Climate change perceptions, impacts and adaptation practices of fishers in southeast Bangladesh coast

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Abstract

Purpose – The small-scale artisanal fishers in coastal Bangladesh are comparatively more vulnerable to climate risks than any other communities in Bangladesh. Based on practicality, this paper aims to explain the local level climate change perception, its impact and adaptation strategies of the fisher in southeast coastal villages in Bangladesh.

Design/methodology/approach – To achieve the above objective, this study used structural, semi-structured interviews and focus group discussion in two coastal communities, namely, at Salimpur in the Sitakund coast and Sarikait Sandwip Island, Bangladesh. It reviews and applies secondary data sources to compare and contrast the findings presented in this study.

Findings – Results show that the fishers perceived an increase in temperature, frequency of tropical cyclones and an increase in sea level. They also perceived a decrease in monsoon rainfall. Such changes impact the decreasing amount of fish in the Bay of Bengal and the fishers' livelihood options. Analysing seasonal calendar of fishing, findings suggest that fishers' well-being is highly associated with the amount of fish yield, rather than climatic stress, certain non-climatic factors (such as the governmental rules, less profit, bank erosion and commercial fishing) also affected their livelihood. The major adaptation strategies

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undertaken include, but are not limited to, installation of tube well or rainwater harvesting plant for safe drinking water, raising plinth of the house to cope with inundation and use of solar panel/biogas for electricity.

Originality/value – Despite experiencing social stress and extreme climatic events and disasters, the majority of the fishing community expressed that they would not change their profession in future. The research suggests implementing risk reduction strategies in the coastal region of Bangladesh that supports the small-scale fishers to sustain their livelihood despite climate change consequences.

Keywords Bangladesh, Perception, Climate change, Adaptation, Fisher

Paper type Research paper

1. Introduction

A plethora of research worldwide provides evidence of climate change symptoms and impacts (Gillett *et al.*, 2021; Pokhrel *et al.*, 2021). For example, Bangladesh and its adjoining areas have warmed by 0.5°C over the past 100 years (MoEF, 2009). It is also evident that 193 tropical cyclones have affected Bangladesh's coastal and offshore island communities between 1484 and 2009 (Alam and Dominey-Howes, 2014). Considering the inevitable effects of climate change, two approaches – mitigation of the Green House Gases and adaptation to cope with the changing environment – are considered strategies to live with and sustain climate change (Brown, 2014). Climate change effects are disproportionate to the agricultural and fishing communities' burden, whose life and livelihood are closely affected by climate change and associated extreme events. It is highly uncertain how the resource-poor community will adapt to climate change (Wood *et al.*, 2014), which demands them to develop effective local adaptation strategies (Niles *et al.*, 2015). However, the adaptation strategies are unlikely to be effective without understanding the fishing communities' perceptions of climate change, which mainly depends on their direct experience and cognition of climate change. Considering these interrelationships, this research focusses on exploring fishers' climate change perceptions, impact and adaptation undertaking examples from southeastern Bangladesh coastal and island communities – a world top location of climate risks.

Bangladesh is in the frontline of the adverse effects of climatic change due to a combination of several physical (location, low-elevation and fragile environments) and social characteristics (i.e. poverty, population density and lack of resources leading to a less adaptive capacity). Bangladesh coast and offshore islands (such as Sandwip, Kutubdia and Hatiya – located in the Bay of Bengal) are subjected to frequent tropical cyclones (e.g. Cyclone 1991, 1997; Sidr, 2007; Alia, 2009; Roanu, 2016) and coastal erosion. The coastal communities are continuously adopting survival strategies to live with changing climatic conditions (McNamara *et al.*, 2020; Alam and Collins, 2010).

In Bangladesh, the fishery sector contributes 3.57% to the national gross domestic product (GDP), and it shared one-fourth of the agricultural GDP in 2017–2018 (DoF, 2018). More than 11% of the country's total population is engaged in the fishing sector. It also contributes to 60% of the animal protein in its whole food and nutrition supply. The small-scale coastal fisheries support the livelihoods of half of a million fisherfolk and their household members, who catch almost 82% of the total marine caught in Bangladesh (DoF, 2018). Bangladesh and its fisheries sector are victims of global climate variability and change (BBS, 2020; Islam *et al.*, 2020). Different climatic variables, including tropical cyclone and storm surge, salinity, sea-level rise, water temperature, rainfall and drought, have adverse effects on coastal fishing productivity, affecting the fishing community's livelihood and overall well-being (Alam *et al.*, 2018; Vivekanandan *et al.*, 2016).

The Government of Bangladesh (GoB) undertook a policy on addressing climate change impacts. The country's 7th five-year plan coincided with the final Millennium Development Goals, and the launch of the United Nations post-2015 sustainable development goals, which highly emphasises climate-resilient development growth. The Bangladesh Climate Change Strategy and Action Plan identifies extreme climate events' adverse effects as a significant development challenge. Notably, poor people are more vulnerable to climate change and associated extreme events (Thomas *et al.*, 2019). On many occasions, their economic achievements and progress are obstructed by extreme climate events. Limited research focusses on the artisanal fishing community perceptions, impacts (Section 1.1) and adaptation strategies (Section 1.2). From the current literature, three research gaps are identified. They include:

- limited efforts for understanding fishers' perceptions of climate change and subsequent adaptation strategies;
- most of the climate change impacts and adaptation actions were undertaken on the southwestern Bangladesh coast (Islam *et al.*, 2014; Khan *et al.*, 2011), eschewing the eastern region; a highly susceptible area; where the density of population is higher than nearby districts and where major economic zones of the country are located; and
- it is less clear whether fishers will continue autonomous adaptation strategies in the context of future climate change.

Using survey data from both mainland coastal and offshore island communities in southeast Bangladesh, this paper aims to address this knowledge gap by exploring fishers' perceptions of climate change. It then explores the impacts and adaptation strategies that the poor fishers adapt to cope with extreme climate events. These understandings are imperative to develop coherent and comprehensive strategies for the fishing community's resilience to extreme climate events on the Bangladesh coast. The research questions investigating these are:

RQ1 What are the local fishing communities' perception of climate change, and do their perceptions correspond to meteorological records?

RQ2 What are the perceived impacts of extreme climate events on the livelihood of fishing communities? What are the autonomous adaptation strategies and challenges encountered by the fishers?

RQ3 To what extents are the fishers satisfied with their livelihood means and future adaptation plans to combat extreme climate events?

1.1 Climate change experience and effects on coastal communities

Local people experience hydro-climatic events (i.e. heatwave, floods, tropical cyclones, extreme rainfall) through the frequent impact of climatic stressors on their livelihood. Local communities' experience of these events is valid when considering short-term variability than those variables' long-term trends (Shameem *et al.*, 2015). Climate change effects may include but are not limited to livelihood, migration and health (Table 1). The cause of migration, food insecurity, health problems or other problems attributed to climate change is difficult due to the scientific evidence that the relationship between the former with climate change and variability is unclear. For example, people who live in tropical cyclone-prone areas wishing to move to other areas cannot be directly and solely attributed to climate

