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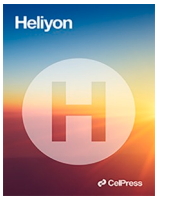

Factors of cyclone disaster deaths in coastal Bangladesh

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ABSTRACT

Bangladesh's success in disaster risk management is often evidenced by referencing the reduction of deaths caused by tropical cyclones — the Cyclone Gorky 1991 caused 147,000 deaths, the Cyclone Sidr 2007 caused 4500 deaths and only 6 deaths by the Cyclone Mora in 2017. This raises questions of how deaths occurred by tropical cyclones in the past and what factors still might contribute towards deaths from cyclone hazards? This study answers these questions through face-to-face interviews with 362 residents, field visits and observations across coastal Bangladesh. The findings indicate that there have been improvements in house structures and design, warning responses and evacuation processes to public cyclone shelters and informal cyclone shelter centres. In the past, due to a lack of built infrastructure, strong residential houses and public cyclone shelters, deaths occurred whilst living in fragile houses; attempting to survive through holding trees and floating in storm surges. The top ten factors that may still cause deaths by tropical cyclones include: (1) Living adjacent to the coast without an embankment or lack of embankment, or the failure of an established embankment; (2) the repeat of a 1991-like cyclone; (3) non-evacuation following early warning; (4) poor roads in remote areas to facilitate mass movement; (5) distance to and insufficient number of public cyclone shelters; (6) lack of protective measures for the rising number of elderly and disabled people; (7) community's unawareness; (8) communication failure during the emergency period; (9) failure to evacuate people from remote locations; and (10) Poor radio signal and mobile network issues resulting in no warning information being effectively and timely communicated. This study provides several key recommendations addressing these factors of deaths, to be implemented by individual, community, private sectors, non-government organisations (NGOs) and public sectors across coastal Bangladesh.

1. Introduction

Over the last several decades, technological improvement in tropical cyclone (TC) detection, forecasting and disseminating warning signals to vulnerable communities have significantly contributed towards risk reduction associated with climatic hazards. Deaths associated with TCs have remarkably reduced in many high risk countries including Bangladesh, a country that has experienced 50% of all known global casualties [1]. For example, TCs that occurred in 1970 killed 500,000 people and the cyclone Gorki in 1991 led to 147,000 recorded deaths; whereas the deaths by Cyclone Sidr in 2007 were 4,500 and only 6 in the Cyclone Mora in 2017 (Table 1). This success has been achieved through implementing risk reduction activities by country governments, United Nations, international non-governmental organisations (INGOs), non-governmental organisations (NGOs), community-based organisations (CBOs) and increases in community's awareness and capacities [2]. Over the last three decades, disaster research has progressed

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through mainly identifying the key known reasons and factors for differential vulnerabilities among communities [3–6]. Research is further required when understanding what factors contributed towards deaths associated with TCs over the last five decades. This study explores the varying factors which caused these deaths during TCs from the period of 1970–2021, and identifies factors and reasons that still may contribute and cause deaths by TCs. Thus, the findings may assist to identify what needs to be undertaken to continue the current progress of targeting sustaining risk reduction approaches.

1.1. Cyclone disaster risk management in Bangladesh

The Government of Bangladesh (GoB) had developed a Standing Order for Disasters (SoD) in 1997 [7]. Since then the GoB has been active in creating and updating policies, plans, acts, rules, action plans and strategies for disaster management over the last three decades. Some examples of these include the Disaster Management (DM) Act 2012, DM Policy and Rules in 2015, Disaster Management Plan 2016–2020, and the SOD) 019 (updated from 1997) [2]. These reflect the GoB's commitment and partnership with international (i.e. Hyogo 2005–2015 and Sendai 2016–2030) and regional frameworks (i.e., SAARC for Action 2006–2015). The GoB has undertaken initiatives to implement these international frameworks into country level disaster risk reduction and development policies and planning.

