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Limits and barriers to adaptation to climate variability and change in Bangladeshi coastal fishing communities

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ABSTRACT

Limits and barriers to adaptation restrict people's ability to address the negative impacts of climate change or manage risks in a way that maximises their wellbeing. There is a lack of evidence of this on small-scale fishing communities in developing countries. This study identifies and characterises limits and barriers to adaptation of fishing activities to cyclones and examines interactions between them in two fishing communities in Bangladesh, using household questionnaires, oral history interviews, vulnerability matrices and focus group discussions. The limits include physical characteristics of climate and sea like higher frequency and duration of cyclones, and hidden sandbars. Barriers include technologically poor boats, inaccurate weather forecast, poor radio signal, lack of access to credit, low incomes, underestimation of cyclone occurrence, coercion of fishermen by the boat owners and captains, lack of education, skills and livelihood alternatives, unfavourable credit schemes, lack of enforcement of fishing regulations and maritime laws, and lack of access to fish markets. These local and wider scale factors interact in complex ways and constrain completion of fishing trips, coping with cyclones at sea, safe return of boats from sea, timely responses to cyclones and livelihood diversification. The findings indicate a need for further detailed research into the determinants and implications of such limits and barriers, in order to move towards an improved characterisation of adaptation and to identify most suitable means to overcome the limits and barriers.

1. Introduction

Adaptation is inevitable to address the impacts of climate variability and change but adaptation efforts are impeded in many ways. Limits and barriers to adaptation restrict people's ability to identify, assess and manage risks in a way that maximises their wellbeing [1–4]. Limits are obstacles that are in some sense absolute [5], while barriers are mutable [6]. Limits and barriers to adaptation arise due to certain characteristics of the people involved, the nature of the specific systems involved and/or the larger context within which the people and systems operate [4]. Barriers to adaptation can prevent the development and implementation of adaptations from taking place [5]. Due to presence of barriers high adaptive capacity does not necessarily translate into successful adaptation [7].

Small-scale fisheries that support livelihoods of more than 90% of capture fisherfolk and produce about 50% of global seafood catches [8] are impacted by climate variability and change. These impacts include not only those on fish populations [9–11] but also on the livelihoods of the dependent communities [12–17]. To minimise these impacts and take advantage of opportunities they need to adapt successfully. Morgan [18] suggests that due to the high vulnerability of fisherfolk and a heavy reliance on specific fisheries for income, fishing communities may face considerable limits and barriers to adaptation to climate change. Many of these limits and barriers are interrelated and combine to constrain adaptation [5,19]. But there is a lack of evidence on limits and barriers to adaptation and interactions between them. The objective of this study is to identify and characterise the limits and barriers to adaptation of fishing activities to cyclones and examine interactions between them, gaining insights from two coastal small-scale fishing communities in Bangladesh.

In what follows, Section 2 reviews the existing literature on limits and barriers to climate related adaptation. Section 3 describes case studies and methodology. Section 4 identifies and characterises the limits and barriers to adaptation as well as examines their interactions. Section 5 situates findings into other

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literature and discusses the theoretical contribution. Section 6 concludes by highlighting the main findings and practical implications.

2. Limits and barriers to adaptation to climate variability and change

Adaptation is the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" [1, p. 869]. In many cases local adaptation measures are reactive and short-term (coping strategies) [20] which can limit the scope for adaptation in the longer term [2]. In this study both short- and long-term responses are regarded as adaptation. Limits and barriers to local adaptation measures can emerge at multiple spatial and temporal scales [21].

Some distinguish limits and barriers to adaptation, while others use the terms interchangeably. This study considers limits as "the conditions or factors that render adaptation ineffective as a response to climate change and are largely insurmountable" [5, p. 733]. These limits are faced when thresholds or tipping points associated with social and/or natural systems are exceeded [2]. On the other hand, "barriers are the conditions or factors that render adaptation difficult as a response to climate change" [22, p. 142] but they are often mutable [6] or can be "overcome with concerted effort, creative management, change of thinking, prioritisation, and related shifts in resources, land uses, institutions, etc." [4, p. 22027].

Limits and barriers to adaptation can be natural, technological, economic, social or formal institutional. Natural limits range from ecosystem thresholds to geographical and geological limitations [19]. Dramatic climate change may alter physical environment so as to limit adaptation possibilities [23]. The limits of adaptation will also depend on the inherent sensitivity of some ecosystems, habitats and species [5]. The impacts of climate change can surpass critical thresholds [5] and cause ecosystem regime shifts [24], which in turn can limit economic and social adaptation [25] especially of communities those directly depend on ecosystems such as fisheries and agriculture [5].