	Sectors of effects	Description of effects	Sources
Livelihood	Food security	A decrease in rice production	Dasgupta *et al.* (2018)
	Marine and inland fishing	Decrease of fishing in the Bay of Bengal, Bangladeshi coast and freshwater sources	Islam *et al.* (2020)
	Crop diversity	Decrease of crop varieties due to the intrusion of saline water and monoculture	Dasgupta *et al.* (2018)
Migration	Forced migration from the coast to Bangladesh mainland	The residents who lost housing and agricultural land due to coastal erosion and storm surge inundation migrated to the adjacent urban city. They generally formed two types of settlement. These are: slum-dwelling within major city areas and settlement on the slope of hills	Mallick *et al.* (2020)
	Forced migration to adjacent Indian regions	Sea level rise and natural hazards induced displacements found to take illegal migration to adjacent India	Bose (2013)
	Voluntary stay and trapped population	Fishing communities are part of the voluntary staying community or some of them are trapped	Mallick and Schanze (2020)
Health	Deaths and injuries	Deaths resulting from cardio-respiratory diseases associated with high and low temperatures Deaths associated with a tropical cyclone, lightening and droughts, events	Shahid (2009)
	Malnutrition	The reduction of food diversity leads to malnutrition rate among coastal residents	Cooper *et al.* (2019)
	Safe drinking water	Coupled rise of tide levels and frequent coastal flooding increase salinity in groundwater. Drinking of saline contaminated water increases skin diseases, hair loss, diarrhoea, gastric and high blood pressure	Rakib *et al.* (2020)
	Gender dimensions of effects	A decrease in women income, rights, less food intake and undertaking stressful social life	Reggers (2019)
	Climate extreme induced disease and sickness	Mosquito-borne diseases, tick-borne disease (e.g. malaria, dengue), diarrhoea, gastric and acid secretion, high blood pressure, air pollution-related mortality and morbidity	Rahman *et al.* (2020)

Table 1.
Effects of climate extreme on life and livelihood of the Bangladeshi coastal communities

extremity. However, some other pull factors (such as better income, education and health opportunity) may contribute to the migration (Gemenne and Blocher, 2017). Notwithstanding, it is most likely that climate change is one of the main push factors for migration.

1.2 Vulnerability and adaptation to climate change and variability

Vulnerabilities are those factors that compromise the capacity of a community to prepare and respond to natural hazards. It has also been generally emphasised as identifying the capacities (such as physical/material, social/organisational and motivational/attitudinal) of communities to reduce vulnerabilities (such as physical/material, social/organisational and motivational/attitudinal) (Wisner *et al.*, 2004; Birkmann *et al.*, 2013). Islam *et al.* (2014) identified that livelihood vulnerability comprises exposure to floods and cyclones, sensitivity and lack of adaptive capacity in terms of physical, natural and financial capital and diverse livelihood strategies, varying depending on place and context. For example, livelihood vulnerability results from combined but unequal influences of communities and households' biophysical and socioeconomic characteristics and does not necessarily depend on exposure.

Islam *et al.* (2014) identified the limits of and barriers to climate change adaptation of the Bangladeshi fishing communities. The limits include the climate and physical sea characteristics, such as the frequency and duration of tropical cyclones and hidden sandbars that obstruct the fishing communities' safe return to the coast. The barriers include technologically inadequate boats, inaccurate weather forecast, weak radio signals, lack of access to credit, low income, underestimation of cyclone occurrence, coercion of fishers by 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.

Adaptation can be viewed in several ways based on scale, actors, agents, processes and sectors (Castells-Quintana *et al.*, 2018; Schipper, 2020). It can be incremental or transformational. Incremental adaptation actions are the processes where the central aim is to maintain the essence and integrity of a system or process at a given scale. In contrast, transformational adaptation changes the fundamental attributes in response to climate and its effects. Transformation can occur in technological or biological systems, financial structures and regulatory, legislative or administrative regimes. An example of transformational adaptation is the development of climate risk screening guidelines, which might make downstream development projects more resilient to climate risks. Smit and Wandel (2006) generally divided adaptation activities into two groups: government-led adaptation on behalf of society and individuals' autonomous adaptation. Adaptation assessment refers to the practice of identifying options to adapt to climate change and evaluating them in terms of criteria, such as availability, benefits, costs, effectiveness, efficiency and feasibility. This research relates to assessing the fishing communities' autonomous adaptation strategies regarding existing disaster resilience practices.

Adaptation can be good or bad. It might lead to maladaptation (Schipper, 2020). Effective adaptation leads to resilience. Following the identification of 40 essential criteria of human, physical, financial, natural and social assets, Sharifuzzaman *et al.* (2018) identified resilience factors which include experienced fishers, natural abundance of hilsa (*Tenualosa ilisha*), ability to assert decision on fish selling, nets and boat ownership, social harmony and capacity of buying food as essential livelihood assets for the fishers at Hatiya Island, Bangladesh. Individuals are undertaking autonomous adaptation strategies in the three main sectors: livelihood, human habitation and health as a response to tropical cyclone hazards, salinity intrusion into inland areas and other extreme climatic conditions (Table 2).

2. Research methods and materials

This paper addresses and resolves several specific scientific and technical issues related to the diverse disciplinary fields of climate change perceptions, impacts and adaptation of the fisherman communities on the Bangladesh coast to fulfil the objectives mentioned above. Both quantitative and qualitative methods were used in this research to understand better fisher communities' perception of climate change and its impacts and adaptation strategies.

Adaptation sectors		Description of adaptation strategies	Sources
(1) Livelihood	Changing rice crop farming to non-rice farming	A variety of crop farming, cultivation of jute, wheat, plum and pulses	Sarkar *et al.* (2013)
	Increased involvement in a variety of income sources	Earning money by wage labour, small business, construction works and livestock, poultry and duck rearing	Pouliotte *et al.* (2009)
	Selling land and taking a loan	Poor household often temporarily adapt to extreme climate events by selling land and taking loans	Alam (2002)
	Gender dimensions	Women are forced to adopt a hard job outside Grassroots innovations to climate change	Khalil *et al.* (2020)
	Mangrove plantation and conservation	Mangrove creates alternative livelihood and helps disaster risk reduction	Iqbal (2020)
	Temporary changes in occupations	For example, fishers temporarily undertake non-fishing jobs	Alam (2017)
	Raising homestead and plinth Using concrete as house construction materials	Low lying coastal and island inhabitants often raise homestead and plinth much higher than mainland people to mitigate the severe effects of coastal flooding Communities put best efforts to construct concrete-built houses	Kashem Shakil (2019)
(2) Human habitations	Planting trees	Planting trees around the house to reduce the intensity of storm surge attack	Younus (2017)
	Migration	Climate displaces and "refugees" move to urban centres	Mallick *et al.* (2017)
(3) Health	Self-care as health care	Season specific household levels strategies (i.e. self-knowledge, previous healing experience and caring for themselves) preventing sickness and diseases from extreme heat, cold and precipitation	Nibedita *et al.* (2016)

Source: Authors compilation 2021

Table 2.
Community-led autonomous adaptation actions of Bangladeshi coastal communities

Both approaches have their limitations (Gregory *et al.*, 2009). However, mixed methods provide more robust results than either qualitative or quantitative approaches when used separately (Creswell, 2009). For this research, data have been collected from primary sources through field visits and surveys. Both quantitative and qualitative data have been collected through structured, semi-structured and open-ended questionnaires, observation (overt and covert) and focus group discussions (FGDs).