The GoB has undertaken both engineering approaches often familiar as structural measures and non-structural approach for cyclone disaster risk management [7]. Structural measures include construction of public cyclone shelters, coastal embankments and *killas, or* earthen mounds. Many donors, international development organisations, INGOs, NGOs, and benevolent persons have contributed towards the construction and improvement of public cyclone shelters in Bangladesh. Internal and external financial support raised cyclone shelter numbers from 44 in 1970 to over 2500 in 2018 [8]. Notwithstanding, these shelters are grossly insufficient for the 35 million coastal residents of Bangladesh during a cyclone emergency. In the past, the most common strategy was that of coastal embankment, however these were mainly made of compacted earth. Since 2013, these earthen made embankments have been improved upon through block embankment under the Coastal Embankment Improvement Project. A *Killa* engineered in a size of 24.4 m X 18.3 m to 61.5 m X 30.5 m with the height elevated above the maximum known storm surge height was undertaken primarily to protect livestock and animals. Currently there are 550 *killas* in the region of Bangladesh.

Since 1972, the national Cyclone Preparedness Programme (CPP) has been actively disseminating early warning signals for an approaching TC. The CPP's headquarters is located in Dhaka; it is operational from seven zonal offices in coastal districts. Under these zonal offices, 48 sub-district level offices manage overall 381 union committees. A total of 3701 units work under the union committees, comprising of 20 volunteers for each unit. As of July 2022, 74,020 registered volunteers work for the CPP across various field level operations [9]. The CPP is installed with 130 HF and VHF wireless stations for its operational network. Bangladesh Meteorological Department (BMD) maintains the Storm Warning Centre (SWC) that relays special weather bulletins to the headquarters of the

Table 1
List of land falling TCs on Bangladesh coast between AD1484 and 2017.

Event No	Date of event			Landfall locations	Physical characteristics		Effects of tropical cyclone		
	Year (AD)	Month	Day		Wind speed (kmph)	Height (m)	Deaths	Injuries	Affected
1	1484	*	*	Chittagong	*	*	200,000	*	*
2	1582	*	*	Barisal	*	*	200,000	*	*
3	1584	*	*	Barisal	*	*	200,000	*	*
4	1822	5	*	Noakhali	*	*	45,000	*	*
5	1822	6	6	Barisal	*	5.26	75,000	*	*
6	1831	10	31	Barisal	*	2.12-4.55	22,000	*	*
7	1876	10	31	Noakhali	220	13.7	300,000	*	*
8	1897	10	24	Chittagong	*	*	175,000	*	*
9	1948	5	19	Chittagong	82	*	1,200	*	*
10	1960	10	11	Noakhali	201	6	9,537	*	*
11	1960	10	31	Chittagong	210	6.6	10,000	*	200,000
12	1961	5	30	Chittagong	148	6.10-8.84	10,466	*	*
13	1963	5	29	Chittagong	241	5.18	25,000	*	1,000,000
14	1970	11	12	Barisal (Bhola)	223	6.10 -9.14	300,000	*	3,648,000
15	1985	5	25	Noakhali	154	4.57	11,069	*	1,300,000
16	1988	11	30	Barisal	160	4.5	5,708	*	8,568,860
17	1991	4	29	Chittagong (Gorky)	225	6.10-7.62	138,866	138,849	15,000,000
18	1997	9	27	Chittagong	150	4.55	188	63	750,000
19	1998	5	20	Chittagong	173	1.83-2.44	19	504	108,440
20	2007	11	15	Khulna (SIDR)	223	4.57-6.10	4,234	55,282	8,923,259
21	2008	10	27	Barisal	83	*	15	200	*
22	2009	4	18	Chittagong	100	*	7	84	19,125
23	2013	5	16	Noakhali (MAHASEN)	100	1.1	17	*	1,500, 000
24	2015	7	30	Chittagong (KOMEN)	65	1.52-2.13	45	*	*
25	2016	5	21	Chittagong (ROANU)	128	1.22-1.53	26	*	*
26	2017	5	30	Chittagong (MORA)	146	1.2-1.5	6	136	*

Note: Asterisk (*) indicates no information available.
Source: Alam and Dominey-Howes (2015) and compiled by the author

CPP. The headquarters of the CPP is then responsible to pass on the message through its HF wireless set to the seven coastal zonal offices at district and sub-district level stations. The sub-district station passes on information to the union level committee to ensure remote locations are informed. Finally, the union team leaders in association with the unit team leaders and volunteers disseminate information through megaphones, handheld bullhorns, and bicycle-mounted loudspeakers to the at-risk community.

