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Economic and non-economic loss and damage to climate change: evidence from a developing country shrimp farms to cyclone Bulbul

Md. Monirul Islam[1], Tanjila Akter Nipa[1], Md. Sofiqul Islam[2], Mahmudul Hasan[3], Makidul Islam Khan[1,4,*]

[1] *Department of Fisheries, University of Dhaka, Dhaka-1000, Bangladesh*
[2] *Department of Fisheries, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh*
[3] *Department of Oceanography, University of Dhaka, Dhaka-1000, Bangladesh*
[4] *International Centre for Ocean Governance, Faculty of Earth and Environmental Sciences, University of Dhaka, Dhaka-1000, Bangladesh*

Abstract

Loss and damage have become a vital contemporary issue in climate change studies and actions in developing countries. However, studies are scant on this in the fisheries sector around the world. In Bangladesh, there is no study on the loss and damage in fisheries dependent communities. This study assesses economic and non-economic loss and damage to coastal shrimp farms due to cyclone Bulbul in Gabura Union of Shyamnagar Upazila, Satkhira district, using a mixed method approach. Results show that all shrimp farms' dependent communities are affected by cyclone Bulbul to some extent. About 14%, 57%, and 29% of the farms were totally, heavily and moderately damaged due to farm inundation and dyke damage. The estimated mean loss and damage per shrimp farm was worth USD 4,633. Around 31% and 72% of the farms' fencing nets and traps were lost, which was worth USD 333 per farm. There were also loss and damage to other resources such as houses, solar panels, livestock and agricultural crops where the estimated mean loss and damage per household was worth USD 3,170. This study reported that the rich shrimp farmers encountered proportionately more economic loss and damage than their poor counterparts. However, this does not mean that the poor suffered less. The current study found a range of non-economic loss and damage in different aspects of the shrimp farmers' household members such as unbearable mental pain, deterioration of health, physical injuries, disabilities, etc. and access to services (e.g., inadequate food, lack of safe drinking water, lack of medical facilities, disruption of education systems), social infrastructure (e.g., damage of roads and markets) and disturbance of cultural functions. The findings suggest that urgent short- and long-term actions may be taken to save the aquaculture farms and dependent livelihoods from economic and non-economic loss and damage to cyclones in future.

Keywords: Loss and damage, Economic and non-economic, Climate change, Aquaculture, Cyclone Bulbul, Bangladesh

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***Corresponding author:** Makidul Islam Khan
International Centre for Ocean Governance, Faculty of Earth and Environmental Sciences, University of Dhaka, Dhaka-1000, Bangladesh
Tel: +880-1739-923974, **E-mail:** makidul07@gmail.com

Introduction

Loss and damage have turned into an important contemporary issue in climate change studies and actions, especially after the establishment of the Warsaw International Mechanism for Loss and Damage linked with Climate Change Impacts, to discourse loss and damage related impacts of climate change in developing countries that are predominantly vulnerable to the hostile impacts of climate change at COP19 (19th Conference of Parties under United Nations Framework Convention on Climate Change in 2013). Loss and damage are defined by the impacts of climate change that happen regardless of adaptation and mitigation efforts. The meaning attributed to loss and damage, and considerations of how to approach it, vary across actors (Boyd et al., 2016). Climate change impacts that are everlasting and irreversible are categorized as loss, whereas damage refers to impacts where recompense or refurbishment is possible (UNFCCC, 2012). Loss and damage also refer to undesirable effects of climate variability and climate change that people have been unable to deal with or adapt to (Warner & van der Geest, 2013).

Loss and damage can be assessed from economic or non-economic perspective that has been included in the agendum of the Warsaw International Mechanism (Fankhauser et al., 2014). Economic loss and damage refer to loss and damage to resources that are generally traded in market such as physical resources, disruption of economic activities and livelihoods (Fankhauser et al., 2014). Non-economic loss and damage can be defined as loss of life, deterioration of health, unbearable mental pains, loss of sovereignty, disturbance of cultural functions, loss of biodiversity and ecosystem services whose market value cannot be estimated in general statistics (Andrei et al., 2014; Fankhauser et al., 2014; McNamara et al., 2021; Serdeczny, 2019).

Globally, Bangladesh is one of the most climate vulnerable countries (Climate Change Cell, 2007) and according to the Global Climate Risk Index 2020, she has been ranked 7th as the most affected countries because of climate change around the world from 1999–2018 (Eckstein et al., 2019). Climatic hazards are intensifying the impact of climate change in a range of sectors, with the fisheries sector among the hardest hit. Cyclones and other climatic hazards are considered as potential threats to the economy, livelihood and environment of coastal fisheries (Ahsan & Brandt, 2015). While the coastal fisheries and fishing communities are still recovering from the devastating cyclones like Gorki, Sidr and Aila (Islam et al., 2014; Mallick & Vogt, 2012), two more cyclones hit the country namely – Fani and Bulbul in 2019. Between them, the latter cyclone Bulbul — hit in November 2019 — is regarded as a severe cyclonic storm and has brought major losses and damages to 14 coastal districts of Bangladesh. The south-western part of Bangladesh especially Satkhira, Khulna and Bagerhat are amongst the severely impacted zones (Fig. 1). Bulbul was hit with a wind speed of 120 km/hr and gusts up to 150 km/hr. The cyclone stayed in the country for around 36 hrs — one of the longest enduring cyclones that Bangladesh has ever faced in the last five decades and left 12 dead in the coastal districts of Bangladesh (Needs Assessment Working Group, 2019). In total, cyclone Bulbul affected 0.73 million people in 14 coastal districts of Bangladesh. The joint rapid assessment reports showed that 20,849 and 133,442 houses were fully and partially damaged, respectively (Needs Assessment Working Group, 2019). Total 289,006 ha of agriculture land was affected and around 22,836 ha of agriculture land's crops were completely damaged, which was worth USD 31 million (Needs Assessment Working Group, 2019). The estimated monetary loss in aquaculture and livestock in coastal Bangladesh was around USD 5.5 million and USD 285,000, respectively (Needs Assessment Working Group, 2019).

Bangladesh is placed the 5th and the 3rd position in aquaculture and inland open water capture fish production around the world, respectively (FAO, 2020). This is because Bangladesh has vast waterbodies including inland freshwater (e.g., floodplains, ponds, rivers, oxbow lakes, large depressions — locally known as haor and beel), estuaries, coastal and brackish waters, and untapped huge volume of marine waters which significantly contribute in fisheries and aquaculture production (Table 1).