Technological barriers (sometimes classified as limits if unaffordable) to adaptation include lack of hard engineering structures, e.g., [26] but lack of smaller equipment, tools and techniques may also constrain adaptation. Although some adaptations may be technologically possible, they may be constrained by economic and cultural barriers [5]. Technological barriers may also lead to inaccurate information due to, for example, limitations in modelling the climate system or lack of accurate weather forecasts. Insufficient information and knowledge on the impacts of climate change may continue to hinder adaptation particularly in Asia [27].

Economic barriers constrain adaptation of low-income households and communities [5]. Mahon [28] contended that cost of vessel insurance, gear replacement, repairs, operation, safety measures and increased investment were all barriers to adaptation among fishing communities. In agricultural communities, lack of financial capital is one barrier to adaptation, such as adoption of improved crop varieties and diversification of livelihoods [29]. In recent years microfinance has emerged in many developing countries but it does not often reach the poorest and most vulnerable groups [30,31]. Budget constraints can also pose a barrier when adaptation measures involve high upfront cost. Those with limited financial capital will focus on short-term gain rather than on the potential long-term benefits of reduced vulnerability [32,33].

Some studies have pointed out the significance of social barriers to adaptation [6,14,19,34]. Adger et al. [6] suggest that ethics (how and what people value), knowledge (how and what people know), risk (how and what people perceive) and culture (how and what people live) are key aspects of social barriers. Thus social barriers are concerned with the social and cultural processes of society [19] including informal institutions and human capital. People perceive, interpret, and think about risks and adaptation to them depending on their worldviews, values and beliefs [4,5]. People frequently underestimate the possibility of the occurrence of climate events even if they are aware of the risks [35]. Some empirical studies have shown that individuals may not seek information on these possibilities of the occurrence of climate events before making their decisions [36–38].

Formal institutional barriers may constrain adaptation because they define the processes and rules that govern and regulate access and entitlement to livelihood assets. The ways in which actors are able to access assets play a role in determining their vulnerability and ability to cope with and adapt to stress [39]. Institutions can restrict the choice of livelihood strategies for some people; on the other hand they can open up opportunities for others [40] and favour some groups over others [41]. Institutional barriers have limited the ability of the rural communities to cope with extreme climate events by limiting access to markets and in terms of unfavourable development policies [42,43].

The discussion above indicates that a range of limits and barriers may influence adaptation to climate variability and change by stopping, delaying or diverting the adaptation process [4]. Empirical studies on limits and barriers to adaptation to climate change have been published in biological, agronomic, economic, sociological, psychological, and urban planning literature. These studies often focussed on a single limit or barrier; hence how they interact has not been properly investigated. A number of studies have developed theoretical frameworks for limits and barriers, e.g., [4, 6]. More empirical studies are needed to aid adaptation decision-making. As Moser and Ekstrom [4, p. 22029] suggest "more systematic empirical research must be undertaken to verify our observations". Most of the studies published to date focus on agricultural communities, e.g., [19, 44]. The studies on fisheries and climate change have largely focussed on physical climate impacts on oceanic productivity and fish production, e.g., [9–11], and macro scale impacts on economies and society, e.g, [45,46]. A limited number of recent studies have focussed on impacts, vulnerability and adaptation to climate variability and change in fishing communities and on their livelihoods, e.g., [13–15], but none has examined limits and barriers at the local scale in developing countries. This study seeks to fill the gap by identifying and characterising limits and barriers to adaptation of fishing activities to cyclones and examining interactions between them in two small-scale fishing communities in Bangladesh. This study focusses only on fishing related limits and barriers because fishing is one of the main livelihood activities in the two communities [15]. This research focusses on both minor and major cyclones as these are the main climate shocks affecting fishing activities.

3. Case study, materials and methods

This article examines coastal small-scale fisheries of Bangladesh, a country with low incomes, poor infrastructure and high dependence on natural resources for livelihoods [47]. Bangladesh and its fisheries sector are victims of global climate variability and change [1,45,48]. The coastal small-scale fisheries support the livelihoods of half a million fisherfolk and their household members [49]. These fisherfolk catch 93% of the total marine catch of Bangladesh [49].

Most fishery-dependent people live in the coastal low-lying areas which are highly exposed to climate change impacts [50]. 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 [15]. There have been more cyclones in the Bay of Bengal

between 1985 and 2009 [51] and they will be more common in future due to climate change [51,52]. Ahmed and Neelormi [53] observed a reduction of fishing days in Bangladesh due to minor cyclones and greater fluctuation in fish production may occur due to climate change [54,55]. Taken together, these effects may further increase livelihood vulnerability in Bangladeshi coastal fishing communities without adaptation.