1.2. Cyclone disaster studies in Bangladesh

The earliest research on human responses to natural hazards were led by Islam [10] and Khan (1974) who noted communities perception, survival strategies and the reasons for colossal deaths by associated TCs in 1960s and 1970s. In the early 1970s there were a very limited number of cyclone shelters and the majority of coastal regions did not have public cyclone shelters. Disregard in warnings, or not taking adequate preparedness and undertaking self-instinct ill-devised survival strategies during the storm surge period, were also identified as the reasons for deaths associated with TCs. The 1985, the Urir Char cyclone resulted in over 11,000 deaths [11]. Bangladesh Space Research and Remote Sensing Organisation detected a severe cyclone formation on May 23, 1985 and Bangladesh Red Crescent Society (BDRCS) disseminated warnings, however, the community did not take adequate preparation resulting in a number of deaths on the two offshore islands — Sandwip and Urir Char, located on the path of cyclone landfall [12]. The major reasons for community level non-responses include distance to cyclone shelters, underestimating the severity of hazards, limited knowledge of cyclones and difference in opinions relating to the requirement for or how to conduct an evacuation [12].

The reasons for higher deaths associated with the Gorky 1991 that claimed deaths of over 138,000 people on coastal Bangladesh were studied and the following conclusion were derived [1,13,14]. These studies demonstrated that despite a hazard warning process that was successful; the communities did not effectively respond due to lack of trust in these warnings, fear of robbery, and limited cyclone shelters, which when combined resulted in colossal deaths [14]. Coastal residents' vulnerability to TCs also encompasses a broader risk landscape such as a crime that may include the theft of a boat resulting in loss of a household's primary means of a livelihood [15]. The severity of TCs, the distance of public cyclone shelters from residences, a lack of proper management and maintenance of cyclone shelters, disbelief of warnings among coastal residents and an improper disaster management system are the main factors differentiating the extent of cyclone damage [16,17].

The reasons for disproportionate deaths of women, elderly and children than other groups were explored within the Bangladesh coastal region. The reasons for higher deaths of women include: reluctance to leave homes, a mother's desperate attempt to save her children even by sacrificing her own life, and women's clothing and women's long hair hindering movement when attempting to swim in a tidal surge [15,18,19]. For preparedness and evacuation before an approaching cyclone, this also requires decision-making and authority that is not necessarily found in a paternal society. Women had limited participation in such roles or decision making [15]. To this end, the GoB, NGOs and international development partners have included gender dimensions of vulnerability and their rights in their course of action as a risk reduction approach.

From the experience of Gorky 1991, there were improvements in warning dissemination with active participation of CPP volunteers, local civil administration and local government representatives, resulting in more successful evacuation of a greater proportion of coastal communities. These improvements are thought to have reduced cyclone associated deaths reduction in coastal Bangladesh. Paul et al. [20], studied the same community to understand evacuation behaviour of coastal communities with a comparison between Cyclone Gorky 1991 and Sidr 2007 and observed remarkable rises in formal evacuation— only 3% of all respondents evacuated during the *Gorky* however, it increased to 33% during the *Sidr*. A quantitative analysis of 277 Sidr survivors suggest that over 75% of all respondents received cyclone early warnings and direction for evacuation prior to Sidr landfall [21]. Comparatively, fewer deaths by Sidr showcased the GoB efforts for disaster reduction and this received international attention. The reasons for such success can be divided into two broader types: (1) accurate cyclone forecasting and disseminating early warnings and effective evacuation of residents from the predicted path of Cyclone Sidr by the GoB; (2) physical characteristics of Cyclone Sidr including both duration of the storm and storm surge, cyclone landfall time and location, coastal embankment and ecology [22].