2.1 Study sites and an introduction to fishing communities

To understand climate change perceptions and adaptation of fishing communities in southeast Bangladesh coast, interviews were conducted with the fishers' households from offshore and mainland coastal communities. The fisher from the villages of Sarikait in Sandwip Island and Salimpur in the Sitakunda mainland coast has been consulted for this research (Figure 1). Sandwip Island is located on the track of positively tropical cyclone landfall in the Bay of Bengal. The island experienced over 10,000 deaths by the cyclone Gorky in 1991. The Sarikait, a remote local union [1] council, is located on the southern coast of the island, which is first hit by tropical cyclone wind and storm surges. The physical infrastructure is frangible with mud road and is 5 km away from the adjacent growth centre of Sandwip Island. According to the past census held in 2011, the total population of Sarikait

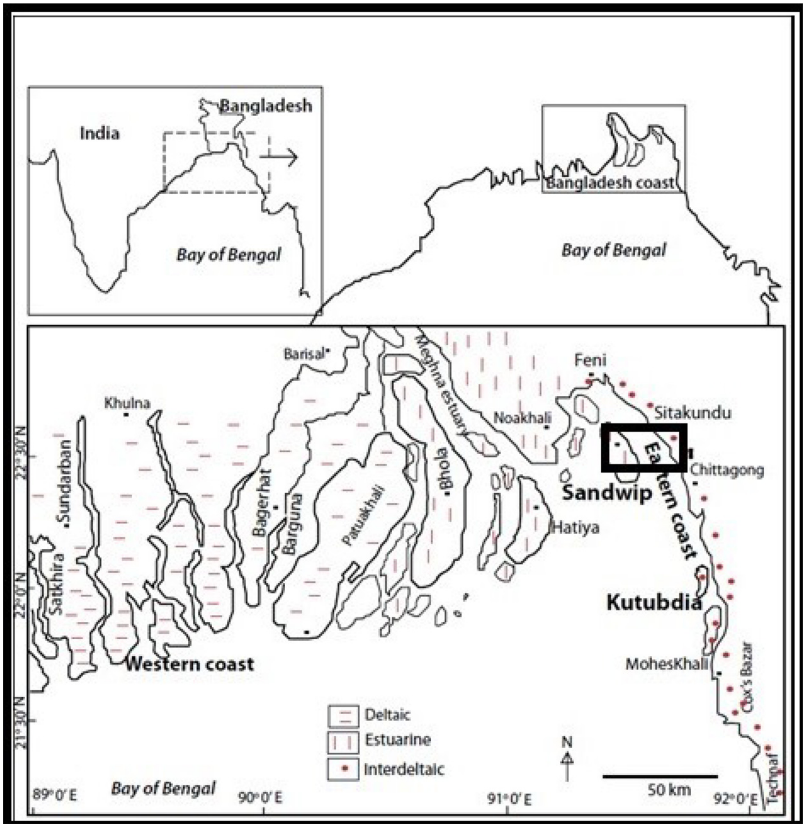


Figure 1. Location of Bangladesh coast and rectangular showing selected study areas for this research

is 24,543, of which 900 were fishers. Salimpur is a suburban union council located along the Sitakunda coast. It is approximately 11 km from Chittagong City Centre and is well connected with other urban facilities (i.e. built road transport, water supply, electricity, etc.). The total population in Salimpur is 54,797, of which the total numbers of fishers were 734.

Marine fisheries are divided into two categories based on the technology used and the purpose of fishing: industrial and artisanal. Industrial fisheries, also known as commercial fishing involving a high level of technology and investment, aims to catch large-scale fishing within the national boundary in the Bay of Bengal. Artisanal fishing is small-scale fishing by smaller boats involving low capital undertaken by individual fishing households commuted daily with approximately 8 km from the coast. Household surveys were conducted on the artisanal fishers who did fishing professions as the first choice of livelihood and continued the profession by generation or first job in their lives. Although the researchers randomly selected the participants, all of those interviewed were male because fishing is historically recognised as a male-dominated practice in the Bay of Bengal. The average age of the respondents was 56.15 years. They completed seven years of schooling and have been fishing as their first profession for 37 years (Table 3).

2.2 Sampling, questionnaire, data collection and analysis

For this research, the unit of analysis was the household head as the key informant. Before conducting the field survey, a list of the fishers' households was collected from Salimpur and Sarikait union councils. A total of 135 semi-structured and open-ended questionnaire surveys (duration 40–60 min for each interview) were administered randomly from the selected household list; of these 135 participants, 68 and 67 from Sitakunda and Sandawip, respectively. From 1634 (900 + 734) households, 8% of fishers were included in the survey. Concerning a cross-sectional household survey, Bartlett *et al.* (2001) argued that 5% of the population is a good representative sampling selection. A computer-generated random number table was applied to the fishers' families' list to select 135 households randomly. In the case of a non-response, the interviewers proceeded to the next household until the respondents' targeted number was reached. Before conducting the survey, the questionnaire was tested with 25 respondents to test adequacy, validity and relevancy and avoid ambiguity.

Questionnaire surveys and consultations with fishing communities had been conducted face-to-face between August 2019 and September 2019. The questionnaire sought information on climate change perceptions, symptoms, observed effects, consequences on life and livelihoods, seasonal calendar of fish collection and well-being, coping and adaptation strategies, limits and barriers for adaptation, livelihood strategies and future profession. Four FGDs, consisting of two from each study site, were undertaken among

Characteristics	Mean	SD
Age of household head (years)	56.15	8.405
Years of schooling	1.48	1.931
Monthly income from main occupation (fishing)	20,315.31	6,342.31
Monthly income from secondary occupation	6,711.03	1,823.21
Monthly income from father's main occupation (fishing)	12,204.20	13,329.79
Monthly income of second person if involved in fishing	12,171.55	9,007.87
Year of fishing experience	37.13	10.83

Source: Field survey, August–September 2019

Table 3. Socioeconomic characteristics of the surveyed households

fishing communities to understand their life experiences and uncover common notions of living strategies with climate change. The duration of each FGD was 1-h long. The time and location of FGDs have been pre-arranged in consultation with participating fishing communities. At least eight fishers who were cooperative and enthusiastic attended each FGD session. Throughout the research processes, the present study observes the social science survey norms rigorously by paying due attention to data collection issues from the rural community and participant's rights.

After collecting the data from all sources, these were processed and analyzed sequentially, both manually and automatically, using MS Word, MS Excel and SPSS. Statistical analysis, such as descriptive analysis and a five-year moving average for the temperature and rainfall data, was conducted to compare these with household perceptions of climate change parameters. Frequencies and percentage of responses were estimated for the questions on perceptions, effects and adaptation.

3. Results

In the following sections, key findings are provided. These findings may help the GoB and relevant stockholders to develop effective strategies for fishing communities' resilience to extreme climate events in Bangladesh. The sections include climate change perceptions, symptoms, effects, comparison between local accounts of climate change and meteorological information, consequences of climatic changes and extreme events on the livelihood, limit and barrier to adaptation, satisfaction on various aspects of living and changing profession in future.

3.1 Climate change perceptions, symptoms and effects

All the fishers who participated in the survey have personal beliefs and knowledge that climate change is occurring. Data obtained through individual interviews and FGDs confirmed that the fishers' community perceived the change in temperature, rainfall, seasonality, tropical cyclone, inundation pattern and the type and sea-level changes (Table 4). The fishers observed temperature changes as increased warm days and night, heatwave and decrease of cold days/night. Their perceptions of climate parameters are related to the global temperature-related change reported by the IPCC (2014). The fishers described a decreased trend in total annual rainfall, rainy days and high rainfall for a short period.

The fisher described their observed changes in seasonality patterns in many ways, of which the most common changes experienced include longer and hotter summer than before and late-onset of the monsoon season. Changes in tropical cyclones were described by an increase in intensity and frequency of tropical cyclones and the height of tropical cyclone-induced storm surges. In total, 22.8% of respondents could not relate their understanding between climate change and tropical cyclones. The fishers, particularly those from the Sarikait of Sandwip Island, experienced salinity intrusion and more area being inundated during high tide. The fisher community provided mixed responses concerning sea-level change, including increasing and decreasing, and no change. The fishers living adjacent to the coast in Sandwip experienced sea level rise because of erosion-induced advancement of sea level and intrusion of tidewater due to the embankment breach. Data obtained through FGDs in both study sites confirmed that the respondents were less likely to perceive it as a manifestation of rising sea levels due to global warming. The fisher from the Salimpur coast opined that they observed that the sea levels decreased.