In Bangladesh, shrimp is called 'white gold' because of their significant contribution to the national economy (Ahmed & Diana, 2015). Yearly total shrimp production of Bangladesh was 72,809 MT in 1986–1987 which was rocketed to 241,281 MT in 2019-2020 (DoF, 2020) (Fig. 2). However, there are undying controversies on the impacts of shrimp farming on social, economic and environmental sustainability of coastal communities (Abdullah et al., 2017; Paprocki & Huq, 2018). In coastal areas of Bangladesh, shrimp farming has caused some environmental damages like increasing soil and groundwater salinity and destruction of mangrove forests (Paprocki & Huq, 2018), social inequalities (Murshed-e-Jahan et al., 2014) and economic imbalance (Belton, 2016) to some extent. Beyond negative arguments, shrimp farming has mostly brought widespread social and economic benefits. For example, it has increased income, improved food security and better employment opportunities for coastal

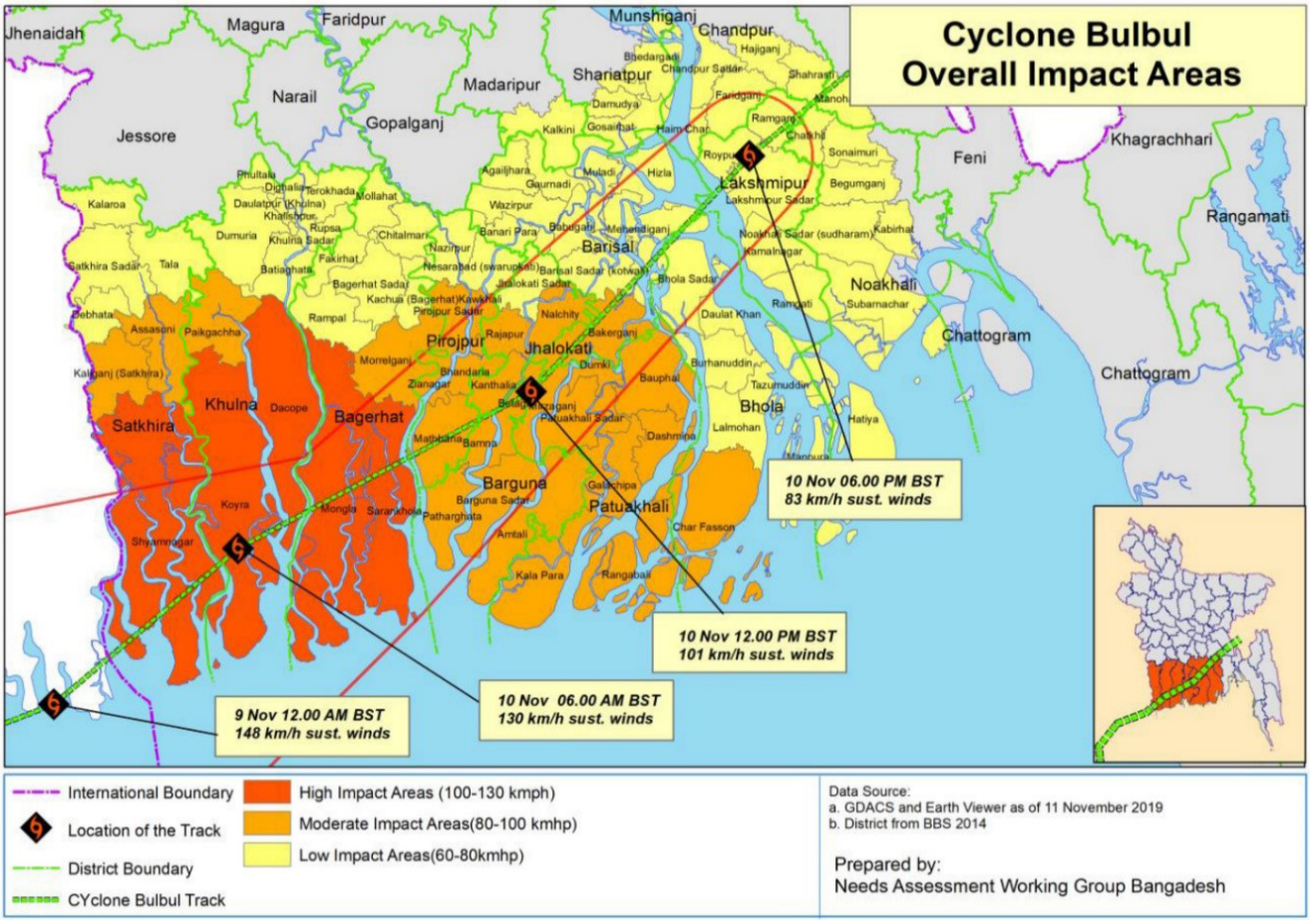

Fig. 1. Impact areas of cyclone Bulbul on coastal regions of Bangladesh. Adapted from Needs Assessment Working Group (2019) with CC-BY.

people (Ahmed, 2013; Belton et al., 2014; Murshed-e-Jahan et al., 2010; Pokrant & Reeves, 2003). However, shrimp farms are adversely affected by climatic changes (Ahmed & Diana, 2015; Kais & Islam, 2018; Shameem et al., 2015) that result in loss and damages to the farms.

In the global context, only a few studies have been conducted on climate-induced loss and damage (Acosta et al., 2016; Clarke et al., 2021; Doelle & Seck, 2020; Singh et al., 2021; Thomas & Benjamin, 2020; Warner & van der Geest, 2013). Most of the studies on loss and damage focused on non-fishery related households due to the impacts of climatic hazards. In particular, previous studies assessed the non-economic loss and damage caused by heatwave (Barriopedro et al., 2011), salinity intrusion and portable water crisis (Rakib et al., 2019), sea-level rise (Wong et al., 2014) and other climatic hazards on the overall livelihoods of coastal people. In the context of Bangladesh, in spite of intensifying evidence of climate change impacts on livelihoods and socio-economic circumstances of fisheries (Hossain et al., 2018; Huq et al., 2019; Islam et al., 2014; Minar et al., 2013), there is no study on the loss and damage of the fisheries and dependent communities. Recently, Bhowmik et al. (2021) assessed the climatic hazard-related loss and damage and the state of adaptive capacity of rural coastal communities of Bangladesh that were different from the fisheries perspective. Though the fisheries sector portrays an imperative role in the economy, food security and employment opportunities, the frequent and intense hit by devastating cyclones in recent years in coastal areas of Bangladesh has made the loss and damage study a forefront research agendum. The loss and damage happened in many different ways within the fisheries sector which has not been reported so far. Therefore, it is badly needed to assess the economic and non-economic loss and damage of this sec-

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tor in order to identify ways to better adapt and build resilient communities. Thus, the objective of this study is to assess the economic and non-economic loss and damage of some shrimp farms in south-west Bangladesh that were the hardest hit by cyclone Bulbul.

With this understanding, it will be possible to develop policies and strategies to mitigate loss and damage in coastal shrimp farms as well as in the whole fisheries sector of Bangladesh. Studying loss and damage will help to produce evidence of the climatic impacts for vulnerable developing countries like Bangladesh to claim resilience and adaption funds and supports from the developed countries that are mostly accountable for climate change. This will ultimately play a role in poverty reduction among the fisheries dependent people and sustainable development of the country, more broadly.