After Cyclone Sidr in 2007, there was no category 4 TC that made landfall in Bangladesh until to present time of writing. Between 2013 and 2017, with the exception of the year 2014, four category 1 cyclones namely Mahasen 2013, Komen 2015, Roanu 2016 and Mora 2017 affected the coastal region of Bangladesh. The deaths associated with each extreme weather event was below 50 persons. The reasons identified for these deaths were not moving to shelter centres and non-compliance with warning signals during these TCs [23,24]. Demographic, psycho-social, economic, locational and environmental factors of cyclone disaster deaths were studied separately following the occurrence of each cyclone [10,12,20,25–27]. Complementing the existing knowledge of non-compliance to cyclone warnings, this study documents factors and reasons that still might contribute to deaths by TCs. A driver of this study is that there is a dearth of research into the changings factors and reasons for deaths associated with TCs. The study aims at addressing this issue through field visits, investigation, and face-to-face interviews with residents who experienced several cyclones between 1970 and 2021 on the Bangladesh coast. The research reported here aimed to identify factors of deaths in changing contexts within which people are vulnerable to cyclone hazards on the Bangladesh coast. Particularly, it explored: (1) perceived factors that could have contributed towards a reduction in deaths from cyclone hazards in Bangladesh; (2) perceived factors that still may contribute to deaths from cyclone hazards.

2. Methods and approaches

Application of a range of qualitative approaches including in-depth interviews and observations may be essentially used in exploring communities responses to and the effects of a disaster [28,29]. Field visits, investigation and face-to-face interviews were

conducted to understand change in factors of cyclone hazard associated deaths in fifteen sites, located in high cyclone risk areas of the Bangladesh coast (Table 2 and Fig. 1). The study sites are located within 3 km from the Bay of Bengal coast and among these, seven study sites, Kutubzome, Samiti Para, Kalatoli, Shamlapur, Maghnama, Boro Goph, and Durong are located in the Cox's Bazar district.[1] Six study sites, Sarikait, Moghdara, Gandamara, Alekdia, Patenga and Halishahar, are located in Chittagong district. The study sites, Kuakata and Dacope, are located in the Patuakhali and Khulna districts, respectively. Data collection ethics maintains norms of social survey and participants' rights including receiving informed consent and withdrawal from the interview at anytime. The Institutional Review Board of the Rabdan Academy has approved the ethical protocol of this research (RAREC $\neq$ 0007, date: November 15, 2021).

To understand varying factors of cyclone disaster deaths over time, data collection was conducted between December 2021 and March 2022 in a combination of face-to-face interviews using a semi-structured and open-ended questionnaire, participant observations and field visits across coastal sites. Four data collectors were employed for the data collection and the author of this study was directly involved in data collection, the supervision and monitoring of the data collection process. A list of households from these study sites was prepared prior to conducting the questionnaire survey. Only those household heads available for interview were considered in the list. From this list, 362 face-to-face interviews were conducted randomly with household heads who were aged over 59 years of age. These households had experienced multiple extreme TCs from 1960 to 2022 (Table 3). Of the 362 household heads interviewed, male and female were 81 and 19% respectively. The rationale behind this approach is that a woman seldom holds the position as a head of the household in Bangladesh. Despite gender difference among the studied population, much valuable information was gathered through the headship of household which was the criterion for sample selection.

The respondents, who are over 70 years old, could recall their memories from the experience of cyclones in 1960 and 1965 (Table 3). By single event type, the majority of respondents recall their experiences from 1991, 1997 and 2007 TCs. The interview questions include two sections. It commences with a semi-structured and open-ended questionnaire of cyclone experience, previous deaths and losses in houses, trust in and responses to warning signals, the factors and reasons for higher deaths before two decades, the reasons for deaths in the last two decades, difference in losses by settlement pattern, factors and reasons that still may cause deaths by TCs. Finally, it collects participants' socio-demographic characteristics, including age, gender, number of family members, type of family, livelihoods, income and education levels. Prior to conducting the face-to-face survey, this questionnaire was tied-out to resolve any deficiencies noted.

Field survey data were first checked and collated for analysis purposes. Then, answers on semi-structured and open-ended questions were transcribed and translated into English. The findings were delineated based upon the theme of the evidence in line with the objectives of this research. Responses from semi-structured and open-ended questions have been calculated by frequencies using MS Word and MS Excel and are presented in Tables 4 and 5 with weighted response. The findings were also cross-checked with participant observations and field notes. For demographic and socio-economic related questions, responses were received through structural questionnaire; total responses, percentage and average were estimated. The findings were explained by contrasting and comparing existing relevant literature alluded to earlier in this paper and beyond.

