathurapur,

"Sundarbans gives us food, shelter, security and all other livelihood assets what we need. It protects us from all the natural disasters".

Impacts of climatic hazards

The Sundarbans mangroves dependent fishing communities of Mathurapur and Datinakhali are highly exposed to cyclones, floods, riverbank erosion and salinity intrusions due to their geographical location. Based on semi-structured interviews and FGDs, the percentage of fishers affected by any climatic hazards were shown in Figure 2. The impacts of climatic hazards are described below:

Impacts of cyclones

In Mathurapur and Datinakhali, cyclones are the most devastating climatic hazards which affected the regions with a huge loss and damage to physical assets. According to KIIs, it was reported that the Sundarbans area had experience seven or eight major

Table 2. Available Sundarbans ecosystem services for the fishing communities of Mathurapur and Datinakhali of Bangladesh, recorded during semi-structured interviews and focus group discussions.

Provisioning services	Regulating services	Ecological and environmental services	Supporting services
Fisheries (fish, shrimp and crab) Honey Forest product Medicine Employment	Protecting from cyclones Regulation of climate Protection from floods Protection from riverbank erosion Purification of water and air Recreation and ecotourism	Conservation of biodiversity Nursery and breeding ground of fish and other animals	Supporting habitat Soil formation

Table 3. Livelihoods dependency on the Sundarbans based fisheries for the fishing communities of Mathurapur and Datinakhali of Bangladesh, recorded during semi-structured interviews.

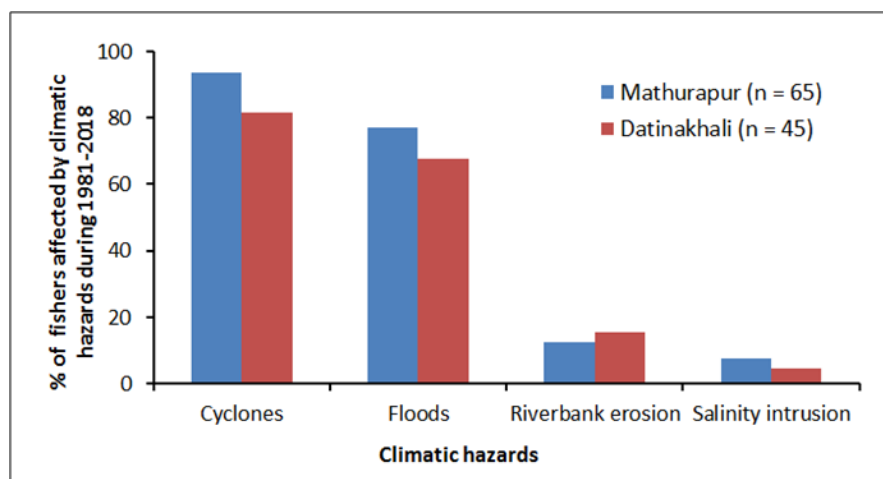| Types of activities	% of fishers in each activity	
	Mathurapur (n = 65)	Datinakhali (n = 45)
Only fishing inside Sundarbans	67.7	42.2
Fishing inside Sundarbans and day laboring outside	26.2	2.2
Fishing and woodcutting inside Sundarbans	4.6	–
Fishing and honey collecting inside Sundarbans	–	46.7
Fishing inside Sundarbans and crab fattening outside	–	6.7
Fish selling outside	1.5	–

Fig. 2. Impacts of climatic hazards on the Sundarbans-based fishers of Mathurapur and Datinakhali of Shyamnagar, Bangladesh, based on *semi*-structured interviews and focus group discussions.

cyclones from 1981–2018. Among these cyclones, the 'Sidr' and 'Aila' were the most serious which occurred in 2007 and 2009, respectively. From semi-structured interviews, it was found that 93.8 % and 81.5 % of the fishers' houses in Mathurapur and Datinakhali were damaged or lost because of cyclones, respectively. Poor household conditions and use of low-quality materials such as mud and thatch for housing are the main cause of vulnerability to cyclones. Besides these, 19.8 % of fishers in Mathurapur had lost their fishing crafts, whereas, 32.4 % of the fishers in Datinakhali had lost their livestock. Fishers in both fishing communities missed their fishing trips because of cyclones. From semi-structured

interviews, it was found that in Mathurapur and Datinakhali, around 75.6 % and 46.7 % of the fishers were physically injured by cyclones, respectively. According to KIIs, five fishers in Mathurapur and three fishers in Datinakhali died during the mighty cyclones Aila.