3.2 Comparison between local accounts of climate change and meteorological information

The fisher had described their experiences about rainfall changes in various ways: decrease in total rainfall in the rainy season; the number of annual rainy days decreased; increased high

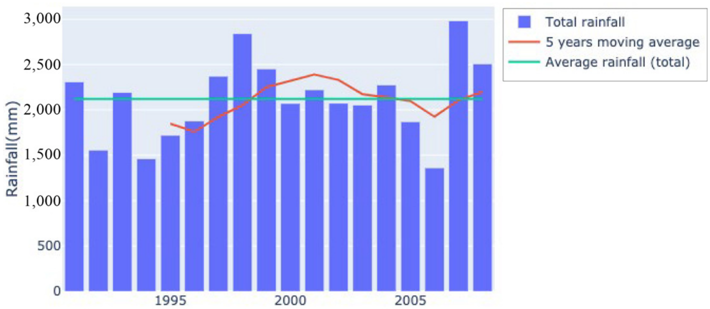
Table 4.
Local perceptions on elements of climate, seasonality, tropical cyclones and physical environment

Local perceptions on elements of climate, seasonality, tropical cyclones and physical environment		Frequency
Temperature	Increased warm day/nights	135 (34.7)
	Increased heatwaves	134 (34.5)
	Decreased cool day/nights	120 (30.8)
Rainfall	Decreased in total rainfall in the rainy season	113 (39.1)
	Number of annual rainy days decreased	107 (37.0)
	Increased high rainfall in a short period	69 (23.9)
Seasonality	Long summer season	135 (38.7)
	Summer hotter than before	135 (38.7)
	Late-onset of monsoon season	79 (22.6)
Tropical cyclones	Increased intensity of wind speed of the tropical cyclone	54 (30.0)
	Increased frequency of tropical cyclones	50 (27.8)
	Increased height of storm surge	35 (19.0)
	No responses	41 (22.8)
Physical environment	More area being intruded by salinity	104 (28.2)
	More area being inundated during high tide	95 (25.7)
	Increased sea level	81 (22.0)
	Decreased sea level	59 (16.0)
	No change in sea level	30 (8.1)

Note: Multiple responses were counted and numbers in parenthesis indicate per cent distribution
Source: Field survey, August–September 2019

rainfall in a short period. To verify their claims, fishers' perceptions of precipitation changes were compared with rainfall data from a local meteorological station. The seasonal rainfall (Monsoon season – June, July, August and September) time series for 18 years (1991–2008) does not show any statistically significant changes (at 5% significance level) over this period (Figure 2).

The decadal frequency (an aggregate of 10 years) of major cyclonic storms striking over coastal regions of Bangladesh during 1970–2017 (Figure 3) shows that there is a decreasing trend in the frequency of total major cyclonic storms landfilling over Bangladeshi coasts during the three decades, except for the 1980s–1990s and the rate of decadal decrease was 55.6% during the 1970s to 1980. Between the 1980s and 1990s, the trend reversed towards increased cyclones at the rate of 50%. There has been a 50% decrease in the frequency of total significant cyclones in the first decade of the 21st century from the previous decade.



Source: Authors' compilation 2021

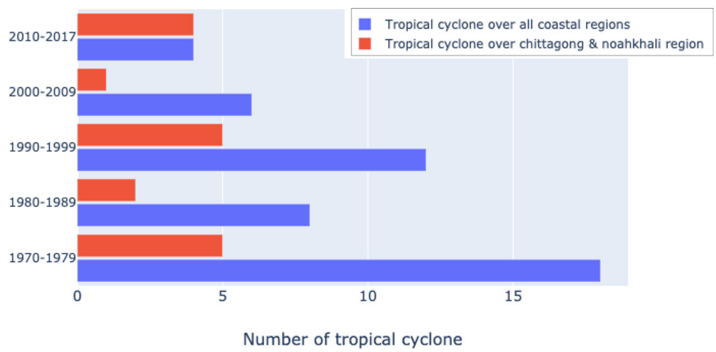
Figure 2.
Annual departure of monsoon rainfall from 1970 to 2015 mean in Chittagong

The fisher reported that tropical cyclones' frequency and intensity have increased along with the storm surge height and inundation. This opinion may be related to recent landfalling tropical cyclones on the Chittagong coast and the Noakhali coast. For example, since 2013, four severe cyclones (i.e. Cyclones Mahasen, 2013; Komen, 2015; Roanu, 2016; Mora, 2017) made landfall in Bangladesh occur on the Chittagong coast. In the longer term, from 1970 to 2017, 48 major storm surges made landfall in Bangladesh (total five landfall segments: Khulna, Barisal, Noakhali, Chittagong and Cox's Bazar), of which 17 occurred on the Chittagong and Noakhali coast. Within the past 30 years (1990 to 2019), 22 tropical cyclones made landfall, of which 10 occurred in the Chittagong and Noakhali coast. The fishers' observation about the salinity intrusion into the non-saline area and the rising salinity level in soil and water was consistent with the soil survey and water quality monitoring records that observed changes in soil salinity class level of salinity towards an increasing trend that had been reported.

3.3 Consequences of climatic changes and extreme events on the livelihood and limit and barrier to adaptation

Results show that climate changes and associated extreme events have impacted the fisher communities' life and livelihood strategies. In response to a question regarding the effects of summer temperature rises, decreased seasonal rainfall and late-onset of the rainy season, most fishers opined the decrease in fish in the Bay of Bengal. Findings obtained through the FGDs confirmed similar challenges in both Salimpur and Sarikait coast. The other problems opined by the fisher communities are also directly related to their life and livelihood strategies, such as increased heatwaves causing sickness, decreased fish in large areas and decreased some popular fish species. Due to the increase in intensity and frequency of tropical cyclones, the fishers often cannot go catching fish in the Bay of Bengal. Even though they dare to catch fish in the Bay of Bengal, it is life-threatening to them. Sometimes they might return to the coast due to due to turbulent sea weather during cyclone periods. They also experience damage to houses and roads during tropical cyclones.

3.3.1 Seasonal calendar of fish collection and well-being of the fishing community. The months of *Kartik* [2] (October–November) and *Ashar* (June–July) are comparatively considered very good for fishing due to the abundance of fish in the Bay of Bengal

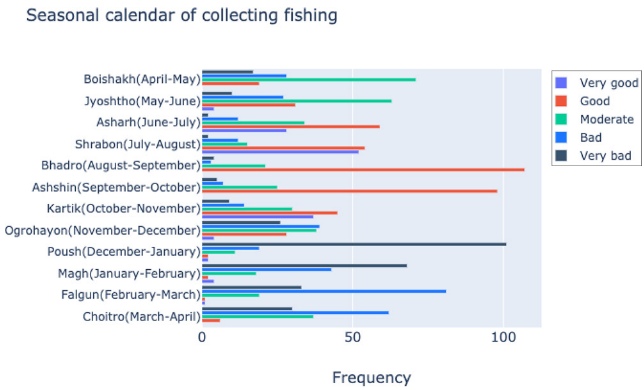


Data source: Alam and Dominey-Howes (2015) for the period 1970–2009 and from the Bangladesh Meteorological Department for 2010–2019

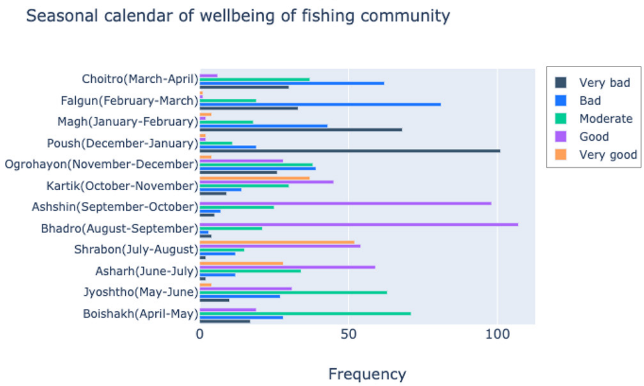
Figure 3. Decadal frequency of cyclonic storm over Chittagong and Noakhali coast and all the Bangladesh coastal regions during 1970–2019