Table 1. Area of aquaculture and fisheries and fish production in Bangladesh

Sub-sector of aquaculture and fisheries	Water area (ha)	Production (MT)
Aquaculture	821,923	2,488,601
Pond	397,775	1,974,632
Seasonal cultured waterbody	144,217	217,340
Oxbow lake (Baor)	5,671	10,343
Crab farm	9,377	12,084
Shrimp/prawn farm	258,553	258,039
Pen culture	6,330	12,361
Cage culture	176,213 (m^3)	3,802
Inland open water capture fisheries	3,890,282	1,235,709
River and estuary	853,863	325,478
Sundarbans	177,700	18,282
Large depressions (Beel)	114,161	99,890
Kaptai lake	68,800	10,578
Floodplain	2,675,758	781,481
Subtotal	4,712,205	3,724,310
Marine Fisheries	118,813 (km^2)	659,911
Industrial		107,236
Artisanal		552,675
Grand total		4,384,221

Adapted from DoF (2020) with permission of Author.

Materials and Methods

Description of the study site

This study was conducted in Gabura, a coastal island union (a union has several villages inside it), located at Shyamnagar Upazila (sub-district) in Satkhira district of southwest Bangladesh (Fig. 3). More than a century ago, it was a part of the world's largest mangrove (Sundarbans) where people started living for shelters and livelihoods (Alam et al., 2015). It is surrounded by the Kholpetua and Kopotakhsa rivers, which separate it from the mainland. At present, it has become a distinct island covering an area of 33 km^2 with a population of 43,262 in 8,321

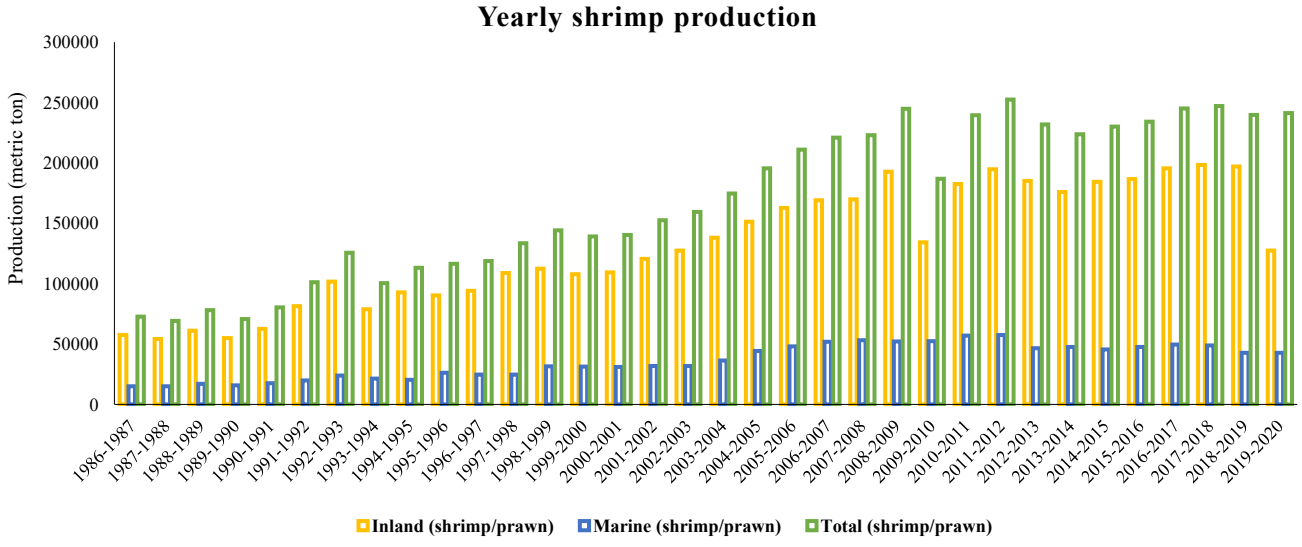

Fig. 2. Yearly shrimp production in Bangladesh from 1986–2020. Adapted from DoF (2020) with CC-BY.