Impacts of floods

Floods affected fishers' physical assets, fishing activities and overall livelihood outcomes in both fishing communities. This study found that 76.9 % and 67.7 % of fishers in Mathurapur and Datinakhali were affected by floods, respectively. According to semi-

structured interviews and FGDs, this study found that floods damaged fishers' houses and fishing crafts in both fishing communities in several ways. Impacts of floods included temporary or permanent unemployment, displacement from home, increased water-borne diseases like diarrhoea, dysentery and many skin diseases, increased risk of poisonous insects and snakes, and hampered children's education (as fishers of both communities had to took temporary shelter in the primary school during the floods). Fishers reported during semi-structured interviews that they missed fishing trips during flooding for days which resulted in decreased income from fishing.

Impacts of riverbank erosions

In Mathurapur and Datinakhali, 12.3 % and 15.4 % of the fishers were affected by riverbank erosion to some extent, respectively. Many houses in both fishing communities are also currently at the risk of extinction due to riverbank erosion. During FGDs, one of the respondents in Datinakhali said,

"My brother lost his house due to riverbank erosion and he left this village".

In Datinakhali, the dam which was constructed by the government on the bank of Kholpetua River is at the risk of riverbank erosion. If the erosion destroys this dam, the people of this village will become highly vulnerable to floods. The cyclone shelter, which is located near the dam, is also at risk. On the other hand, Mathurapur has better protection against riverbank erosion, but due to the poor housing conditions and low-quality housing materials make them vulnerable to riverbank erosion.

Impacts of salinity intrusions

Salinity intrusion is a common problem in both study areas as 7.7 % and 4.6 % of the fishers of Mathurapur and Datinakhali were affected by salinity intrusion, respectively. Salinity intrusion along with tidal inundation, hampered the soil quality for agricultural activities and destroyed standing crops. According to key informants interviews, fishers who depend on agro-farming partially could not grow home vegetation. As a result, many agricultural lands have been converted to shrimp farming pond or salt pan in Mathurapur and Datinakhali. Due to the transformation of low lying agricultural land into shrimp ponds, salinity intrusion further accelerated. Salinity becomes much higher during dry seasons. Fishers who do not have access to tube-well water, could not use river or pond water for drinking due to increased level of salinity in these sources. As stated by some key informants, salinity in this area has increased dramatically after the cyclone Aila. They further added that brackish water of the mangroves are spawning grounds for some fish species, but

salinity intrusions altered their spawning grounds and ultimately reduced fish diversity.

Barriers to adaptation

Climatic hazards adversely affected fishers' lives and livelihoods in both fishing communities. Fishers' adaptation strategies to minimise the impacts of climatic hazards were confronted with various barriers. In this study, barriers to climate change adaptation are categorized into six groups and they are described below:

Natural barriers

Both the fishing communities (Table 4) were vulnerable to climatic hazards such as cyclones, floods, riverbank erosions and salinity intrusions considered as natural barriers. Continuous climatic hazards are eventually reducing fishers' adaptive capabilities. For example, missing fishing trips in the rivers inside the Sundarbans during cyclones had deteriorated fishers' financial gains which impeded their adaptation strategies. On the onset of cyclones, fishers could not get enough time to go to a safe place when they catch fish inside the Sundarbans. Moreover, poor quality boats and engines slow down their travel. One of the participants in Mathurapur said, 'We cannot stop cyclones, but we can take some precautionary actions to minimise the adverse impacts of any climatic hazards. However, we cannot get enough time to take necessary actions due to the uncertainty of any climatic hazard'. Floods inundated and damaged houses and other infrastructures, and caused many water-borne diseases such as diarrhea and itching. Fishers in both communities suffered severely due to the scarcity of drinking water and livelihood activities as salinity level increased continuously in those areas. Thus, natural barriers impacted on fishers' physical, human and economic capitals negatively which obstructed their adaptation strategies to climate change.