([Figure 4](#)). Next to these two months, *Bhadra* (August–September) and *Arshin* (September–October) are also considered suitable for fishing in the Bay of Bengal. Meanwhile, *Poush* (December–January) and *Magh* (January–February) are considered very bad for fishing in the Bay of Bengal. *Falgon* (February–March) and *Chaitra* (March–April) are also considered bad for fishing in the Bay of Bengal. *Boishakh* (April–May) and *Jyoshtho* (May–June) are considered as average/fair for the abundance of fishing in the Bay of Bengal. Comparative analysis of the seasonal calendar of fish collection and the fishing community's overall well-being suggests that these are somewhat correlated. For example, the month of *Ashwin* is considered suitable for fishing, but considering the fishing community's overall well-being, the month has been considered very good. *Poush* (December–January) and *Magh* (January–February), which are considered very bad for fishing, are also rated the same as the fishing community's overall well-being. *Boishakh* (April–May) and *Jyoshtho* (May–June), which are considered average for the abundance of fishing in the Bay of Bengal, these months have also been rated the same fisher for their well-being.

3.3.2 Challenges in boosting income from the fishing profession and strategies undertaken to overcome livelihood challenges. They opined that rather than climatic stress, they experienced non-climatic factors which regularly hindered their profession (Table 5). For example, the GoB imposed a 65 days ban on fishing activities in the Bay of Bengal without



(a)



(b)

Figure 4.
(a) The abundance of fishing in the Bay of Bengal by month (b) The overall well-being of the fishing community by month

prior consultation with fishing communities which provides further stress on their living without having any income for such a long period (Rozario, 2019). In protest of the imposed ban, the entire fishing communities went for a strike and appealed to the GoB to minimise the fishing ban period. The fishers do not receive profits in comparison to their investment. Findings of the FGDs suggest that constant riverbank erosion induced landlessness and shifting of houses is a significant challenge for the fishing communities in Sandwip Island. The small fishing communities do not have enough money to purchase fishing gear and experience obstacles when attempting to obtain loans from different financial organisations. The other challenges to boost income from fishing professions include deficiency in the abundance of fishes, commercial fishing travellers' dominance and disturbance by significant problems. The fishing community undertook self-help and institutional assistance to overcome livelihood challenges, including taking a loan from the GoB/non-governmental organisations (NGOs), fishing the Bay in a highly abundant period, increasing investment in fishing gears and increasing income level by alternative livelihood.

3.3.3 Challenges during tropical cyclones and adaptation with adverse climate condition. The fisher experienced damages in houses, nets, boats, crops and vegetation during the tropical cyclone period. During every high cyclonic period, fishers' communities living along and adjacent to the coast experience destruction in their houses and, sometimes their boat and net are destroyed (Table 5). The fishers opined that every year some of their members died. In contrast, undertaking fishing in turbulence weather in the Bay of Bengal, beyond those casualties and missing fishers, occurred during the significant tropical cyclones (i.e. April 1991 cyclone Gorky and 2009 Aila events). During the tropical cyclone period, roads are submerged in the rain and tidal water and plantation is destroyed. The other notable challenges faced during tropical cyclones include cattle

Challenges to boost income from fishing profession	Frequency (%)	Strategies adopted to overcome livelihood challenges	Frequency (%)
Recent government ban to catch in the Bay of Bengal	53 (36.3)	Appeal to the GoB to withdraw/ minimise forbidden period in the Bay of Bengal	49 (35.8)
Do not get profit from the investment	29 (19.9)	Taking a loan from the GoB/ NGOs	39 (28.4)
Riverbank erosion induced landlessness and house changes	14 (9.6)	Fishing the Bay in highly abundance period	10 (7.3)
Fishes are not found sufficiently	8 (5.5)	Taking legal help from society	6 (4.4)
Obstacles faced during tropical cyclone period	Frequency (%)	Adaptation strategies with the adverse climatic condition	Frequency (%)
Destruction of houses	124 (37.0)	Installation of tube well for safe drinking water	131 (21.6)
A fishing boat and net destroyed	87 (25.9)	Raising plinth of the house to cope with inundation	119 (19.6)
Fishers dead in the Bay of Bengal	28 (8.4)	Use of solar panel/biogas for electricity	118 (19.4)
Destruction of roads due to submersion in the rain and tidal water and storm surges	33 (9.8)	Rainwater harvesting as a source of safe drinking water	109 (18.0)
Total	146	100	

Note: Multiple responses were considered
Source: Field survey, August–September 2019

Table 5. Most reported survey results on challenges to boost income from the fishing profession, strategies adopted to overcome these, obstacles faced during tropical cyclone period and adaptation strategies with the adverse climatic condition

deaths, plantation destructions, lack of a safe place, increases risk in fishing and other livelihood and daily activities. The fisher communities frequently undertake adaptation strategies to live with climate extremes and tropical cyclones associated losses. The primary adaptation strategies include, but are not limited to, installation of tube well for safe drinking water, raising plinth of the house to cope with inundation, use of solar panel/biogas for electricity and rainwater harvesting as a source of safe drinking water. Those poor fishers living in sub-standard housing along the coastal embankment are compelled to relocate temporarily to save lives from the severity of wind speed and storm surges. To adapt with adverse climate conditions, the fisher also engaged in alternative livelihood strategies, including fish drying and processing works, farming and housewives of fisher being forced to work outside (who would have stayed at home otherwise).

3.3.4 Limits and barrier to climate adaptation. Of the 12 identified limits and barriers (Table 6) to the adaptation strategies to combat the adverse climatic conditions and events, the top five were not associated with climate extremes; instead, they were related to dynamic social characteristics. Low income, lack of education and unfavourable credit schemes interact with each other, limiting and barring the adaptation strategies to combat the adverse climatic conditions and events. To survive during extreme climate events, the fisher took informal loans from moneylenders with a higher interest rate which are sometimes double or triple than the formal banking loan rate. The analysis of data on limits and barriers to the adaptation suggests that investment in education, alternative livelihoods and favourable loan schemes may enhance the fisher's income label. Combined results of this with enhancement in providing accurate weather information may help adapt to climate change. Of the 12 identified limits and barriers to adaptation strategies, the fishers identified only three reasons directly related to climate extremes. These include increased frequency, intensity and duration of tropical cyclones. This reinforces the need to undertake vulnerability reduction approaches among Bangladesh's coastal communities.

Limits and barrier to the adaptation	Frequency	(%)
Low income in the family causes a financial crisis during extreme events	135	11.5
Lack of education	135	11.5
Unfavourable credit schemes sometimes put more pressure during extreme events	130	11.0
Due to inaccurate information, sometimes underestimated the cyclone occurrence and faced troubles	126	10.7
Lack of technical skills that reduces the chances of livelihood alternatives	118	10.0
Increased the frequency of tropical cyclones	90	7.6
Lack of enforcement of fishing regulations and maritime laws	84	7.1
Increased duration of tropical cyclones	69	5.9
Lack of access to fish markets	66	5.60
Increased wind speed of tropical cyclones	50	4.2
Inaccurate weather forecast increases the danger of lives	27	2.3
Weak radio signal hampers getting the correct information	17	1.0
Total	1,179*	100.00

Note: *Multiple responses were counted
Source: Field survey, August–September 2019

Table 6.
Limits and barrier to the adaptation strategies to combat the adverse climatic conditions and events

3.4 Satisfaction on various aspects of living

The 28% of fisher rated their income from the fishing profession as satisfied, and the overwhelming majority (70%) rated their satisfaction level as average (Table 7). Only 1.5% of fishers were unsatisfied with their level of income from fishing activities. Although the fishers were identified randomly for the survey, those interviewed came to this profession by generation. When they were asked about satisfaction level on social status as fisher, 78.5% were satisfied with the profession and the remaining 21.5% provided their rating for social status as average. None of them was unsatisfied with their profession. It is remarkable that most fisher (81.5%) were satisfied with their relationship with neighbours and other people in society. The remaining 18.5% rated this relationship as either very satisfied or average, while there is no unsatisfaction report. This relationship with neighbours and others implies social and religious harmony in Salimpur and Sarikait coast on Chittagong.