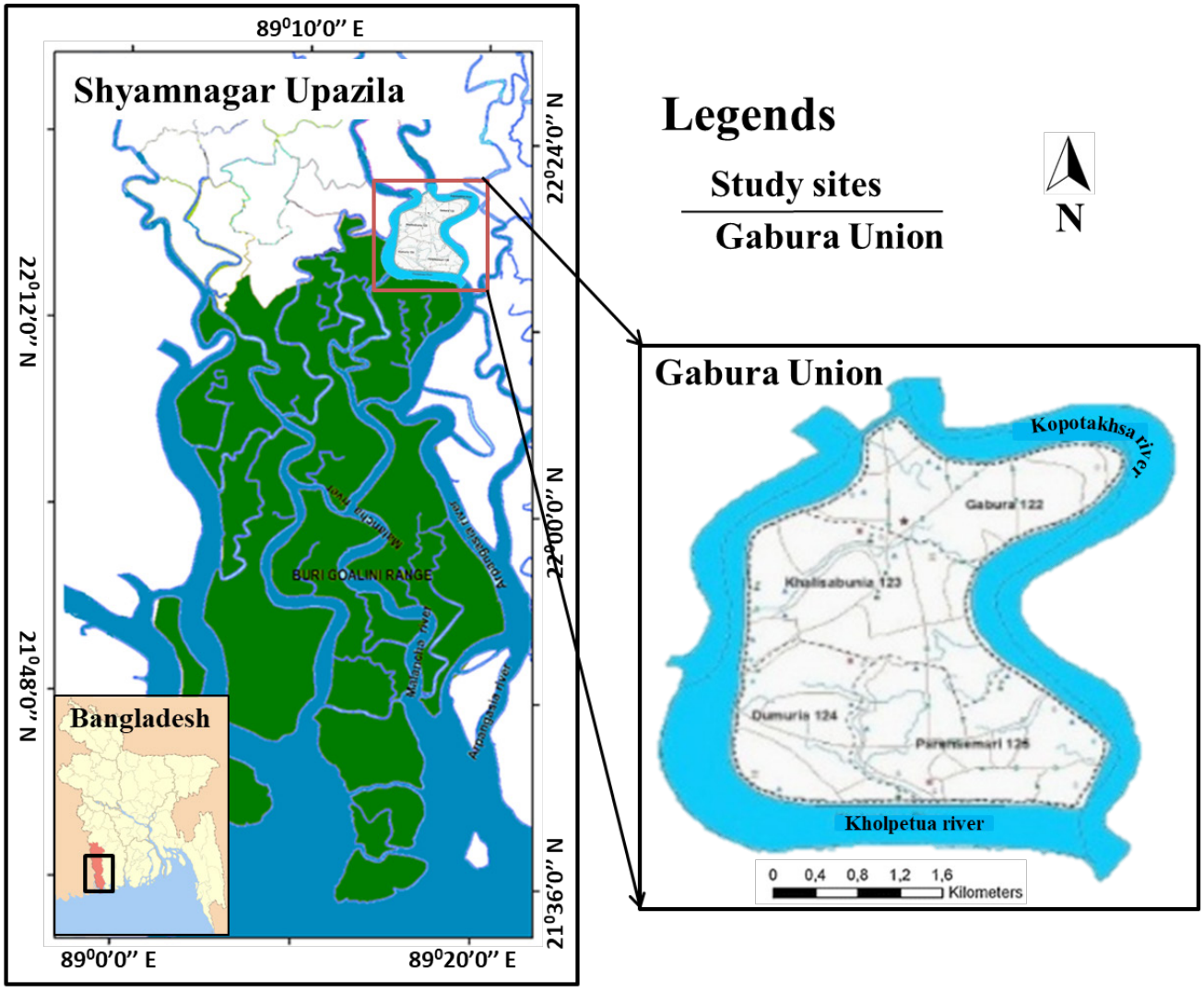

Fig. 3. Map of the study sites in Gabura Union of Shyamnagar Upazila, Satkhira district.

households (Gabura Union Parishad, 2019).

Gabura was selected as the study site because it was one of the most affected unions in the worst affected district of Satkhira due to the adverse impacts of cyclone Bulbul (Fig. 1). In addition, it was highly vulnerable to frequent cyclones and floods (Rakib et al., 2019). This island is situated less than 1 m above sea level and as a result, it is prone to being often flooded by storm surges and tidal surges. Over the last two decades, two super cyclones — Sidr in 2007 and Aila in 2009 — caused huge loss and damage in this union. Cyclone Sidr inundated this area for a record time and resulted in immense loss and damage of lives and properties. The destruction of Aila was more devastating as death toll was 28, the number of lost houses was 11,450 and the heavily damaged shrimp farm areas were 43 km^2 in Gabura (Tajrin & Hossain, 2017).

Most of the people in Gabura Union depend on fisheries and agriculture-related activities for their livelihoods. According to Gabura Union Parishad (2019), almost 80% of the households are involved in shrimp farming. In this union, shrimp farms covered an area of 11 km^2. The main cultured shrimp and prawn species are - *Penaeus monodon* (Tiger shrimp - Bagda chingri), *P. indicus* (Indian white shrimp - Chaka chingri), and *Macrobrachium rosenbergii* (Giant freshwater prawn - Galda chingri). In addition, shrimp farmers also culture some finfish species such as *Liza parsia* (Brackish water mullet - Parse), *Scatophagus argus* (Spotted scat - Chitra), *Oreochromis mos-*

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sambicus (Tilapia), *Mystus cavasius* (Gangetic mystus - Golsha tengra), *Mystus tengara* (Tengara catfish - Bajari tengra) and *Lates calcarifer* (Seabass) along with the shrimp. Around 20% of the households rely on agriculture and other alternative livelihood activities such as day labouring, driving, honey and firewood collecting, selling and shop keeping.

The socio-demographic conditions of Gabura Union are not good because of low-quality houses, poor transportation and medical facilities, low-quality social-infrastructure, lack of enough cyclone shelters, etc. (Table 2). Around 72% of the houses are earthen which mostly made of low-quality materials such as mud and thatch. The transport system is not well developed because of having no direct land connection with the mainland, except for a small bridge. As a result, local people use waterway transportation such as mechanized and non-mechanized boats, trawlers, etc. The land transportation facilities inside the union are also very poor due to muddy roads (85%) which become very slushy and slippery during the rainy season, and full of dust, dirt and ditches during the dry season. Local people also face great trouble with medical services due to lack of skilled doctors, inadequate supply of urgent medicines, lack of or insufficient urgent medical equipment's, etc. A summary of the socio-demographic characteristics of the Gabura Union is given in Table 2.

Data collection

An initial scoping study was conducted to get an overall idea about the study site and overall impacts of the cyclone Bulbul. Data were collected applying a mixed-method approach from January to March 2020. Data collection tools are given below.

Questionnaire survey

A semi-structured questionnaire was used for household survey to gather data on livelihood assets and activities, vulnerability, exposure to risks and hazards, and loss and damage due to cyclone Bulbul. Loss and damage of shrimp farms due to the impacts of cyclone Bulbul were categorized into five groups such as 'total loss or damage' = no harvest was possible from the farms because of total shrimps escaping or mortality due to farms inundation and dyke damage, 'heavily damage' = more than or equal to 66% of shrimp harvest was lost because of shrimps escaping or mortality due to farms inundation and dyke damage, 'moderately damage' = more than 33% to less than 66% of shrimp harvest was lost because of shrimps escaping or mortality due to farms inundation and dyke damage, 'light damage' = less than or equal to 33% of shrimp harvest was lost because of shrimps escaping or mortality due to farms inundation and dyke damage, 'no loss or damage' = no harvest loss or damage. A list of tangible and non-tangible resources of the shrimp farmers is given in Table 3. To estimate economic loss and damage, the status of the fisheries resources such as market price before cyclone Bulbul (pre-disaster stage) and after cyclone Bulbul (post-disaster stage) was collected. Depending on the scoping study and literature review, a questionnaire was developed at first. The survey questionnaires were pilot-tested with a small number of participants to check and validate the suitability of the questions asked and the phrasing used. All the questions were translated from English to Bengali before being asked. These questions were asked in face-to-face interviews with the household heads. The households for the questionnaire survey were selected by applying a stratified random sampling method from the sampling frame of the Gabura Union using a web-based random number producer tool (Randomness and Integrity Services Limited, 2019). In this study, a total of 120 shrimp farmers were interviewed, and each interview was continued for 1–1.30 hrs.

Key informant interviews (KIIs)

KIIs were conducted with the people who had enough knowledge on the impacts of cyclone Bulbul and fisheries especially shrimp farms of the study area. For KIIs, government fisheries officers, shrimp farmers, leaders of shrimp farms association, and experts from non-governmental organization (NGO) were selected. The interviewees were purposefully sampled so that all wealth groups, especially shrimp farmers were included. The purpose of the qualitative interviews was to obtain a rich, detailed and contextually grounded concept of the root causes of loss, damage, vulnerability, and their linkages with livelihood patterns. A tentative checklist for these interviews was prepared, which was revised after scoping and pilot studies. The most cooperative and enthusiastic household heads were also selected for KIIs. In this study, a total of 25 KIIs were conducted and each interview lasted for 1–1.30 hrs.