Social barriers

In this study, lack of education and awareness, insecurity at cyclone shelters and fear of pirates in the rivers inside the Sundarbans are considered as social barriers (Table 4). Semi-structured interviews showed that around 59.8 % and 67.3 % of the fishers in Mathurapur and Datinakhali respective were unable to write and read. Due to lack of proper education, fishers are reluctant to take training to involve in diverse livelihood activities to cope with and adapt to the adverse impacts of any climatic hazards.

Because of fishers' lack of awareness, they felt insecure at the cyclone shelters. One key informant in Mathurapur reported that some women household members felt insecure to share the common places with members of other households at the cyclone shelters. In addition, household members also felt

Table 4. Barriers to climate change adaptation in the fishing communities of Mathurapur and Datinakhali of the Sundarbans, Bangladesh, recorded from semi-structured interviews, focus group discussions and key informant interviews.

Groups of barriers	Barriers to adaptation	Fishers' response (%)	
		Mathurapur	Datinakhali
Natural	Increasing frequency and magnitude of the climatic hazards like cyclones and floods	–	–
Social	Lack of privacy for female household members in the cyclone shelters	–	–
	Lack of education	59.8	67.3
	Insecurity for households physical properties when fishers took shelters in the cyclone shelters	–	–
	Insecurity during fishing in the rivers inside the Sundarbans because of pirates	95.7	94.4
Institutional	Poor enforcement of the fisheries regulations and maritime law	86.2	66.7
	Unfavourable fishing bans	100	100
	Lack of research for introducing saline tolerant crops	100	100
Financial	Unfavourable credit systems or dadons*	50	35
	Low income (below mean monthly income; see Table 1)	58.5	40
	High cost for building cemented house or making elevated plinths or high basement	84.6	60
	Commissions for collecting natural resources	100	100
Technological	Inaccurate weather forecast or lack of radio signals	–	–
	Lack of safety equipment on boats	–	–
	Poor quality boats and engines	–	–
Informational	Lack of training on hazards management	94	42
	Lack of training and livelihood alternatives	100	57.8
	Misunderstanding of the weather forecast	–	–

*Dadons is an advance transaction made upon an informal (verbal) lending contract between the fisher and the mahajan (moneylender who gives a loan with high-interest and some unofficial conditions).

insecure to leave their household properties behind because of the fear of losing them. As a result, they are reluctant to take shelters at the cyclone shelters. These attitudes exacerbated the vulnerability of the fishers to any climatic hazards.

Pirates are one of the main social barriers to the fishers' adaptation process in Mathurapur and Datinakhali. In Mathurapur and Datinakhali, 95.7 % and 94.4 % of fishers were affected by pirates at least once, respectively. One of the FGD respondents in Datinakhali mentioned, "The pirates are very cruel. If the victim fishers' family cannot give them ransom, the pirates tortured the victim [fisherman] and sometimes killed and threw them in the river". This social barrier has reinforced because of poor surveillance of the criminal activities and ultimately, it is underpinning economic barriers. Generally, fishers have high risks of being kidnapped by pirates while fishing inside the Sundarbans. Because of these uncertainties and fear of losing their fishing boats and engines to the pirates, they are forced to buy high-grade boats and engines with safety equipment. These insecurities exacerbated the fishers' vulnerabilities to climate change adaptation.