3.5 Changing profession in future

Although the fishing communities experience social stress and extreme climate events and disasters frequently, 84% of the respondents opined that they would not change their profession in the future. This is because they became fishers by generation and want to stick to the ancestral profession to respect them. However, 16% of respondents want to change their profession, claiming they would like to do a job, run a business or go overseas for job purposes. Of the 135 respondents, the sons of the 47% of respondents may continue the fishing profession. The main reason for continuing the fishing profession is to maintain current earning by the fishing professional inherited due to ancestral generation. The fishers also considered that they might not get current earnings if they went to other professions due to a lack of alternative skills. The remaining 53% of fisher opined that their sons would not pursue their profession as fisher because the latter may attempt to excel by continuous education, lack of skill for this job, brutal nature of fishing jobs and lack of honour profession cohort.

4. Discussion

This study focusses on the fishermen and their livelihoods in the face of climate change, how they perceive climate change and how they survive and plan for their future. Results show that fishermen perceived both sea-level rise and decrease. The perceived increase in sea level coincided with findings from IPCC (2011) and Unnikrishnan and Shankar (2007), whereas the residents' perception of a decrease in sea level coincided with Sarwar's (2013) findings, which showed a fall in sea level along the Chittagong coast. The changes in climate characteristics perceived by the fishers have been evaluated to ascertain the degree of

Various aspects of living	Very satisfied	Satisfied	Average	Unsatisfied	Very unsatisfied	Total
Income	–	38 (28.1)	95 (70.4)	2 (1.5)	–	135 (100)
Social status	–	106 (78.5)	29 (21.5)	–	–	135 (100)
Relation with neighnour and others	7 (5.2)	110 (81.5)	18 (13.3)	–	–	135 (100)
Total	7 (5.2)	254 (188.1)	142 (105.2)	2 (1.5)	–	–

Note: Number in parenthesis indicate per cent distribution
Source: Field survey, August–September 2019

Table 7. Satisfaction on income, social status and relationship with neighbours and others

correlation with the scientific record of observed hydro-meteorological trends in the study region.

The fisher community reported a decrease in the quantity of fish in the Bay of Bengal with summer temperature rises, decreased seasonal rainfall and late-onset rainy season. They also noted other climate change problems, such as increased heatwaves causing sickness, decreased number of fish in a large area and decreased some popular fish species. According to the fishing calendar in the Bay of Bengal, the months of *Kartik* (October–November) and *Ashar* (June–July) are optimal for fishing due to the abundance of fish. In contrast, *Poush* (December–January) and *Magh* (January–February) are considered bad for fishing. The month of Ashwin (September–October) is rated as average for fishing; however, but is considered good based on the fishing community's overall well-being.

Bangladesh and its adjoining areas have warmed by 0.5°C over the past 100 years. The rise of temperature is generally observed in the monsoon season (June–August). Average maximum and minimum temperatures during monsoon season have increased annually at the rate of 0.05°C and 0.03°C, respectively. The Climate Change Cell of the Department of Environment found increasing linear trends in seasonal and annual mean temperature between 1980 and 2007 for all the 34 stations in Bangladesh. The Climate Cell reports the rising trends in the country's annual and seasonal mean maximum temperatures since the 1970s. The warmer trends have been statistically significant since 1980 for the months of May to September. Because mean temperature has increased significantly since 1980, the fishers have likely experienced extremely hot temperatures in the summer and monsoon seasons. Thus, there is a likely correlation between the fishers' perceptions of an increase in warm weather and actual temperature records.

An analysis by Climate Change Cell showed that at a regional scale throughout 1981–2001, monsoon rainfalls appeared to have decreased in the central and southern parts of the country but increased in the Northern part (Bogra, Mymensingh and Sylhet areas) compared to the reference period of 1960 to 1980. In contrast, Hasan *et al.* (2014) showed that monsoon rainfall has increased in the southern part of the country since 1990 compared to the reference period 1949 and 1989.

Fishermen claimed an increase of the frequency of cyclone disaster in their region. Though the studies on the frequency and intensity of tropical cyclones in the Bay of Bengal are not conclusive, some studies showed that the frequency of tropical cyclones has increased in May and November, while others claimed that the frequency had decreased despite an increase in sea surface temperature. Rathore *et al.* (2017) suggested that despite interdecadal variation in the past 50 years, there is no significant trend in the frequency of cyclonic disturbances crossing over the Bangladeshi coast. Although Unnikrishnan *et al.* (2011), Balaguru *et al.* (2014) suggest that the intensity of tropical cyclones in the Bay of Bengal has increased, limited records are available showing a decreasing trend of tropical cyclones. The intensity of significant tropical cyclones (wind speed $> 49\ \mathrm{m\ s^{-1}}$) in the post-monsoon Bay of Bengal increased during 1981–2010 (Balaguru *et al.*, 2014). While analyzing the global trend of tropical cyclone intensity, Klotzbach (2006) showed that the trend of tropical cyclone intensity in the Bay of Bengal was "flat" between 1986 and 2005.

The finding of this study regarding expanding inundation areas due to rising high tide water levels has coincided with other studies in the coastal region (Abedin *et al.*, 2014; Bhuiyan and Dutta, 2012). Analysing 22 years of data (AD1977–1998), SMRC (1998) showed that relative sea level in the Bay of Bengal had risen 4.0 mm/year and 7.8-mm/year along the Western and Eastern coasts, respectively.

To cope with this stress, fishermen appeal to the GoB to reduce the ban period, took loans and attempted to catch fish in a high abundance period. The fishers experienced damage in houses, nets, boats, roads and plantations during the tropical cyclone period. The primary adaptation strategies undertaken include, but are not limited to, installing tube well for safe drinking water, raising the plinth of the house to cope with inundation, using solar panels/biogas for electricity and rainwater harvesting as a source of safe drinking water. Low income, lack of education and unfavourable credit schemes all played a role in limiting and barring the adaptation strategies to combat the adverse climatic conditions and events.

The small fishing communities have financial constraints to purchase fishing accessories. Decreasing trends in the abundance of fish results in a lack of adequate income. Taking institutional assistance to overcome livelihood challenges is the key to survive; therefore, they take a loan from the GoB/NGOs that puts them into a vicious debt in the long run.

Interestingly, the identified limits and barriers (Table 6) to the adaptation strategies are mainly not associated with climate extremes; instead, they were related to dynamic social characteristics. Low income, lack of education and unfavourable credit schemes are major constraints for their secured livelihood. As the fisher has to take informal loans from moneylenders with a high interest rate and need to pay a double or triple than the formal banking loan rate, consequently keeping them in a credit trap. Despite having such difficulty in maintain their livelihood, one-third of the fishermen were satisfied and the majority of them did not want to change their profession in near future.