Focus group discussions (FGDs)

FGDs were conducted to further evaluate the key observations from the questionnaire survey and KIIs and to triangulate them. A list of themes and probable questions related to loss and damage due to the impacts of cyclone Bulbul was prepared before starting the discussion to check whether the discussions

Table 2. Socio-demographic characteristics of Gabura Union, Shyamnagar Upazila, Satkhira, Bangladesh

Socio-demographic factors		Percentage (otherwise specified)	Remarks
Livelihood options	Fisheries	80	Most of the household members are involved in shrimp farming. Other fishery related activities are fishing, shrimp and fish marketing, boat making and repairing, net mending, etc.
	Agriculture and other alternative livelihood activities	20	Other alternative livelihood activities are day labouring, driving, poultry and goat rearing, groceries and shop-keeping.
House	Earthen	72	Earthen houses are generally made of low-quality materials such as mud and thatch.
	Semi-concrete	18	Semi-concrete houses have either bricks, cement and iron made foundation or concrete made plinths. Walls and rooftops are generally made of tin, thatch or woods.
	Concrete	10	Concrete houses are made of concrete, bricks, cement and iron.
Literacy rate (mean)[1)]		35.9	Mean literacy rate of male and female is 38.8% and 33.2% respectively.
School	Primary and secondary	Number: 14	Some of these schools are used as temporary cyclone shelters. A few of these buildings become very old and weak.
Market		Number: 3	Most shops are made of mud and bamboo fence. Infrastructure is not well developed.
Road	Unpaved or earthen road (44 km)	85	In rainy season, they often become muddy, slippery and waterlogged and in the dry season, they become dusty, dirty and ditch.
	Brick pavement road (8 km)	15	Brick pavement or soling road often gets broken.
Medical facilities	Community and satellite clinic	Number: 12	Lack of skilled doctors, inadequate manpower, insufficient urgent medical instruments and medicines, etc.
Sanitation facilities	Hygienic latrine	22	Hygienic latrines include both pit latrines and poured flush water seal toilets. Usually, 3-4 households' members are using one toilet.
	Unhygienic latrine	60	Unhygienic latrines are generally set beside ponds and rivers. As a result, feces contaminate the surrounding water and deteriorate the environmental condition.
	No latrine	18	Those households' members who do not have any toilet defecate on the open place. Female household members are the worst victim of these circumstances.
Drinking water facilities	Deep tube-well	95	Most people use deep tube-well water for drinking. However, they use river waters for bathing, washing clothes and utensils, etc.
	Pond Sand Filter (PSF)	23	PSF was introduced in the community with the help of few non-governmental organizations. However, the number of PSF is not adequate to provide safe water for most of the people.
Electricity facilities	Grid lines	0	No grid electricity is available in the union.
	Solar panel	100	Solar panels are used in all households.
Cyclone shelter		Number: 3	Insufficient in number, shortage of space, male and female members of different households stay tightly sharing common place. In this circumstances, female household members feel insecure in the cyclone shelters and as a result, they show reluctance to come in cyclone shelters during any disaster.

[1)] Adapted from Bangladesh Bureau of Statistics (BBS, 2014) with permission of Author.
Adapted from Gabura Union Parishad (2019) with permission of Author.

move on right directions. More emphasis was given to validating topics which seemed vague in the questionnaire survey and KIIs. Each session was lasted for about 3 hrs and discussed 5–8 topics. For an FGD, a group of 8–10 homogenized household heads of shrimp farms was selected considering their age and gender following the methods of Powell & Single (1996).

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Table 3. List of tangible and non-tangible resources for estimating economic and non-economic loss and damage to shrimp farmers of Gabura Union, Shyamnagar Upazila, Satkhira, Bangladesh

Tangible resources	Non-tangible resources
Shrimp farms	Loss of life
Fencing nets	Deterioration of health
Fishing traps	Mental pains
Mechanized and non-mechanized boat	Physical injuries
Housing condition	Disabilities
Earthen	Psychological problems
Semi-concrete	Loss of memories
Concrete house	Loss of sovereignty
Kitchen	Disturbance of cultural functions
Toilet	Loss of biodiversity
Jewelries	Ecosystem services
Solar panels	Access to services or assets
Television	Food
Radio	School
Cell phone	Pure drinking water
Livestock	Medical service
Cows	Roads
Goats	Cyclone shelter
Poultry	Market
Agricultural land	Firewood

During each session, concentration and momentum were kept to ensure that there was actual involvement and termination on each question. A session summary was written based on notes and audio recordings which included: (i) Profession, number and gender of each session's participants; (ii) Location and length of each session; and (iii) Key findings of each FGD. A total of 8 FGDs were directed in this study.

Data analysis

The qualitative data — KIIs and FGDs — were audio-recorded. The recorded data were transcribed into native language (Bengali). The qualitative data were analyzed applying the adapted grounded theory approach (Strauss & Corbin, 1990). Literature review (and scoping study and researcher's personal expertise on the events under study) permitted probable predetermined categories (themes) of empirical data before analyzing them (a priori approach). Categories of themes were reviewed and revised during multiple stages of data analysis (grounded theory approach). A content analysis technique (Miles & Huberman, 1994) was applied to analyze the qualitative data before translation. Selected quotations were translated into English. For quantitative data, data were analyzed using descriptive statistics in Microsoft Excel (version 13) and data were represented in tabular forms. Economic loss and damage were estimated from the mean market price differences of any asset before and after cyclone hit following the method of World Bank (2010).

Results

Socio-economic status of shrimp farmers

Socio-economic characteristics and available resources of the shrimp farmers of Gabura showed their overall living standards. It also represented their vulnerability to cyclone Bulbul. Based on the impacts of cyclone Bulbul on those resources, their economic and non-economic loss and damage were assessed in this study. A glimpse of the socio-economic characteristics and available resources of the shrimp farmers of Gabura is shown in Table 4 and Table 5.

This study found from the questionnaire survey that the mean age of the shrimp farms' dependent household heads was 46 years (Table 4). Most of the shrimp farmers have been involved in shrimp farming for more than 25 years on average for their livelihoods. Though the majority of the farmers were traditionally involved in shrimp farming, new farmers have also started this practice because of the high profit within short culture periods. The shrimp farm size varied depending on the farmers' financial resources. In this study, shrimp farmers were grouped into three categories such as rich farmers (farm size ≥ 750 decimal), middle-class farmers (farm size < 750 decimal but ≥ 300 decimal) and poor farmers (farm size < 300 decimal). This study has found that 20%, 27%, and 53% of the shrimp farmers were rich, middle-class, and poor farmers, respectively. This study reported that 74% and 86% of shrimp farmers used fencing nets to cover their farms and fishing traps in their farms to catch shrimps, respectively (Table 5). However, none of the farmers used lines and hooks, or mechanized boats in their farms. Only 29% of the farmers had their own non-mechanized boats. The mean monthly income of most shrimp farmers was higher than the mean monthly expenses (Table 4). However, few respondents reported that their mean monthly expenses often exceeded their mean monthly income. This study found that all shrimp farms were dominated by male household heads. Female household members were primarily reliant on male household members for the majority of their needs.