Institutional barriers

Institutional barriers include lack of fisheries rules and regulations, lack of regular maritime surveillances and unfavourable fishing bans (Table 4). Fishers have to obtain licences for their fishing vessels after checks for safety standards. One key informant in Mathurapur reported that some fishers managed to obtain licences illegally without having any safety equipment such as life jackets or global positioning system (GPS). They are more vulnerable to the impacts of climatic hazards comparing the counterparts who have safety equipment. And they cannot travel fast to reach a safe place because of poor quality boats and engines. Lack of enforcement of the fisheries rules and regulations exposed the fishers to the impacts of climate change and limited their adaptation capabilities.

All fishers in Mathurapur and Datinakhali reported that the 2-months fishing bans in the Sundarbans mangroves affected their livelihoods negatively. During the ban periods, they could not enter into the canals, rivers or creeks inside the Sundarbans to catch fish, crabs or any other aquatic animals. One fisher from Mathurapur said, "During the ban periods, we cannot enter into the Sundarbans and as a result,

we cannot catch any fish. As many of us do not have any other job except fishing, so we suffer a lot during this time". This institutional barrier has reinforced fishers' financial barriers and forced them to fish during any unusual weather conditions like cyclones and make them vulnerable to the impacts of climatic hazards.

During KIIs, it was noted that the introduction of saline tolerant crops could help some fishers who are partially dependent on agro-farming in Mathurapur and Datinakhali. Fishers can also grow some saline tolerant vegetation at their home. FGDs participants reported that they were not able to introduce saline tolerant crops themselves without assistance from the government. One key informant in Datinakhali reported that there was not enough research as well as sufficient funds to introduce saline tolerant crops. Consequently, fishers cannot implement this adaptation strategy to cope with climate change.

Financial barriers

The findings indicated that fishers' lack of access to adequate loans or credits, informal loans or "dadons", low income from fishing and commissions for collecting natural resources are considered as financial barriers (Table 4). Due to fishers' lack of, or insufficient resources or collateral, most of the governments and private banks are reluctant to give them loans. From semi-structured interviews, it was found that in Mathurapur and Datinakhali more than 50 % and 65 % of the fishers did not get any loans from the banks, respectively. Those fishers who did not get any loan from the banks are taking informal loans (advanced money) from Mahajan (moneylender). After providing the loan, the Mahajan makes a verbal contract with the fisher to sell the fish to him at a 20 % – 40 % lower price than the market value or he gets a 5 % or 10 % commission (of the sales revenue) when fish is sold to a third person. Thus, "dadons" binds the fishers to the Mahajan in a debt cycle. As a result, fishers who took loans cannot get a fair price for their fish. Fishers' income from fishing also decreased because of poor quality market structure, lack of preservation facilities and poor transportation system. Because of their low income from fishing, they cannot save money after meeting their daily needs. Consequently, they cannot afford to make a cemented house or buy a good quality boat and engine with safety equipment (e.g., life jackets or buoyancy). To repay the loan to the Mahajan, the fishers struggle hard to catch fish even in the adverse weather conditions, which make them more vulnerable to climatic hazards. These opportunity-cost reinforced their financial barriers which constraints the fishers' adaptation strategies to climate change.

The study showed that commission for collecting natural resources from the Sundarbans is identified as a financial barrier. The fishers of Mathurapur and Datinakhali have to register and pay a weekly fee for harvesting of the natural resources (Table 5). As the fees are different for each activity, they cannot change their registered activities unless they pay a weekly fee for the specific activity, i.e. if a fisher registered only for fishing, then he cannot catch crabs or collect honey or leaves of *Nypa fruticans* (locally known as "goal pata"). These commissions hindered the fisher form diversifying their livelihoods and impeded their adaptation to climate change.

Table 5. Commissions for collecting natural resources from the Sundarbans of the fishing communities of Mathurapur and Datinakhali of Shyamnagar, Bangladesh, recorded during semi-structured interviews and focus group discussions.

Pass category	Registration fees (USD*)	Fees per week (USD*)	Catch limit
Only fishing	5.9	4.1	30 kg
Catching crab	4.7	3.6	30 kg
Collecting honey	11.8	5.9	Not Applicable
Collecting leaves	4.7	Varies depending on weight	Not Applicable

*USD1 = BDT84.45 (Date: 14 April 2020).