3. Results and discussion

3.1. Demographic and socio-economic characteristics of the respondents

The 362 respondents consisted of 81% males and 19% females. The average age of the respondents was 66.87 years since this study only considered respondents over 59 years. The minimum and maximum ages of the participants were 60 and 87 years respectively. The category of the respondents by family type, nuclear and extended family, were 47 and 53% respectively. The average size of the family is 6.47 members. The average income of the respondents per month is Taka 13,083 (USD = 120.80). Although the literacy rate of Bangladesh in 2022 is 76%, about 51% of our respondents were illiterate since this study only interviewed people over 59 years. For the remaining 49% of respondents, the percentage breakdown of the completion of primary (1–5 years of schooling) lower secondary (6–8 years of schooling), secondary school certificate (SSC), higher secondary school certificate (HSC), and graduate were 40.61, 1.38, 2.76, 2.76, 1.11 and 0.28% respectively. Predominantly, approximately 33% of the respondents were agriculturist and 12% were either retired or unemployed. The percentage breakdown of the remaining percent of respondents for profession were in fishermen, day labourer, unemployed, small traders, housewife, fish traders, service, remittance and business were 13.81, 13.26, 10.50, 10.22, 2.49, 1.93, 1.38 and 0.55% respectively.

3.2. Tropical cyclones and tidal surges experience

In response to a question about how many times in the last three years the participant had observed cyclone formation in a year, the responses ranged from one to four times. On average, the respondents faced approximately two severe cyclonic wind speed events in a year. The coastal residents are used to receiving early warning signals multiple times in a year.

In response to a question about how many times the participants observed cyclone associated sea surge in their lifetime, the average response was two and half times. Except when sea surge was associated with TCs, the residents from low-lying coastal areas face

[1] There are 64 districts in Bangladesh. A district is the second largest administrative unit, considered a vital unit of government administration, consisting of several *thanas*. A *thana* comprises of several *unions,* and several villages form a union. A typical village in Bangladesh contains 30–500 households [Bangladesh Bureau of Statistics (BBS), 2002].

Table 2
Details of the sites and participants considered in this study.

Site name	Sub-district/district	Number of participants		
		Male	Female	Total
Kutubzome	Maheskhali, Cox's Bazar	26	7	33
Samiti para and Kalatoli	Cox's Bazar City	15	3	18
Shamlapur	Teknaf, Cox's Bazar	7	3	10
Maghnama	Pekua, Cox's Bazar	14	1	15
Boro Goph and Durong	Kutubdia, Cox's Bazar	27	3	30
Gandamara	Banskhali, Chittagong	12	1	13
Sarikait and Moghdara	Sandwip Island, Chittagong	61	12	73
Sonaichari (Alekdia)	Sitakunda, Chittagong	20	10	30
Patenga and Halishahar	Chittagong city coast	27	7	34
Kuakata	Patuakhali	50	8	58
Dacope	Khulna	34	14	48
Total		293	69	362

Source: The author

Fig. 1. The location of study areas in Bangladesh coast.

Table 3
Tropical cyclones and tidal surges experience.

Year of the cyclone	Tally (Percentage)
1960	8 (1.00)
1965	10 (1.25)
1970	23 (2.87)
1985	65 (8.14)
1991	222 (27.78)
1997	98 (12.27)
2007	115 (14.39)
2015	55 (6.88)
2016	59 (7.38)
2017	67 (8.38)
2019	33 (4.13)
2020	44 (5.55)
Total	799 (100)

Source: Field survey, December 2021 to March 2022

Table 4
Factors contributing to deaths during tropical cyclones from 1970 to 2021.