Table 4. Socio-economic characteristics of the shrimp farmers of Gabura Union, Shyamnagar Upazila, Satkhira, Bangladesh

Shrimp farmers' information	Minimum	Maximum	Mean
Age of household head (years)	30	68	46
Education of the household head (years)	0	15	10
Mean household size (number of members)	3	9	5
Involvement in shrimp farming (years)	15	27	25
Area of shrimp farms (decimal)	165	1,320	597
Monthly income of the household (USD)[1)]	94	493	335
Monthly expenditure of the household (USD)[1)]	70	493	234

[1)] USD 1 = BDT 84.80 (Bangladesh Taka, Date: November 13, 2020).
Source: questionnaire survey.

Table 5. List of shrimp farmers livelihoods and household's resources of Gabura Union, Shyamnagar Upazila, Satkhira, Bangladesh

Household resources	Percentage of household that has/uses the resource(s)
Shrimp farms	100
Fencing nets	74
Fishing traps	86
Lines and hooks	0
Mechanized boat	0
Non-mechanized boat	29
Housing condition	
Earthen house	72
Semi-concrete house	18
Concrete house	10
Kitchen	100
Toilet	100
Jewelries	57
Access to drinking water (tube-well)	76
Solar panels	100
Electricity facilities (grid)	0
Television	29
Radio	43
Access to newspaper	14
Mobile phone	100
Cows	0
Goats	29
Poultry	57
Agricultural land	57

Source: questionnaire survey.

Economic loss and damage

The shrimp farmers of the Gabura Union have encountered huge economic loss and damage to cyclone Bulbul which are described below.

According to the questionnaire survey, this study found that all shrimp farmers encountered either loss or damage to cyclone Bulbul. Mostly shrimp farms were severely damaged due to inundations and dyke damages followed by the destruction of fencing nets and traps. Based on the questionnaire survey, it was found that 14% of shrimp farms were totally lost followed by 57% and 29% were heavily and moderately damaged respectively (Table 6). This might be because of the hit of cyclone Bulbul prior to the peak harvesting period (November to December) of the shrimp. One shrimp farmer in Gabura reported during the questionnaire survey *"Cyclone Bulbul hit our farms just before the time of peak harvesting (November to December). We were not able to harvest any shrimp neither fully nor partially."* These happened because most of the shrimp farms were severely inundated (Fig. 4) and dykes were damaged due to the adverse impacts of cyclone Bulbul and as a result, shrimps were escaped from the farms which resulted in economic loss and damage. In addition, one shrimp farmer reported that the shrimp farm water got polluted after the impacts of cyclone Bulbul and as a result, huge shrimp mortality was started which exacerbated the economic loss. Immediately after the cyclone Bulbul, the market price of the shrimps was decreased to some extent. One of the FGD participants said, *"We were bound to sell harvested shrimp at any cost as we did not have any preserving facility. As a result, the mean market price per kg of shrimp had declined from USD 8 to USD 5."* The estimated mean loss and damage per shrimp farm was worth USD 4,633 (Table 7). The KIIs and FGDs data suggest that the rich shrimp farmers encountered proportionately more economic loss and damage than their poor counterparts because of the loss of major investment in the big shrimp farms. One key informant reported that the cyclone Bulbul hit the poor severely, but the rich lost the most. These might be occurred due to rich farmers' having more physical assets than poor counterparts who were affected by the cyclone Bulbul. However, this does not mean that the poor were less affected by the cyclone.

This study reported that around 31% of the farms' fencing nets were lost and another 14% were heavily damaged (Table 6). One of the shrimp farmers said, *"We covered our ghers [shrimp farms] with nets to stop the escaping of shrimp from the ghers, but strong gusts of wind and water surges from cyclone Bulbul*

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Table 6. Impacts of cyclone Bulbul on the valuable resources of the shrimp farmers of Gabura Union, Shyamnagar, Satkhira, Bangladesh

Valuable resources	Impacts of cyclone Bulbul (shrimp farmers' responses in percentage)				
	No loss or damage	Light damage	Moderate damage	Heavy damage	Total damage/loss
Shrimp farm	–	–	29 (34)	57 (68)	14 (16)
Fencing nets	29 (34)	–	–	14 (16)	31 (37)
Fishing traps	14 (16)	–	–	–	72 (86)
Non-mechanized boat	29 (34)	–	–	–	–
House	–	43 (51)	14 (16)	29 (34)	14 (16)
Solar panel	43 (51)	–	–	–	57 (68)
Goat	29 (34)	–	–	–	–
Poultry	14 (16)	14 (16)	14 (16)	15 (18)	–
Agricultural crops	14 (16)	14 (16)	–	–	29 (34)

Number in parenthesis indicated frequency of shrimp farmers responses.
All the shrimp farmers did not have all types of resources.

Fig. 4. Comparative depiction of shrimp farms in Gabura Union of Shyamnagar Upazila, Satkhira district. (a) Typical shrimp farms before cyclone Bulbul and (b) flooded shrimp farms after cyclone Bulbul.

Table 7. Estimated economic loss and damage to cyclone Bulbul of the shrimp farmers of Gabura Union, Shyamnagar, Satkhira, Bangladesh

Affected resources	Market price before cyclone hit (USD)[1)]			Market price after cyclone hit (USD)[1)]			Mean loss
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	
Shrimp farm	943	17,679	6,031	0	3,536	1,398	4,633
Fencing nets	24	589	214	0	2	1	213
Fishing traps	59	354	167	0	118	47	120
House	1,179	11,793	4,717	0	11,550	4,057	660
Solar panel	295	354	339	0	295	74	265
Poultry	35	8,835	2,999	0	2,946	1,010	1,989
Agricultural crops	59	648	276	0	59	20	256

[1)] USD 1 = BDT 84.80 (Bangladesh Taka, Date: 13 November, 2020).
Only those resources damaged/lost are listed here.

resulted in huge loss and damage to the ghers." Most (72%) of their fishing traps were lost. Fishing traps were generally made of split bamboo, which were very light and easily moveable. As a result, most of the fishing traps were displaced from their current positions and lost in the water due to the heavy winds and water flows of cyclone Bulbul. In terms of economic value, the estimated mean loss and damage of fencing nets and traps per farm was USD 333 (Table 7).

This study also found that cyclone Bulbul caused significant loss and damage to physical household resources among shrimp farmers. From the questionnaire survey, this study found that 14% of farmers' houses were lost followed by 29%, 14%, and 43% were heavily, moderately and lightly damaged, respectively. This might be happened because of the use of low-quality materials such as thatch and mud to build the houses (Table 2) which could not withstand cyclone Bulbul. One of the key informants in Gabura reported that more than 1,000 houses were damaged due to cyclone Bulbul throughout the union to some extent. In total, the estimated mean loss and damage per house was worth USD 660. In this study, it was found that 57% of shrimp farmers had lost their solar panels. Most of the solar panels were lost due to the strong gusts of the cyclone Bulbul. The estimated mean loss and damage of solar panels per household was worth USD 265.