Technological barriers

The technological barriers included inaccurate weather forecast or lack of radio signals, lack of GPS and mobile apps, poor quality boats and engines, and lack of safety equipment (Table 4). During semi-structured interviews, most of the fishers in Mathurapur and Datinakhali reported that they did not get any weather forecast because of the absence of radio signal or mobile apps while they were fishing in the rivers inside the Sundarbans. Sometimes, they received the weather forecast before going fishing inside the Sundarbans, but they underestimated or ignored the forecast in some cases because of the earlier inaccurate weather forecast. In some cases, technological difficulties created shortcomings or delay of the forecast transmission. During FGDs, few fishers reported that sometimes they received the forecast at the eleventh hour when they could not get enough time to return to a safe place. All of these circumstances make them vulnerable to the impacts of any climatic hazard.

Non-mechanised fishing boats and poor quality engines are also an important technological barrier against fishers' safe return. In addition, lack of safety equipment (e.g., life jackets, buoyancy, floats, plastic drums) exacerbated the fishers' vulnerability to any climatic hazards during fishing. These technological

barriers reinforce institutional barriers like lack of strict monitoring and surveillance (see section Institutional barriers). Thus, non-mechanised boats, poor quality engines and lack of safety equipment constraint fishers' adaptation strategies to climate change.

Informational barriers

The study revealed that lack of training on climatic hazards management and livelihood diversifications are considered as informational barriers (Table 4). In Mathurapur and Datinakhali, 94 % and 42 % of the fishers did not have any training on climatic hazards management. As a result, sometimes, they do not understand what to do during any climatic hazards. Most of the fishers in Mathurapur had no practical training on alternative activities to diversify their livelihoods to adapt to climate change. However, most of their Datinakhali counterparts (57.8 % of the fishers) had training on alternative livelihood opportunities like crab fattening, honey collection, pickles making and sewing. As a result, the fishers of Mathurapur are confronted comparatively more by informational barriers than their Datinakhali counterparts to adapt to climate change.

Linkages among different barriers

This study showed some linkages among different barriers which are inter-linked or overlapped with each other and confronted the adaptation strategies to climate change (Fig. 3). For example, inaccurate weather forecast or lack of radio signal (technological barriers) increases the chance of misunderstanding or underestimation of the weather forecast warning (informational barriers). Poor quality boats and

engines hindered faster travel during the onset of any climatic hazards like cyclones. In addition, the lack of safety equipment also exacerbated the risk of climatic impacts and confronted fishers' adaptation strategies. Technological barriers have been reinforced by financial and institutional barriers because of inadequate funding for technological development in the fisheries sector and lack of implementation of fisheries rules and regulations. Therefore, there is a close link between technological, financial and institutional barriers which collectively confronted fishers' adaptation to climate change.