3.1. Study sites

This study has assessed limits and barriers to adaptation in the fishing activities in Padma, Barguna District, and in Kutubdia Para, Cox's Bazar District in southern coastal Bangladesh (Fig. 1). Padma's physical infrastructure is poor with dirt roads and houses. It is 8 km away from Patharghata local municipality. Households have inadequate access to cyclone shelters, health facilities and education, and no access to electricity and clean drinking water. Kutubdia Para's physical infrastructure is slightly better than that of Padma. It is 6 km away from Cox's Bazar tourist town. Half of its roads are made of brick and the other half of dirt. The quality of houses and access to health facilities and education are similar to Padma. Households have better access to cyclone shelters, electricity and clean drinking water.

Livelihood characteristics of fishing-dependent households vary between the two communities (Table 1). Most households in the two communities directly depend on fisheries; small-scale

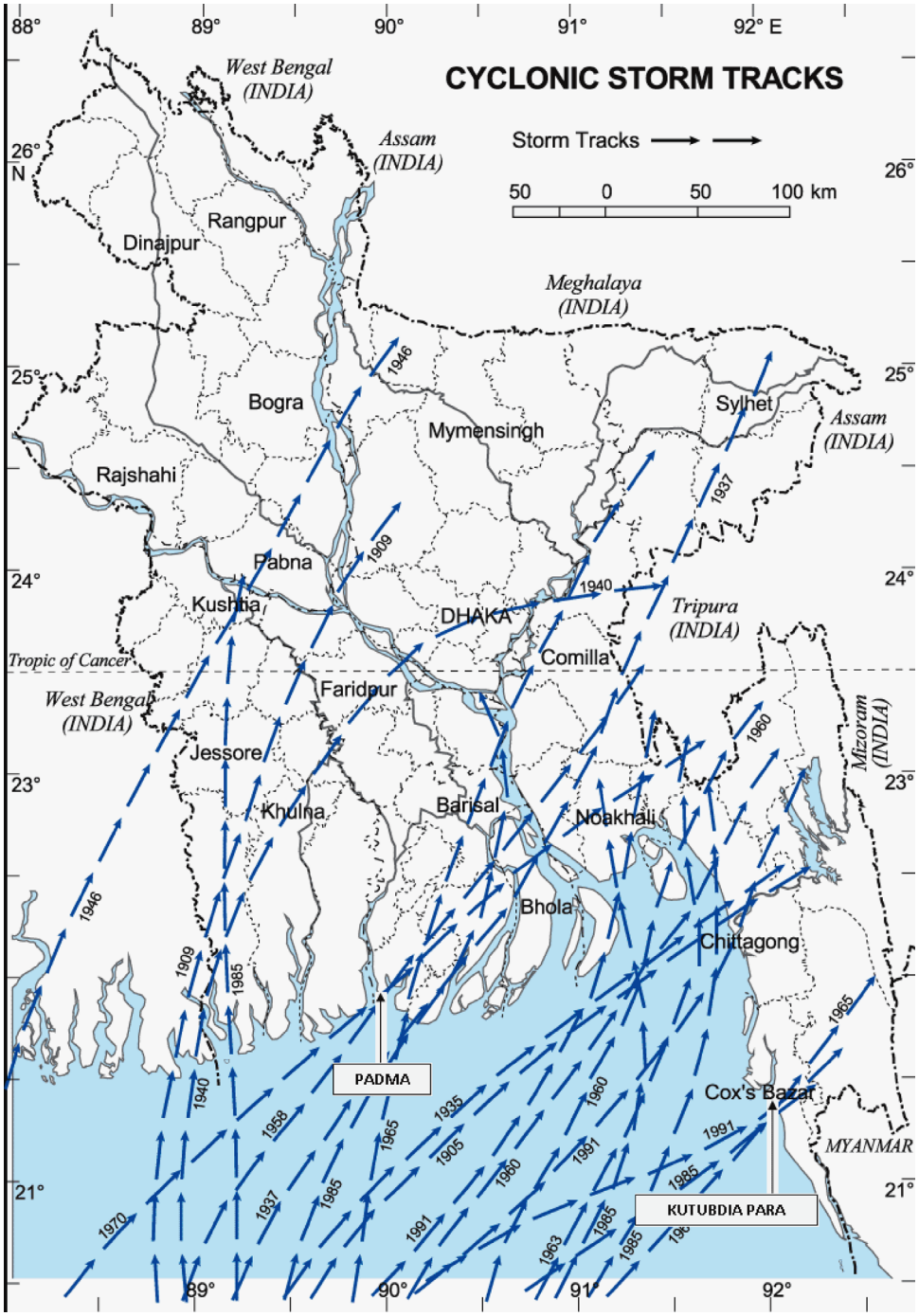

Fig. 1. Bangladesh study site locations and cyclone tracts modified from [56].