Non-economic loss and damage

This study found a wide range of non-economic loss and damage to cyclone Bulbul of the shrimp farm dependent communities of the Gabura Union. They are described below.

According to the household questionnaire survey and FGDs, the majority of the household members in the shrimp farm dependent communities suffered significant non-economic loss and damage as a result of cyclone Bulbul, such as physical injuries, unbearable mental pains, deterioration of health, disabilities, severe psychological problems, memory loss, and so on. According to the questionnaire survey, 73% of shrimp farmers reported that at least one of their household members was physically injured during cyclone Bulbul to some extent. Some of them were severely injured. For example, one shrimp farmer said, *"My 12-year-old son was terribly hurt by a flying corrugated sheet while the sheet on the roof of the house was blown away by the cyclone Bulbul. His forehead was severely injured and his left leg was broken."* Two FGD participants reported that a few villagers were critically injured during cyclone Bulbul, leaving them physically disabled. Another FGD participant said, *"While we were approaching the cyclone shelter, my six-month pregnant daughter got slipped due to slushy roads and strong gusts of wind. Instantly, she started groaning with her lower abdomen pain."* In this study, most of the respondents during the questionnaire survey reported that many of their household members, especially children and the elderly, caught colds and fever after cyclone Bulbul. Furthermore, some elderly people, women, and children were psychologically traumatized as a result of the effects of cyclone Bulbul, resulting in good memory loss. One shrimp farmer said during the questionnaire survey, *"My teenage daughter was traumatized, and as a result, she can hardly recall good memories."*

Besides the direct impacts of cyclone Bulbul on the shrimp farmers' households, there were many indirect impacts that resulted in non-economic loss and damage to the household members. The indirect impacts included reduced access to important livelihood services and assets due to the cyclone as outlined in Table 8. About 14% and 29% of shrimp farmers' ac-

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cess to food was moderately and lightly damaged (Table 8). As a result, household members' food consumption (three meals per day) was affected where the elderly, pregnant women and children were the worst victims. This study also found that 43% of households' access to safe drinking water was heavily and moderately damaged because of the contamination of the water sources by upsurge water from the cyclone. This study found from questionnaire surveys, KIIs and FGDs that many diseases such as cholera, dysentery, diarrhoea, and skin problems were spread after the cyclone due to contaminated water, and as a result, most of the affected household members faced unbearable psychological pains.

According to the findings of this study, the majority of household members suffered significant non-economic loss and damage as a result of cyclone Bulbul's disruption of social infrastructure and access to services such as roads, markets, medical facilities, education systems, firewood collections, and grazing livestock. FGDs participants reported that they could not get proper health care due to lack of adequate doctors and nurses, and lack of emergency medicines. In this study, 29% and 14% of households' access to medical services were heavily and moderately damaged (Table 8) because of weak transportation and slushy roads during cyclone Bulbul. One key informant reported that earthen roads became slippery, slushy and waterlogged during cyclone Bulbul's induced flooding. One of the respondents said, *"My pregnant wife was groaning in labor pains but we couldn't take her to the hospital due to lack of transport and the bad condition of the roads."* The supply chain for shrimp was disrupted temporarily due to disturbances in market facilities and bad conditions on the roads.

In this study, disruption of the education system and insecurity in the cyclone shelters were also reported as non-economic loss and damage. According to the questionnaire survey, 86% of students' access to school faced moderate or light damage due to the cyclone. Moreover, 9 out of 12 primary schools were used to give shelter to vulnerable people during cyclone Bulbul. As a result, many students' educations were temporarily disrupted in different villages of Gabura. This study found during the questionnaire survey that household members faced trouble accessing cyclone shelters because of their insufficient number and space, as well as their long distance from home. About 28% of households reported that their access to cyclone shelters was heavily or moderately damaged (Table 8). In the cyclone shelters, women household members faced unbearable miseries due to lack of securities as they had to share common space tightly with other male and female members outside their household. One FGD participant said, *"In the cyclone shelter, women did not have any privacy, especially the lactating mothers, as they had to stay tightly shared in the common place with other members including males. There were no separate toilets for women."*

In this study, disturbance of cultural functions was also reported. Most of the shrimp farm dependent households' financial conditions deteriorated due to the adverse impacts of cyclone Bulbul, and as a result, they were unable to celebrate different cultural festivals like 'Nobanno Utshob' (new harvest festival), 'Pitha Uthsob' (cake festival), 'Jamai Sasthi' (son-in-law day), wedding ceremonies, circumcisions and religious functions such as Eid-e-Milad un-Nabi, Kali Puja, Durga Puja,

Table 8. Non-economic loss and damage to cyclone Bulbul of the shrimp farms dependent households of Gabura Union, Shyamnagar, Satkhira, Bangladesh

Access to services/assets	Impacts of cyclone Bulbul (shrimp farmers' responses in percentage)				
	No loss or damage	Light damage	Moderate damage	Heavy damage	Total damage/loss
Food	57 (68)	29 (34)	14 (16)	–	–
Pure drinking water	57 (68)	–	29 (34)	14 (16)	–
Medical service	57 (68)	–	14 (16)	29 (34)	–
Roads	33 (39)	17 (20)	33 (39)	17 (20)	–
School	14 (16)	43 (51)	43 (51)	–	–
Cyclone shelter	29 (34)	43 (51)	14 (16)	14 (16)	–
Market	17 (20)	43 (51)	33 (39)	17 (20)	–
Firewood	43 (51)	43 (51)	–	–	14 (16)
Grazing livestock	14 (16)	–	–	14 (16)	14 (16)

Number in parenthesis indicated frequency of shrimp farmers responses.

etc. like before. One shrimp farmer during the questionnaire survey said, *"Today we are in miserable circumstances after losing everything due to cyclone Bulbul. Now we are thinking about how we can feed ourselves in coming days rather than celebrate any cultural festival or gather guests."*

According to this study, not only shrimp farm owners and farmers, but also many shrimp farms' dependent workers, lost their jobs temporarily as a result of the destruction of shrimp farms caused by cyclone Bulbul. As a result, their financial circumstances became very bad and they failed to meet their basic needs.

Discussion

In this study, it was found that most of the shrimp farmers faced economic and non-economic loss and damage to cyclone Bulbul. In terms of direct monetary value, most of the farmers encountered either loss or damage because of the destruction of their farms, fencing nets and traps, and other non-fishery related households' resources such as houses, solar panels, livestock, and agricultural crops.