Discussion

In this study, the barriers to fishers' adaptation strategies to climate change were identified and categorised into six groups, including natural, social, institutional, financial, technological and informational barriers. Natural barriers are difficult to overcome, whereas other barriers might be overcome through proper management and policy development. Natural barriers such as increasing frequencies and magnitudes of the climatic hazards such as cyclones and floods posed a great threat to the fishing communities and exacerbated their vulnerability to climate change impacts. Natural barriers, along with low income from fishing, low-grade fishing boats and engines, lack of safety equipment, obstructed their adaptation to climate change. These findings agree with Jones and Boyd (2011) and Islam et al. (2014a), who reported that natural barriers constraint adaptation strategies to overcome the impacts of climate change. Natural barriers also vary from ecosystem thresholds to topographical limitations (Jones and Boyd, 2011) which might alter the physical environment severely and dwindle adaptation
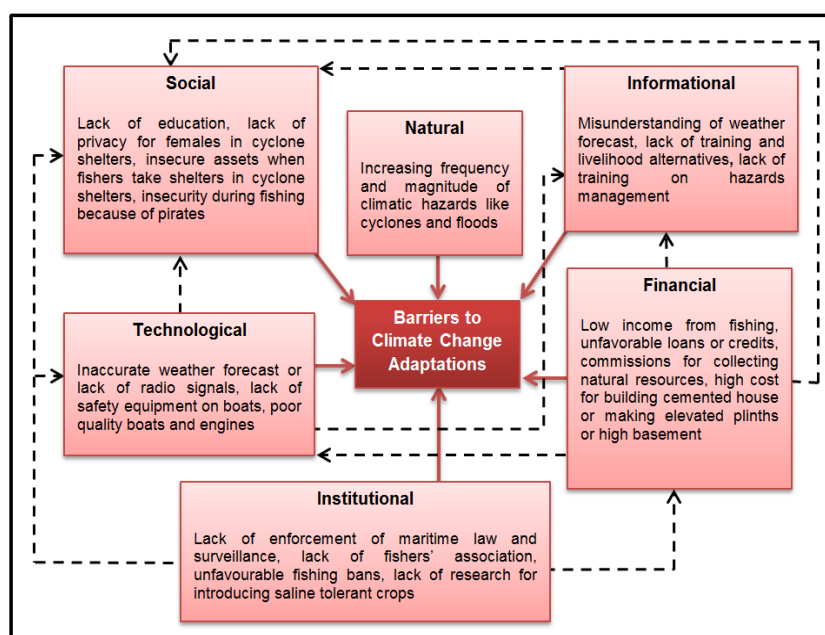

Fig. 3. Linkages among different barriers confronting Sundarbans based fisheries dependent communities' adaptation strategies to climate change. Solid arrows indicate the direct barriers and dotted arrows showing the interrelations among different barriers.

opportunities (Nicholls and Tol, 2006). Because of uncertainty and poor understanding of the impacts of climatic hazards, strategies are not successful in overcoming the natural barriers to climate change.

Lack of awareness, societal beliefs and poor understanding of the impacts of climate change are important social barriers to adapt to climate change. It employs a range of cognitive approaches which engendered from individuals and communities level. In this context, an appreciation of the local perspective within which climate adaptation takes place is critical. Earlier studies have highlighted that the barriers imposed by socio-cultural constraints in several communities on adaptation actions (Adger et al., 2009). For example, societal norms and values could act as the main social barrier to successful climate adaptation (Jones and Boyd, 2011).

Financial barriers like low income from fishing, lack of credits and collaterals restricted fishers to take measures for proper adaptations to minimise the adverse impacts of climate change. Due to lack of financial resources, they cannot do much for proper adaptation strategies like buying high-grade boats and engines along with safety equipment. Islam et al. (2014a) also reported that low income from fishing is considered as an economic barrier for the fishers of coastal Bangladesh. In general, lack of training or skill development, prevent the fishers from diversifying their livelihoods to adapt to climate change. Consequently, their livelihood diversifications are also constraint by their lack of investment for alternative jobs which exacerbated their vulnerability to climate change impacts.

Overcoming the technological barriers are challenging for climate change adaptation because the success of any technology to adapt to climate change depends on the trained human capital (Kithiia, 2011). Technological barriers to adaptation include lack of safety equipment, tools and techniques. Islam et al. (2014a) also reported that technological barriers are reinforced by economical and institutional barriers which might hinder climate change adaptation. Though several adaptations might be possible to implement technologically, they are confronted with financial and socio-cultural barriers (Adger et al., 2009). Technological barriers might also produce inaccurate weather forecast because of imprecise modelling of the climatic data. These inaccuracies of weather forecast or informational barriers obstructed adaptation processes to climate change (Boyd et al., 2013).