Table 1
Livelihood characteristics of fishing-dependent households (source: structured household questionnaires—see Section 3.2).

Characteristics	*Padma*		*Kutubdia Para*	
	Mean	*Standard deviation*	*Mean*	*Standard deviation*
Household size	4.64	1.26	5.85	1.78
Age of household head (years)	36.80	10.08	37.15	8.23
Experience in fishing (years)	14.64	9.37	18.29	8.75
Highest level of education (years)	6.81	2.08	5.50	2.22
Income from fishing (%)	89.34	18.01	94.80	12.63
Per capita income (TK/year) (as of July 2011, 1 US$=75.63 TK)	20,873	29,460	20,885	13,657
Time involvement in fishing (days/year)	199.21	39.74	227.06	23.55

Table 2
Characteristics of fishing activities and their exposure to cyclones (source: structured household questionnaires and qualitative data—see Section 3.2).

Characteristics	*Padma*	*Kutubdia Para*
Fishing areas	Bangladeshi coastal waters in the northwest Bay of Bengal	Bangladeshi coastal waters in the northeast and northwest Bay of Bengal
Fishing season	July–October; one third also operates December–April	December–June; one-third also operates July–October
Type of boat	15–50 feet wooden boats with 20–60 HP engines	15–65 feet wooden boats with 40–110 HP engines
Number of fishermen work per boat	3–18	3–30
Duration of a fishing operation	6 h–15 days	6 h–15 days
Distance of fishing area from mainland (km)	2–30	2–35
Cost for making a boat with engine (TK)	100,000–1,650,000	100,000–2,500,000
Primary species of fish harvested	Hilsa shad (*Tenualosa ilisha*), croaker (*Johnius* spp), goby (*Taenioides cirratus*), skates andrays	Bombay duck (*Harpadon nehereus*), ribbon fish (*Lepturacanthus savala*), Gangetichairfin anchovy (*Setipinna phasa*), Indian river shad (*Gudusia chapra*) and hilsa shad
Exposure to cyclones over the past 3 decades	Super cyclonic storms in 2005 and 2007 (*Sidr*); 5–7 minor cyclones each year	Super cyclonic storms in 1991 (*Gorki*) and 1997; 5–7 minor cyclones each year

fishing in the Bay of Bengal is one of their main livelihood activities. Table 2 reports the main characteristics of fishing activities and their exposure to cyclones. Three types of actors are involved in fishing – boat owners (investors), boat captains and fishermen (boat crews). A boat owner provides a boat and materials, and appoints a captain who is in turn responsible for running fishing trips and appointing crews.

In both communities, boats usually have diesel engines and radios. Offshore boats do not receive radio signal. Kutubdia Para's boats are better than those in Padma: they are bigger in size, have more powerful engines and are made more robustly. In addition, some of them are equipped with life jackets and navigation instruments, which are mostly absent on Padma's boats. At the end of fishing trips, the fish (all of Padma and half of Kutubdia Para) are sold at auction markets controlled by the commissioning agents.

In both communities, their fishing activities have been exposed both to major and minor cyclones over the past 30 years (Table 2). Super cyclonic storms have caused major destruction. During *Sidr* 90% of boats and gear were destroyed or severely damaged in Padma and 125 fishery-dependent people died. During *Gorki* 9 such people died in Kutubdia Para but no one died in 1997. Each year 5–7 minor cyclones affect fishing in the two communities by creating the abandonment of fishing trips, and sometimes damaging boats or killing fishermen.

3.2. Data collection and analysis

Amongst all fishery-dependent households, 89% and 34% are involved in fishing activities in Padma and Kutubdia Para, respectively. The heads of these households are boat owners, boat captains or fishermen from whom data were collected. Ninety-nine per cent of these household heads are male.

A multi-method approach that combines both qualitative and quantitative methods was used to collect data during October 2010 and between February and July 2011. Structured household questionnaires (89 in Padma and 34 in Kutubdia Para) were used to collect quantitative and qualitative livelihood data from randomly selected participants. Oral history interviews (20 in Padma and 10 in Kutubdia Para) were also employed to gather rich, detailed and contextually grounded qualitative data on adaptation to climate variability and change, and limits and barriers to such adaptation across the two communities. For this purpose the cooperative and enthusiastic heads representing different fishing actor groups were interviewed. To triangulate the above data vulnerability matrices (5 in Padma and 4 in Kutubdia Para) and focus group discussions (FGDs) (5 in Padma and 4 in Kutubdia Para) were also used. For each vulnerability matrix or FGD a relatively homogenous group was formed from the fishery-dependent households based on their livelihood portfolios, which aimed to sample representatively across each community. Within a group 6–8 cooperative and enthusiastic household heads were selected.