5. Conclusions

This research identified fisher communities' perception and symptoms of climate change and characterised consequences and impacts of extreme events on livelihoods and their adaptation strategies and plans to live with extreme climate events. The fisher community perceived an increase in temperature, tropical cyclone intensity and sea level, and decreased monsoon rainfall. When these local accounts of climate change were compared with the scientific evidence, the correlation between these is positive in rising scenarios of temperature, tropical cyclone intensity and sea level, but not relevant in the case of a decrease in monsoon rainfall. The fishers opined that rather than climatic stress, they experienced non-climatic factors (i.e. the GoB rules, less profit, bank erosion, dominancy by commercial fishers, etc.), which regularly hindered economic activities. Although the fishing communities experienced social stress and extreme climate events and disasters frequently, the overwhelming majority opined that they would not change their profession in the future. It implies that there is scope for implementing risk reduction strategies relating to non-climatic factors in Bangladesh's coastal region while considering the particular needs of small-scale fishers who would love to contribute to continuous protein generation among the communities. As this research identified that *Poush* (December–January) and *Magh* (January–February) are very bad for fishing based on fishers' opinion, the GoB and NGOs may undertake appropriate social safety programme and or alternative livelihood approaches for that period.

The findings presented are based on the semi-structured and open-ended questionnaire surveys with 135 fishers and four FGDs in southeast Bangladesh coast leaving the scope for further validation extending the number of research participants in the other region of the country and beyond.

Notes

1. The smallest unit of local land division and administration is called union in Bangladesh.
2. *Kartik* is a month in Bengali calendar, a luni-solar calendar and corresponds to the months of October–November in Gregorian calendar.

References

Abedin, M.A., Habiba, U. and Shaw, R. (2014), "Community perception and adaptation to safe drinking water scarcity: salinity, arsenic, and drought risks in coastal Bangladesh", *International Journal of Disaster Risk Science*, Vol. 5 No. 2, pp. 110-124.

Alam, E. (2002), "Post cyclone adjustment process: the case of sandwip, Bangladesh", MSc thesis, Department of Geography and Environment, University of Dhaka, Bangladesh.

Alam, E. (2017), "Enhancing community resilience to climate change-an investigation of climate impacts and community led adaptation strategies of remote coastal peoples in Bangladesh", *Climate Change*, Vol. 3, pp. 729-738.

Alam, E. and Collins, A.E. (2010), "Cyclone disaster vulnerability and response experiences in coastal Bangladesh", *Disasters*, Vol. 34 No. 4, pp. 931-954.

Alam, E. and Dominey-Howes, D. (2014), "A new catalogue of tropical cyclones of the Northern Bay of Bengal and the distribution and effects of selected landfalling events in Bangladesh", *International Journal of Climatology*, Vol. 35 No. 6, pp. 801-835, doi: 10.1002/joc.4035.

Alam, E., Momtaz, S., Bhuiyan, H.U., *et al.* (2018), "Climate change impacts on the coastal zones of Bangladesh: Perspectives on tropical cyclones, sea level rise, and social vulnerability", in Islam, M.N. and van Amstel, A. (Eds), *Bangladesh I: Climate Change Impacts, Mitigation and Adaptation in Developing Countries*, Springer International Publishing, Cham, pp. 145-166.

Balaguru, K., Taraphdar, S., Leung, L.R. and Foltz, G.R. (2014), "Increase in the intensity of postmonsoon Bay of Bengal tropical cyclones", *Geophysical Research Letters*, Vol. 41, pp. 3594-3601, doi: 10.1002/2014GL060197.

Bartlett, J.E., Kotrlik, J.W. and Higgins, C.C. (2001), "Organizational research: determining appropriate sample size in survey research", *Information Technology, Learning, and Performance Journal*, Vol. 19, pp. 43-50.

BBS (2020), *Bangladesh Statistical Year Book 2019*, Dhaka: Bangladesh Bureau of Statistics, Government of the People's Republic of Bangladesh.

Bhuiyan, M.J.A.N. and Dutta, D. (2012), "Analysis of flood vulnerability and assessment of the impacts in coastal zones of Bangladesh due to potential sea-level rise", *Natural Hazards*, Vol. 61 No. 2, pp. 729-743.

Birkmann, J., Cardona, O.D., Carreño, M.L., *et al.* (2013), "Framing vulnerability, risk and societal responses: the MOVE framework", *Natural Hazards*, Vol. 67 No. 2, pp. 193-211.

Bose, S. (2013), "Sea-level rise and population displacement in Bangladesh: impact on India", *Maritime Affairs: Journal of the National Maritime Foundation of India*, Vol. 9 No. 2, pp. 62-81.

Brown, A. (2014), "Adaptation and mitigation", *Nature Climate Change*, Vol. 4 No. 10, pp. 860-860.

Castells-Quintana, D., Lopez-Uribe, M.P. and McDermott, T.K.J. (2018), "Adaptation to climate change: a review through a development economics lens", *World Development*, Vol. 104, pp. 183-196.

Cooper, M., Brown, M.E., Azzarri, C., *et al.* (2019), "Hunger, nutrition, and precipitation: evidence from Ghana and Bangladesh", *Population and Environment*, Vol. 41 No. 2, pp. 151-208.

Creswell, J.W. (2009), *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, London: Sage.

Dasgupta, S., Hossain, M.M., Huq, M., *et al.* (2018), "Climate change, salinization and high-yield rice production in coastal Bangladesh", *Agricultural and Resource Economics Review*, Vol. 47 No. 1, pp. 66-89.

DoF (2018), "Yearbook of fisheries statistics of Bangladesh,2017-18", *Fisheries Resources Survey System (FRSS), Department of Fisheries*, Bangladesh: Ministry of Fisheries. 35:129.

Gemenne, F. and Blocher, J. (2017), "How can migration serve adaptation to climate change? Challenges to fleshing out a policy ideal", *The Geographical Journal*, Vol. 183 No. 4, pp. 336-347.

Gillett, N.P., Kirchmeier-Young, M., Ribes, A., *et al.* (2021), "Constraining human contributions to observed warming since the pre-industrial period", *Nature Climate Change*, Vol. 11 No. 3.

Gregory, D., Johnston, R., Pratt, G., *et al.* (2009), *The Dictionary of Human Geography*, West Sussex: Wiley-Blackwell.

Hasan, Z., Akhter, S. and Islam, M. (2014), "Climate change and trend of rainfall in the south-east part of coastal Bangladesh", *European Scientific Journal*, Vol. 10 No. 2, pp. 25-39.

IPCC (2011), "Summary for policymakers", in Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Seyboth, K., Matschoss, P., Kadner, S., Zwickel, T., Eickemeier, P., Hansen, G., Schlömer, S. and von Stechow, C. (Eds), *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2014), "Climate change 2014: impacts, adaptation, and vulnerability", *Final Draft IPCC WGII AR5 Technical Summary*.

Iqbal, M.H. (2020), "Valuing ecosystem services of Sundarbans mangrove forest for improved conservation: approach of randomized conjoint experiment", *Forestry Economics Review*, Vol. 2 No. 1, pp. 117-132.

Islam, M.M., Islam, N., Habib, A., *et al.* (2020), "Climate change impacts on a tropical fishery ecosystem: Implications and societal responses", *Sustainability*, Vol. 12 No. 19, p. 7970.

Islam, M.M., Sallu, S., Hubacek, K., *et al.* (2014), "Vulnerability of fishery-based livelihoods to the impacts of climate variability and change: insights from coastal Bangladesh", *Regional Environmental Change*, Vol. 14 No. 1, pp. 281-294.

Kashem Shakil, B. (2019), "Housing practices and livelihood challenges in the hazard-prone contested spaces of rural Bangladesh", *International Journal of Disaster Resilience in the Built Environment*, Vol. 10 No. 5, pp. 420-434.