In this study, it was found that climate change adaptations constrained by fragmentation among different management groups or organisations. Fragmentation refers to a lack of integration or coordination among institutions, individuals, and policies, at different levels and scales. For example, fisheries of the Sundarbans are managed by the Department of Forest rather than the Department of Fisheries (DoF, 2019). As a result, fishing bans and commissions for collecting natural resources from the Sundarbans affected fishers' financial yields negatively, which obstructed their adaptation strategies to climate change indirectly. Few studies also reported that lack of integration (e.g., land ownership and land-use conflicts) constraints climate change adaptation (Chong, 2014; Lukasiewicz et al., 2016). To overcome these barriers to climate change adaptation, intra- and inter-sectoral collaborations and integrations need to be developed.

Way Forward: Overcoming the Barriers

In the present study, barriers to climate change adaptation in the Sundarbans mangroves-based fisheries dependent communities of Bangladesh were identified. These barriers are interlinked with one another either directly or indirectly. These barriers might be overcome via multi-sectoral measures from individuals to policy levels. At the individual levels, fishers have to appraise climate change information, awareness-raising and skill development. At the policy levels, the government should develop climatic hazards management specific actions like early warning systems and strict monitoring of fishing safety equipment. Some of the specific recommendations to overcome the barriers to climate change adaptation are outlined below.

a) Mitigation of climate change: As it is difficult to overcome natural barriers, so need to take action to mitigate climate change (e.g., reducing global emission of greenhouse gases).

b) Proper education and awareness-raising: Fishers need to be educated and made aware of pre- and post-hazards management approaches to minimise the adverse impacts of climate change. In addition, climatic hazards management training also need to be introduced and implemented for the local communities. Effective information sharing on climate change is essential for adaptation by communities as it helps to increase understanding and awareness.

c) Enforcement of fisheries rules and regulations: This study showed that some fishers used poor quality boats and engines without having any safety equipment on their boats because of poor monitoring and weak enforcement of fisheries rules and regulations. These activities exacerbated their vulnerability to the impacts of climate change. Thus, proper enforcement of fisheries rules and regulations is important to monitor licences, quality of boats and engines, safety equipment. At the same time, maritime surveillance should be increased to stop criminal activities like piracy.

d) Reconsider fishing ban in the Sundarbans: The 2-months ban imposed by the government on fishing in the Sundarbans prevents all kinds of fishing activities. This ban affects the fishers' livelihood negatively as the majority of them have no alternative livelihood options. It is suggested that fishing bans should be restricted to different parts of the Sundarbans or to consider minimising the duration of the fishing bans. Another solution would be to implement alternative income-generating activities along with skill development for the fishers to diversify their livelihoods.

e) Favourable credit systems: This study showed that unfavourable credits or "dadons" impeded fishers' financial conditions which confronted their adaptation strategies. Banks should provide loans with a minimum interest rate, or the government should assist after any climatic hazards.

f) Reduction of fees for collecting natural resources from the Sundarbans: The weekly fee imposed for collecting natural resources from the Sundarbans is considered to be high since the fee is imposed separately for each activity like fishing, catching crabs and collecting leaves. Reduced fees should be considered after discussions with the local communities, fisheries and the forest department.

g) Technological development: Since the fishers could not get an instant up-to-date warning of climatic hazard because of inaccurate weather forecast or lack of radio signals, the cost of technical instruments and sophisticated instruments (e.g., GPS and mobile apps) should be reduced. Similarly, price of quality boats and engines along with safety equipment like life jackets could be subsidised by the government.

Conclusion

Bangladesh is currently a lower-middle-income country and aims to become a middle-income country by 2021 and a high-income country by 2041. In the current transitional period, both economic development and sustainable livelihood of the Sundarbans mangrove-based fisheries dependent people needs to be improved. The results of the present study might be taken into consideration to help formulate policies to overcome the barriers mentioned that impede climate change adaptation. Policymakers need to develop a holistic and coordinated approach in dealing with these barriers. For instance, the government is encouraged to develop state-of-art technology for early warning systems of any climatic hazards like cyclones to aid fishers' in planning their fishing operations. The government should also be encouraged the incorporation of cost-effective, sustainable

strategies in the policy to overcome the barriers to climate change adaptation.

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