Quantitative data were analysed using descriptive statistics. Qualitative data were transcribed in original language (Bengali) and analysed using coding techniques, cf. [57] before translation.

4. Limits and barriers to adaptation of fishing activities to cyclones

Cyclones are identified in both communities as the main climatic shocks impacting on fishing activities. To cope with and adapt to them people use many strategies that are constrained by a

Table 3
Limits and barriers to adaptation of fishing activities to cyclones in Padma and Kutubdia Para.

Form of limit and barrier	Observed by Padma's respondents	Observed by Kutubdia Para's respondents
Natural	Higher frequency and duration of cyclones, and hidden sandbars	Higher frequency and duration of cyclones, and hidden sandbars
Technological	Absence of radio signal offshore, inaccurate cyclone forecast, lack of safety equipment and navigational instruments, and poor quality boats and engines	Absence of radio signal offshore, inaccurate cyclone forecast, and lack of safety equipment and navigational instruments
Economic	Low incomes and lack of access to credit	Low incomes and lack of access to credit
Social	Lack of education, skills and livelihood alternatives, underestimation of cyclone occurrence, and coercion of fishermen by the boat owners and captains	Lack of education, skills and livelihood alternatives, and underestimation of cyclone occurrence
Formal Institutional	Unfavourable credit schemes, lack of enforcement of fishing regulations and criminal laws, and lack of access to fish markets	Unfavourable credit schemes, lack of enforcement of fishing regulations and criminal laws, and lack of access to fish markets

number of limits and barriers (Table 3). In what follows, how adaptation strategies are constrained by limits and barriers as well as interactions between them are discussed.

4.1. Natural limits

The Bay of Bengal is a major cyclone prone area in the world [58]. The participants have found that the rate and duration of cyclones have increased over the past 20–30 years. They consider that super cyclonic storms such as *Sidr* and *Gorki* prevent completion of fishing trips by destroying fishing assets, killing fishermen, and complicating coping mechanisms at sea and safe return of boats from sea. The participants also consider that minor cyclones also constrain fishing activities but to a lesser extent. When explaining the difficulty in responding to these cyclones, a participant from Padma said in his oral history interview that *"the cyclones resulted in rough seas with stronger winds and bigger waves. The waves lifted our boat several feet and damaged it"*.

Two-thirds of the boat captains in both communities consider that when attempting to retreat to safe places they are also constrained by hidden sandbars in near shore areas. One boat captain from Padma said in his oral history interview that *"during cyclonic weather I could not locate the sandbar as the sea became turbid…my boat stuck into the bar and was damaged by the waves"*.

4.2. Technological barriers

Some technological barriers are similar in the two communities while others differ between them (Table 3). One-third of boat captains in both communities, who catch fish offshore, cannot receive the weather forecast because of absence of radio signal. Their chance of being exposed to cyclones therefore increases and they are not able to return safely to shore in time. Two-thirds of those who catch fish onshore do get radio signal but in most circumstances they cannot return safely in time due to shortcomings in the forecasting of cyclones. Oral history interviewees indicate that sometimes there are cyclones in the sea although no forecast is broadcast on the radio. Sometimes when forecasts are broadcast, no cyclone actually occurs. Finally, sometimes forecast comes too late to enable safe return. One oral history interviewee from Kutubdia Para stated that *"we heard the forecast too late both in 1991 and 1997. In both cases we experienced huge loss"*. Hence, inaccurate weather forecast can increase exposure to cyclones.

Oral history interviews highlight that in both communities when captains feel that a cyclone is going to occur, they abandon the fishing trip and try to return to shore. But Padma's boats struggle more to return as well as to stay in the sea at the onset of or during cyclones. A few hours are not enough to return to shore with less powerful engines and without navigational instruments. Their weaker boats are damaged more easily and pose threats to fishing assets and the life of fishermen. Sometimes boats capsize and as 97% of them do not have proper safety equipment (e.g., life jackets), risks to fishermen's life increase. They rely on inadequate measures such as tying net floats together or using plastic drums or bamboo as floats. One fisherman from Padma recalled in his oral history interview that *"…there was no life jacket on the boat and we struggled to drift using floats or plastic drums when a cyclone hit"*.