Factors	TC 1970	TC 1985	TC 1991	TC 1998	TCs 2007–2009	TCs 2013–2016	TCs 2017–2020
1. Lack of effective warning system by the GoB	338[a]	319	199	88	34	13	–
2. Lack of embankment or not repairing embankment	337	246	249	124	59	24	15
3. No or limited cyclone shelters	336	279	215	126	78	28	14
4. The residents did not believe in warning	324	305	255	56	34	16	14
5. Limited volunteers, microphone and loudspeaker to disseminate warning during extreme weather	322	256	245	112	44	23	12
6.Kutcha houses including mud-made houses and their collapse caused people's deaths	327	262	217	131	62	35	31
7. Kutcha road networks	332	272	215	124	55	17	15
8. Limited availability of devices (radio, TV, mobile) to receive warning in the past	316	262	188	57	35	8	–
9. Limited strong building or other type of infrastructure nearby	307	267	265	121	22	9	3
10. Women did not have permission to leave houses	322	236	230	122	56	34	22
11. Fascination to protect properties and livestock	281	291	230	121	56	31	23
12. Women's saree/hair	277	233	244	112	55	23	
13. Economic pressure	–	–	–	–	15	14	16
14. Boat accident during cyclone	–	–	–	–	17	18	19
15. Inability to return from the sea	3	4	5	5	8	9	5
16. Did not recognise danger of it	77	68	89	8	–	–	–
17. Trees fell down	2	2	23	14	12	10	9
18. Disabled people	2	3	5	7	8	8	9

[a] Multiple responses were counted.

Table 5
Factors and reasons that might still cause deaths by tropical cyclones.

Factors of deaths	Frequency
1. Living adjacent to the coast without embankment or lack of embankment or failure of existing embankment	256[a]
2. A repeat of 1991 cyclone type	171
3. Non-evacuation of residents leaving behind animals, properties and livestock	140
4. Distance from the cyclone shelter	82
5. Insufficient public cyclone shelters for accommodating all people	74
6. Poor road transport and very difficult to move to distant cyclone shelter	72
7. Lack of suitable cyclone resilient housing	71
8. Elderly and disabled people not being evacuated during cyclone	69
9. Lacking recent experience in damage or death resulting in carelessness/disbelief	57
10. Poor radio signal and mobile network problem resulting in no warning information	51
11. Lacking warning dissemination in inaccessible areas during turbulent weather	49
12. Superstition, if death is to occur, we die all together at home	42
13. Purdha culture hindering moving to shelter	41
14. Non-evacuation of fishers from the sea when greater danger signal is hoisted	39
15. Severity of wind speed hindering movement at disaster period	38
16. Due to male's out migration, girls and females face trouble in evacuating during emergency	35
17. Trees fall down on top of houses and in the street or whilst moving to public cyclone shelter	18
18. Inability to understand the severity of cyclone to make a decision to evacuate	17
19. I do not believe in warnings	14
20. Underestimating severity such as storm surge height will not be dangerous in this area	13
21. Migrant workers who have limited knowledge and experiences of the TC	9
22. Daily workers cannot put off their work and respond to early warning	9
23. No extra money to spend moving to shelter centre by private vehicle	8

[a] Multiple responses are counted.

inundation from the Bay of Bengal during high tide or any major depression generated in the Bay of Bengal. For example, as of July 2022, there are no coastal embankments in some areas of Alekdia in Sitakunda coast, the eastern coastal region of Bangladesh and the residents experienced flooding and inundation from weather depression in the Bay of Bengal. In cases of the leakage and breakdown of embankment, low-lying areas in Sandwip and Kutubdia islands experience inundation every year during the monsoon season.

3.3. Deaths in family and house losses

Of the 362 respondents, 43% experienced deaths in their family during the past tropical cyclones. Of these deaths over fifty percent occurred during the 1991 Gorky and the remaining deaths occurred across the events of 1960, 1970, 1985, 2007 and 2017 TCs. Of the 530 deaths, male and female were 60 and 40% respectively. Of the participants, 61 and 55% families faced deaths during the previous cyclones in Sandwip and Cox's Bazar respectively. Then, 46% of the participants' family in Maheskhali, Kutubdia, Banskhali, and

Sitakunda experienced deaths. The deaths in the participant's family in the remaining study sites were below 25% with the lowest at 12% in Dacope.