Shrimp farms were mostly affected because of their geographical position in coastal areas of Bangladesh where frequent climatic hazards mainly cyclones had been occurred over the last few decades. This study is in line with the previous studies that also reported that cyclones caused serious loss and damage to the coastal areas including aquaculture and fishery-dependent livelihoods in Bangladesh (Ahsan & Brandt, 2015; Haque et al., 2013; Shameem et al., 2014; Swapan & Gavin, 2011). During cyclone Bulbul, the shrimp farms were inundated by water surges, and the farms' water became more polluted, resulting in massive shrimp mortality on the farms. In addition, the farms' enclosures were destroyed, and as a result, shrimp escaped from the farms with the flow of water to nearby rivers. Similar observations were also reported by Sakai et al. (2017) in the rural Philippines where enclosures of cultured fish were destroyed due to the impacts of Typhoon Milenyo, and as a result, cultured fish were released and lost in the surrounding waters.

The enclosures of shrimp and finfish culture were frequently affected due to the loss and damage of fishing equipment such as fencing nets, traps, and boats (Chowdhury et al., 2012; Haque et al., 2013; Islam et al., 2016). This study found most of the fishing traps were totally damaged because of their light weight and low-quality materials such as bamboo splits which are too fragile to withstand the hostile impacts of cyclone Bulbul. Similar findings are also reported by Aiken et al. (1992) who reported that Hurricane Gilbert devastated 90% of fishing traps and 5% of boats in Jamaica. In the coastal state of Odisha, India, cyclone Phailin severely damaged fishers' fishing gear, and as a result, around 72.67% of the fishers experienced a decline in income after the cyclone in 2013 (Mishra & Malakar, 2020).

This study showed that most of the farmers' houses were made of low-quality materials such as mud, bamboo splits, thatch, jute sticks, wood and tin. Because of their low-quality structures, they could not withstand the adverse gusts of cyclone Bulbul. This study agrees with Haque et al. (2013) who reported that mud houses incurred comparatively more damage than concrete houses from any climatic hazard.

This study found that most of the shrimp farmers faced monetary loss due to cyclone Bulbul. But rich shrimp farmers encountered proportionately more economic loss and damage than their poor counterparts. This might have occurred because of rich farmers' high investment in large shrimp farms and their having many more physical resources to lose due to cyclone Bulbul than poor farmers. Scheidel (2018) criticizes that the poor usually do not possess or own many material assets, and as a result, they lose less compared to the rich. However, this does not mean that the poor suffered less as they had few material assets to lose. This study is in line with Warr & Aung (2019) who reported that within the cyclone Nargis affected regions in Myanmar in 2008, the negative impact of the cyclone was largest in numerical values among richer households, but as a proportion of household expenditures, these negative effects were higher among poorer households. They become the ultimate victims of cyclones losing all of their resources. This is not unusual at country level either. Mendelsohn et al. (2006) reported that poor countries suffered more due to the adverse impacts of climate hazards.

This study showed that the destruction of infrastructure such as roads and markets eventually result in disrupted supply chain of shrimp for export. As a result, the supply of shrimp has increased in the local markets and decreased its price. Though this study calculated economic loss by general market price changes, there might be some other factors that could influence the price changes. However, this study agrees with the results of Sakai et al. (2017) who showed that the market price of cultured fish was temporarily decreased as the supply was increased in local markets after Typhoon Milenyo in the rural Philippines. Consequently, the household's income was also decreased, and in extreme cases, some household members became temporarily unemployed. This finding is consistent with other studies

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(Rimi et al., 2013; Shamsuddoha et al., 2013) that reported that the impacts of climatic hazards like cyclones negatively affect coastal aqua-farming communities with regard to their livelihoods and income opportunities.

This study showed a range of non-economic loss and damage of the shrimp farmers' household members including unbearable pain, physical injuries, deterioration of health and disabilities. This study supports the findings of Andrei et al. (2014) and Serdeczny (2019) who also reported that climatic hazards caused adverse health impacts on affected communities. In extreme cases, climatic hazards can cause death (Badjeck et al., 2010). These are all non-economic loss and damage as one does not (and cannot) buy emotional well-being after going through the trauma of an illness or the death of a loved one.

In this study, lack of access to services, disruption of children educations and disturbance of cultural functions were also non-economic loss and damage to cyclone Bulbul. Household members, particularly women, usually reduce their food consumption (three meals per day) in response to a negative income to adapt to the circumstances (Warr & Aung, 2019). In adverse conditions, households' reduced holdings of valuable assets and investment in children's education in the short-run of any climatic hazard. Women household members often encountered insecurities in the cyclone shelters because of the sharing of common space with other household members, including males. These problems were also reported by Fankhauser et al. (2014) and Andrei et al. (2014).

Integration of both economic and non-economic loss and damage into local, national and international policies along with their implementation might lead to or avert unexpected losses to safeguarded or protect coastal aquaculture dependent livelihoods, economy and people. Assessing loss and damage from the fisheries sector will help to produce evidence of the climatic impacts for vulnerable developing countries like Bangladesh to be included in the work plan of the Warsaw International Mechanism on Loss and Damage (UNFCCC Secretariat, 2014) to claim resilience and adaption funds and support from the developed countries that are mainly accountable for climate change. This evidence might also assist in developing international climate policy in the Warsaw Mechanism on Loss and Damages and in the Paris Agreement as well.

Conclusion

This study estimated climate change-induced economic and non-economic loss and damage to cyclone Bulbul of the shrimp farmers of southwest coastal Bangladesh. The findings of the study showed that all shrimp farmers encountered monetary loss and damage to their farms, fishing equipment and household resources. This study revealed that rich shrimp farmers encountered proportionately more economic loss and damage than their poor counterparts, which does not mean the poor to be less suffered. This study also found that shrimp farmers and their household members faced a wide range of non-economic loss and damage such as unbearable pains, deterioration of health, physical injuries, psychological problems, lack of access to services, etc. The impacts of such intangible losses are often ignored at the local level which are very important for better human wellbeing. Thus, it is very important to pay attention to both economic and non-economic climate-induced loss and damage to integrate them into policies.

This research might help to provide evidence of economic and non-economic loss and damage to cyclone from coastal aquaculture in Bangladesh. The results of this study might aid to include loss and damage in climate policies and strategies to formulate effective measures to reduce economic and non-economic loss and damage in the sector in the coming future. This study also recommends identifying ways forward to loss and damage in order to suggest a national plan for resilient coastal communities to future climatic hazards. This will ultimately play a noteworthy role in the poverty reduction of the fisheries dependent people and the sustainable development of the country more broadly.

Competing interests

No potential conflict of interest relevant to this article was reported.

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Availability of data and materials

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Ethics approval and consent to participate

Data were collected in compliance with the guidelines of Institutional Ethical Committee of Faculty of Biological Science, University of Dhaka, Bangladesh. All authors have participated in the research work and are fully aware of ethical responsibilities. Consents have been taken from all of the participants of this study before taking their interview.

ORCID

Md Monirul Islam https://orcid.org/0000-0001-5875-433X
Makidul Islam Khan https://orcid.org/0000-0003-4154-0153

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