4.3. Economic barriers

Economic barriers are more pertinent in Padma than in Kutubdia Para (Table 3). In both communities fishermen consider fishing as risky activities due to cyclones and most of them do not want to continue to fish. However a number of barriers prevent them diverting from fishing. During oral history interviews they have identified that low incomes and lack of access to credit to invest in alternative livelihood activities are two key barriers. Per capita household income is only around 21,000 TK/year in the two communities (Table 1). To express the level of income, access to credit and desire to divert away from fishing, an oral history interviewee (fisherman) from Padma said *"I am poor and do not have sufficient access to credit… fishing in the sea is risky. If I had money I would do business inland as there is no risk on life there"*.

Padma's boat owners have limited access to formal credit. Household questionnaires indicate that formal sources of credit (banks and NGOs micro-credit) provide only 8% of the credit needed in fishing businesses and charge an interest rate of between 16 and 35% per year. Due to lack of access to formal credit with low interest, the boat owners invest their own savings (provide 12% of total credit) and take informal credit with high interest rates to run their businesses. Local informal money lenders provide 18% of the credit but charge 100% interest per year. *Dadondars* (another type of informal money lender) provide 62% of the credit but charge 2% on fish revenue equating to an interest rate of between 120 and 240% per year, indirectly. Oral history interviewees from Padma emphasise that they need to catch substantial amounts of fish during the fishing season to repay the credit and interest and to gain some profit. Catching substantial amounts of fish requires completing most of the fishing trips even in cyclonic conditions, which increases exposure to cyclones and the chance of loss of boats, gear and life. To minimise the loss of boats and gear, the boat owners in Padma minimise capital investment. Most fishermen said in oral history interviews that boat owners use cheaper and less durable materials to make boats, cheaper and less powerful engines, and do not

provide life jackets or modern equipment. This strategy can be treated as maladaptation as it reinforces technological barriers and increases risks for the fishermen.

In contrast Kutubdia Para's boat owners have better access to formal credit. Household questionnaires suggest that boat owners in Kutubdia Para obtain credit for running fishing businesses from the same sources as Padma. However, in Kutubdia Para, formal, own savings and informal sources provide 42%, 18% and 40% of total credit, respectively. This means that the boat owners do not need to rely mainly on informal credit with higher rates of interest but have better access to formal credit with much lower interest rates. Abandonment of few fishing trips due to cyclonic weather does not create a problem for them to repay the credit and interest, and to gain some profit. This is one of the reasons why the boat-owners in Kutubdia Para do not induce fishermen catching fish in cyclonic conditions and do not reduce capital investment.

4.4. Social barriers

Social barriers are also more pertinent in Padma than in Kutubdia Para (Table 3). Diverting away from fishing activities is constrained, in both communities, by lack of education and skills for alternative livelihoods, and limited availability of alternative livelihood activities. Due to low levels of education (Table 1) people struggle to obtain jobs. Most people have only fishing skills learned from their forefathers. As explained by an oral history interviewee from Padma *"I am illiterate and not qualified to get a job; I do not have any other skills* [*than fishing*] *to change my profession"*. This lack of education and skills is, according to all interviewees, due to low incomes and lack of access to formal credit. Current non-fishery based activities (such as daily labouring) employ people on a part-time basis and are less well paid than fishing, making them less economically viable options.

Inaccurate cyclone forecasts have led to an underestimation of occurrence of cyclones in both communities. Oral history interviews suggest that despite cyclone forecast boat captains frequently think that no cyclones will occur and are reluctant to return at the onset of cyclones. This underestimation increases exposure of boats and fishermen to cyclones and prevents timely response to cyclones when they occur.

Thirty per cent of the fishermen in Padma claim that their boat captains and owners coerce them to catch fish in minor cyclones. Cyclones of scale 3 or above are considered dangerous by the Government of Bangladesh [59]. These fishermen are often forced to continue fishing up to scale 5 cyclones. This strategy generates positive economic outcomes for boat owners and captains (captains who can lead to catch more fish are more paid) but risks the safety of fishermen. The fishermen cannot resist because of fear of punishment by the boat owners' trade union (cooperative society). Thus coercion poses a barrier to adaptation. As one of the boat owners from Padma said: *"…they* [*fishermen*] *must obey the guidelines imposed by us* [*boat owners*]. *If they do not, they are punished by our trade union"*. The punishment can include exclusion from fishing in the following fishing season and a fine. The boat owners' trade union in Kutubdia Para differs. Whilst fishermen are persuaded to maximise catch they are not punished if the catch is reduced by cyclones.