The percentage distributions of deaths in the age group of 0–10, 11–18, 19–59, 60 and above were 29, 10, 31, and 30% respectively. The respondents over 70 years of age could recall their memories from the TCs that occurred in 1960s and 1970s. Of the eleven study sites, the respondents from Sandwip, Maheskhali, Banskhali, Kutubdia, and Kuakata could recall deaths in family members and neighbourhoods during the cyclone of 1965 and 1970. In exception, the respondents from Shamlapur coast from Teknaf reported that they had not experienced any deaths in the area due to TC, although that area is located within 500 m from the Bay of Bengal coast. The area is comparatively higher above sea level than the other coastal regions and the north-south elongated coast is located along Cox's Bazar hill range. The construction of the coastal marine drive (road cum embankment project) in the region also protected the communities. There are some fishermen who live outside of the road and adjacent to the coast who may face cyclone associated damage. This means that the effects of storm surge is very context specific. The participants lost their two houses in their lifetime on an average. Only twelve respondents had ever received only damage in their houses. Of the remaining 88% respondents, 31% lost one house, 27% lost two houses, 16% lost three houses, 6% lost four houses, 6% lost five houses and 2% lost six houses. The people lost houses in the years of 1991 and 2017 in Chittagong region.

3.4. Trust in cyclone warning signals and evacuation response

The findings of this study suggest that significant improvements in the community's trust of cyclone warning signals has developed. Out of 362 participants, 94% of respondents trust in cyclone warnings and the remaining 6% did not trust in warnings. Prior to Gorky 1991, trust and mistrust in TC warning was 54 and 46% respectively. Informal discussions with the participants suggest that those participants who live adjacent to the sea and who lost family members by TCs have higher trust in warnings. The participants in Maheskhali Island uttered that*: 'we did not have trust in warning signal before. Now we get panicked if we see severity of wind. We move to shelter centre; We do not depend on the other people's evacuation decision*'. In the past, there was no effective signal dissemination as the way of warning for an approaching cyclone that has recently been hoisted. Participants at Patenga noted that they live close to the sea and watch the sea roar every day. Due to this, they understand sea water turbulence and respond to the cyclone warning. Generally, the impoverished people who do not have strong and well-constructed housing to resist such extreme weather events prefer to move to a cyclone shelter. Out of 362 participants, 63% evacuated during the last severe cyclone and the remaining 37% did not leave their house. House type surveys suggest that 18% of participants had strong houses. As such, actual non-evacuation is at 19%. The findings noted that those participants who live adjacent to the sea and lost family members by TCs have higher trust in warnings. Those people who lost their family members during the 1991 cyclone, had fear in mind and leave their homes when they hear the cyclone warning signal number over 6 times. Generally, this group evacuates more than those from a non-death family.

3.5. Different factors that contributed to deaths during tropical cyclones from 1970 to 2021

This study attempted to identify which factors contributed towards deaths during TCs in their place of residence between 1970 and 2021 (Table 4). The top ten factors that caused deaths in the past include: (1) Lack of warning system in the past; (2) Lack of embankment or not repairing or maintaining adequately embankment; (3) Limited cyclone shelters in the area; (4) Disbelief in the warning; (5) Limited volunteers, microphone and loud speaker to disseminate warning during extreme weather; (6) Kutcha (non-masonry) houses; (7) Kutcha (unpaved) road; (8) Limited availability of devices to receive warning in the past; (9) Limited strong building or other type of infrastructure nearby; and (10) Women did not have permission to leave houses. The residents stated that they believed that the influence of these factors has been much reduced because of the improvement in disaster risk reduction, socio-economic development of communities and infrastructural development. For example, the lack of warning system was a great challenge before the 1991 Cyclone. The residents no longer have any concerns about the quality and validity of the cyclone warning system and network. The residents also mentioned the availability of devices to receive warnings and efforts provided by CPP and civil administration to disseminate cyclone warnings. In contrast to women lacking decision making capacity before, they are now much more aware and capable to make an evacuation decision. In the past, women died because they wore the *saree* (a typical woman clothing) and attempted to be with *saree* to protect *purdah* or ensure modesty (A Muslim woman covers her body including the face) which was floated by surge water. *Saree* and hair become weighty and cumbersome when immersed in storm surge water resulting in deaths of women by entanglement and drowning. These findings are coincided with earlier studies in the region [10,14,15], although, these factors are a lesser contributory to recent mortality data. In the past, the residents also did not want to leave their dwellings, leaving their animals, food, properties and houses essential to daily living and future livelihoods.