Khalil, M.B., Jacobs, B.C., McKenna, K., *et al.* (2020), "Female contribution to grassroots innovation for climate change adaptation in Bangladesh", *Climate and Development*, Vol. 12 No. 7, pp. 664-676.

Khan, A.E., Xun, W.W., Ahsan, H., *et al.* (2011), "Climate change, Sea-Level rise, and health impacts in Bangladesh", *Environment: Science and Policy for Sustainable Development*, Vol. 53, pp. 18-33.

Klotzbach, P.J. (2006), "Trends in global tropical cyclone activity over the past twenty years (1986–2005)", *Geophysical Research Letters*, Vol. 33 No. L10805, pp. 1-4.

McNamara, K.E., Clissold, R., Westoby, R., *et al.* (2020), "An assessment of community-based adaptation initiatives in the pacific islands", *Nature Climate Change*, Vol. 10 No. 7, pp. 628-639.

Mallick, B. and Schanze, J. (2020), "Trapped or voluntary? Non-migration despite climate risks", *Sustainability*, Vol. 12 No. 11, p. 4718.

Mallick, B., Ahmed, B. and Vogt, J. (2017), "Living with the risks of cyclone disasters in the South-Western coastal region of Bangladesh", *Environments*, Vol. 4 No. 1.

Mallick, B., Sultana, Z. and Bennett, C.M. (2020), "How do sustainable livelihoods influence environmental (non-)migration aspirations?", *Applied Geography*, Vol. 124, p. 102328.

MoEF (2009), *Bangladesh Climate Change Strategy and Action Plan 2009*. Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, Vol. xvii, p. 76.

Niles, M.T., Lubell, M. and Brown, M. (2015), "How limiting factors drive agricultural adaptation to climate change", *Agriculture, Ecosystems and Environment*, Vol. 200, pp. 178-185.

Pokhrel, Y., Felfelani, F., Satoh, Y., *et al.* (2021), "Global terrestrial water storage and drought severity under climate change", *Nature Climate Change*, Vol. 11 No. 3.

Pouliotte, J., Smit, B. and Westerhoff, L. (2009), "Adaptation and development: livelihoods and climate change in Subarnabad, Bangladesh", *Climate and Development*, Vol. 1 No. 1, pp. 31-46.

Rahman, M.S., Karamehic-Muratovic, A., Baghbanzadeh, M., *et al.* (2020), "Climate change and dengue fever knowledge, attitudes and practices in Bangladesh: a social media–based cross-sectional survey", *Transactions of the Royal Society of Tropical Medicine and Hygiene*, Vol. 115 No. 1, pp. 85-93.

Rakib, M.A., Sasaki, J., Matsuda, H., *et al.* (2020), "Groundwater salinization and associated co-contamination risk increase severe drinking water vulnerabilities in the southwestern Coast of Bangladesh", *Chemosphere*, Vol. 246125646.

Rathore, L.S., Mohapatra, M. and Geetha, B. (2017), "Collaborative mechanism for tropical cyclone monitoring and prediction over north Indian ocean", in Mohapatra, M., Bandyopadhyay, B.K. and Rathore, L.S. (Eds), *Tropical Cyclone Activity over the North Indian Ocean*, Springer International Publishing, Cham, pp. 3-27.

Reggers, A., *et al.* (2019), "Climate change is not gender neutral: gender inequality, rights and vulnerabilities in Bangladesh", in Huq, S., Chow, J. and Fenton, A. (Eds), *Confronting Climate Change in Bangladesh: Policy Strategies for Adaptation and Resilience*, Springer International Publishing, Cham, pp. 103-118.

Rozario, R.R.R. (2019), "Fishing ban leaves Bangladeshi fishermen all at sea", available at: www.ucanews.com/news/fishing-ban-leaves-bangladeshi-fishermen-all-at-sea/85283#

Sarkar, M.A.R., Alam, K. and Gow, J. (2013), "Assessing the determinants of rice farmers' adaptation strategies to climate change in Bangladesh", *International Journal of Climate Change Strategies and Management*, Vol. 5 No. 4, pp. 382-403.

Sarwar, M.G.M. (2013), "Sea-level rise along the coast of Bangladesh", in Shaw, R., Mallick, F. and Islam, A. (Eds), *Disaster Risk Reduction Approaches in Bangladesh. Disaster Risk Reduction (Methods, Approaches and Practices)*, Springer, Tokyo, doi: 10.1007/978-4-431-54252-0_10.

Schipper, E.L.F. (2020), "Maladaptation: when adaptation to climate change goes very wrong", *One Earth*, Vol. 3 No. 4, pp. 409-412.

Shahid, S. (2009), "Probable impacts of climate change on public health in Bangladesh", *Asia Pacific Journal of Public Health*, Vol. 22 No. 3, pp. 310-319.

Shameem, M.I.M., Momtaz, S. and Kiem, A.S. (2015), "Local perceptions of and adaptation to climate variability and change: the case of shrimp farming communities in the coastal region of Bangladesh", *Climatic Change*, Vol. 133 No. 2, pp. 253-266.

Sharifuzzaman, S.M., Hossain, M.S., Chowdhury, S.R., *et al.* (2018), "Elements of fishing community resilience to climate change in the coastal zone of Bangladesh", *Journal of Coastal Conservation*, Vol. 22 No. 6, pp. 1167-1176.

Smit, B. and Wandel, J. (2006), "Adaptation, adaptive capacity and vulnerability", *Global Environmental Change*, Vol. 16 No. 3, p. 282-292.

SMRC (1998), *The Impact of Tropical Cyclones on the Coastal Region of SAARC Countries and Their Influence in the Region*, SRMC No. 1, Dhaka, Bangladesh.

Thomas, K., Hardy, R.D., Lazrus, H., *et al.* (2019), "Explaining differential vulnerability to climate change: a social science review", *WIREs Climate Change*, Vol. 10 No. 2.

Unnikrishnan, A.S. and Shankar, D. (2007), "Are sea-level-rise trends along the coasts of the North Indian Ocean consistent with global estimates? Global planet", *Change*, Vol. 57 Nos 3/4, pp. 301-307.

Unnikrishnan, A.S., Kumar, M.R.R. and Sindhu, B. (2011), "Tropical cyclones in the Bay of Bengal and extreme sea-level projections along the east coast of India in a future climate scenario", *Current Science*, Vol. 101 No. 3, pp. 327-331.

Vivekanandan, E., Hermes, R. and O'Brien, C. (2016), "Climate change effects in the Bay of Bengal large marine ecosystem", *Environmental Development*, Vol. 17, pp. 46-56.

Wisner, B., Blaikie, P., Cannon, T., *et al.* (2004), *At Risk: Natural Hazards, People's Vulnerability and Disasters*, Routledge, London.

Wood, S.A., Jina, A.S., Jain, M., *et al.* (2014), "Smallholder farmer cropping decisions related to climate variability across multiple regions", *Global Environmental Change*, Vol. 25, pp. 163-172.

Younus, M.A.F. (2017), "Adapting to climate change in the coastal regions of Bangladesh: proposal for the formation of community-based adaptation committees", *Environmental Hazards*, Vol. 16 No. 1, pp. 21-49.

Further reading

Monirul Islam, M., Sallu, S., Hubacek, K., *et al.* (2014), "Limits and barriers to adaptation to climate variability and change in Bangladeshi coastal fishing communities", *Marine Policy*, Vol. 43, pp. 208-216.

Ray-Bennett, N.S., Collins, A.E., Edgeworth, R., *et al.* (2016), "Everyday health security practices as disaster resilience in rural Bangladesh", *Development in Practice*, Vol. 26 No. 2, pp. 170-183.

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