4.5. Formal institutional barriers

In both communities, the unfavourable credit schemes reinforce economic barriers. The oral history and FGD participants reported that obtaining formal bank credit requires assets as collateral, education, knowledge of the credit system and good relationships with credit providers. Almost all fishermen in both communities, most of the boat owners in Padma, and half of the boat owners in Kutubdia Para do not have the prerequisites for obtaining credit. The participants find that obtaining microcredit does not require similar prerequisites but that it poses limitations: low amounts of credit (10,000–30,000 TK), rigid and frequent (weekly) repayments, and de facto resources for collateral (micro-credit does not formally require collateral but credit providers still need to be confident that there will be no interruption in interest payment).

All the participants reported that piracy occurs in some of the fishing areas because of lack of enforcement of maritime laws. Padma's participants in vulnerability matrices ranked piracy as the main non-climatic factor affecting fishing activities negatively. The pirates sometimes take money before fishing, rob fish and fishing assets, and keep people on-board as hostages for ransoms. One boat owner from Padma said in his oral history interview that *"I need to buy 2 tokens* [*informal money receipts*] *at the cost of* 40,00 *TK from two groups of pirates in a season to do fishing"*. In few cases the pirates have killed fishermen and captains if they resist or do not provide ransom. Together, piracy increases investment and incurs economic losses for the fishing business, thereby reinforcing economic barriers.

All participants observed that overfishing has occurred near-shore due to lack of enforcement of fishing regulations. Near-shore overfishing pushes boats further from shore where they are more exposed to cyclones.

Lack of enforcement of fishing regulations also impairs safety in boats and reinforces technological barriers. According to the fishing regulations each fishing boat needs to have a licence, life-saving equipment for each fisherman, a radio, a transponder (navigation instrument) etc. Yet the authorities frequently ignore the safety code, especially in Padma. According to fishermen in Padma (during FGDs), some boat owners manage to license their boats without following the regulations, by bribing the authorities. Some boats in Padma do not have a licence at all. These boats are hardly monitored at all to check their compliance with regulations.

Lack of access to fish markets makes fishing less profitable and creates pressure to catch more fish. All fish from Padma and half of the fish from Kutubdia Para need to be sold in an auction via commissioning agents. According to oral history and FGD participants these agents charge 1% of the revenue. If informal credit is taken from a commissioning agent (*dadondar*) to run the fishing, then the fish must have to be sold, sometimes at lower prices, via that particular agent who charges for both selling the fish and giving credit. This fish marketing system is considered by the boat owners as unfair as it reduces their profit, and ultimately forces the fishermen to maximise the catch.

5. Discussion

Our results resonate with other recent studies that highlight a range of limits and barriers to adaptation to climate variability and change [1–4,6,18,19]. Adaptation of fishing-people is impeded by both natural and anthropogenic factors: physical characteristics of climate and sea, technologically poor boats, inaccurate weather forecast, poor radio signal, lack of access to credit, low incomes, lack of education, skills and livelihood alternatives, underestimation of cyclone occurrence, coercion of fishermen by boat owners and captains, unfavourable credit schemes, lack of enforcement of fishing regulations and maritime laws, and lack of access to fish markets.

Some earlier literature has suggested that limits and barriers interact to constrain adaptation, e.g., [5,19]. Our findings corroborate this, highlighting how individual, local and broader factors originating from both internal and external sources interact in a

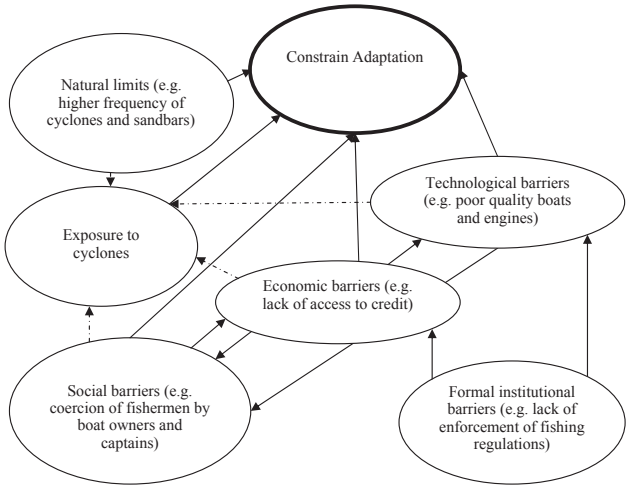

Fig. 2. Interactions between limits and barriers to constrain adaptation of fishing activities to cyclones (→ means X constrain(s) Y;→ means X exposes people to Y more).

complex way to combine to impede adaptation (Fig. 2). Together they constrain completion of fishing trips, coping with cyclones at sea, return of boats from sea safely, timely responses to cyclones, and livelihood diversification.

Natural limits increase exposure to cyclones and damage fishing assets (due to higher frequency and duration of cyclones, and sandbars), and together constrain completion of fishing trips, coping with cyclones at sea and safe return of boats from sea. This is due to the physical characteristics of the Bay of Bengal and its climate. This echoes that geographical limitations can constrain adaptation [19]. Exposure to cyclones also increases indirectly due to all types of barriers. Together these barriers have increased exposure by not informing the boat captains about cyclones at all (absence of radio signal offshore), confusing them about the occurrence of cyclones (inaccurate cyclone forecast), reducing the capability of boats to return to shore (technologically poor boats) or influencing fishing during cyclones (e.g., coercion to fish during cyclones).

Inaccurate cyclone forecasts and poor radio signal are the wider scale technological barriers that constrain adaptation of fishing activities at the local scale. Another technological barrier (technologically poor boats) is underpinned by economic (lack of access to credit) and formal institutional barriers (lack of enforcement of fishing regulations). This finding is in accord with Adger et al. [5] who suggests that technological barriers may be constrained by economic and cultural barriers. Lack of access to credit also leads to maladaptation in the form of reduced investment in boat safety and quality, which undermines the safety of fishermen. This finding is in line with the literature that considers individuals with limited financial capital often focus on short-term financial gain rather than on the long-term vulnerability reduction, despite its benefits [32,33]. Therefore short-term strategies can limit the scope for long-term adaptation [2]. Lack of access to credit is in turn reinforced by unfavourable credit schemes (a formal institutional barrier).

Fishermen's livelihood diversification is constrained by a combination of economic and social barriers that are interrelated. This finding resembles that of Smit and Skinner [29] who found that in agricultural communities livelihood diversification is constrained by a lack of financial capital. In other words, adaptation measures of low-income groups are constrained by economic barriers [5]. While some organisations offer micro-credit, most fishing-dependent people do not have access to it; in line with Amin et al. [30] and Helms [31] who found that micro-credit usually does not often reach the most vulnerable groups.

The direct and indirect impacts of social barriers in constraining adaptation support the theory that individual and social characteristics interact with underlying values to form barriers [6]. Our results also support the evidence that institutional barriers play an important role to constrain adaptation to stresses [41–43,60]. If institutions fail to respond to changing conditions and risks, a system's vulnerability can be exacerbated [61].

Lack of enforcement of fishing regulations, and the coercion of crews to fish by Padma boat owners and captains reduce the fishermen's ability to adapt to cyclones. The presence of boat owners' trade union further reinforces their power. Thus individual adaptation is constrained by social norms and institutional processes as well [19,21].

The fishing activities will face further challenges due to increased frequency and intensity of cyclones in the future [51,52]. Reduction of greenhouse gas emissions is necessary to overcome the limits, which need to be complemented with planned adaptation. There is no single adaptation which would overcome all barriers. Several complementary measures are needed, including improved fishing boats, improved cyclone forecasts and radio signal, increased access to low-interest credit, fish market and insurance, enforcement of fishing regulations and maritime laws, development of human capital through education and skills, and creation of livelihood alternatives.

6. Conclusion

This study has identified and characterised a number of limits and barriers to adaptation of fishing activities to cyclones in two Bangladeshi fishing communities. The natural limits are similar in both communities but technological, economic, social and formal institutional barriers are more contextual. These limits and barriers are also interrelated and combine to constrain adaptation, for example, completion of fishing trips, coping with cyclones at sea, safe return of boats from sea during cyclones, timely responses to cyclones, and fishermen's livelihood diversification from risky fishing activities.

Global climate change mitigation is essential over the longer term to overcome the limits to adaptation and to build resilience, because adaptive capacity may be limited to only lower levels of climate change (≤2–3 °C) [1]. Given the interrelated nature and combined influence of many barriers, overcoming them is complex and needs planned adaptation strategies.

Both internal and external factors pose barriers to adaptation and some barriers are reinforced by others. To overcome these barriers, planned adaptation should occur at multiple scales. Modernisation of fishing technology and improvement of cyclone forecasting and radio signalling can reduce risk and improve responses to cyclones. Access to less expensive credit through institutional reform could help transform fishing technology, prevent maladaptation and diversify livelihood strategies as well as reduce the cost of fishing. Institutional reform can also improve enforcement of maritime laws and access to fish market to help reduce the overall costs of fishing business. Enforcement of fishing regulations and provision of insurance would increase safety of fishermen. Finally, building fishermen's human capital and creation of alternative livelihood activities would help diversify their livelihoods.

These findings form the basis for further detailed research into the determinants and implications of such limits and barriers. More studies are needed in order to move towards an improved characterisation of adaptation and to identify the most suitable means to overcome the limits and barriers.

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