3.6. The losses by cyclone hazard differ from one settlement to the other

The participants explained the differences in deaths associated with cyclone disasters from one settlement to the other, on the basis of their past hazard experiences. The settlement development pattern is very important to understand and explain deaths that occurred in low-lying coastal and island areas, and new emerged land adjacent to the coast. The single house in low-lying areas and close to sea was smashed during the TCs in 1970 and 1991. Participants in Char Maghdara stated that single houses in Char-area could not dig large ponds whereas compact houses made by communities were able to dig large ponds. The rural community dig ponds and use the removed earthen to raise a plinth for the homestead that saves them from storm surge. The single house without vegetation coverage makes it highly susceptible to wind and storm surge.

In Sandwip, the houses within the 2–3 kms from the coast experienced the first onslaughts of storm surge and faced higher losses including lives, houses, crops and infrastructure. Most of the houses in Char area are single without enough vegetation coverage. The outer side of the Island or coast are usually low-land without enough natural vegetation coverage. The people who live in isolated settlements in low-lying areas do not have the social and support networks that the people have in populated areas that is based upon a history of living several generations. The soil type in the latter type of settlement is compact and strong and supported with large trees that cover the area. In Sandwip, the houses that are located within the inner part form a compact settlement that is more resilient to TC and associated storm surges. The trees in larger settlements are older, branched and strong so that they provide better protection. When people from the same clan live together, they also form a compact settlement. The families living together in Patenga for generations formed jointed houses that sustained and endured during storm surge and less damage occurred during Gorky 1991. It was noted that the spread of new and separate houses producing an increase of the nucleus settlement, will experience damage. The participants at Kuakata expressed their belief that the settlement developed along and outside of the embankment is more vulnerable. The participants at South Putivilla in Maheskhali suggested that old settlements standing together at what is considered high land is comparatively better however, small houses at low land are very susceptible to wind and sea surge. In this area, mud is key instruction material for tin made houses which are highly prone to cyclone damage.

Ineffective land management systems allow impoverished people to develop scattered settlements in high cyclone prone areas with limited protection measures. Examples from both TC and river flooding prone areas suggest that these types of settlements experience damage every year [15,30]. The poor people who cannot afford comparatively safer land in the mainland, often settle in hazard prone areas given low land price or free land owned by the government [31]. They are more vulnerable because they are excluded from information aimed at improving preparedness, evacuation following early warning, limited traditional social networks and insufficient public cyclone shelters to protect against sea surge [15]. These constraints reflect some of the wider comments that increasingly emphasise integration of disaster risk reduction and development activities in the places at risk [32,33]. In particular, limited cyclone shelters, transport networks and other informal infrastructures including schools and hospitals along the coastline where scattered and linear settlements form implies that it will require wider integration of disaster risk reduction, climate change adaptation and development activities in the region [34,35].

3.7. Factors and reasons that still might cause deaths by tropical cyclones

The current improvements in warning systems, awareness, road networks and cyclone shelters were explained to the residents and they were asked what factors they believed could still contribute to deaths by TC. The factors and reasons for deaths mentioned by the respondents are mostly the community's development maturity and infrastructural development related (Table 5). Based on impressions derived from field visits, and face-to-face interviews, the findings highlight a range of socio-economic (i.e., poverty and fragile housing condition), environmental (i.e., increase in the severity of cyclone speed), cultural (i.e., superstition), geographical (i.e., exposed coast), infrastructural (i.e., limited cyclone shelters), policy-related issues (i.e., land management policy) that still might cause deaths by TCs on the Bangladesh coast. The top ten factors and reasons include: (1) Living adjacent to the coast without embankment or lack of embankment or breakage of existing one; (2) A repeat of 1991 like cyclone; (3) Non-evacuation of residents leaving behind animals, property and livestock; (4) Distance of the cyclone shelter; (5) Insufficient number of shelters accommodating all people; (6) Poor road transport; (7) Lack of good housing; (8) Elderly people and those will limited mobility or the disabled not being evacuated during a cyclone; (9) Lacking recent experience in damage or death resulting in carelessness/disbelief; and (10) Poor radio signal and mobile network problems resulting in no warning information (Table 5). In comparing the list of top factors of cyclone disaster deaths in the past (Table 4) and present (Table 5), there are improvements in warning systems, community's trust in early warning and message dissemination and spread. For the recent cyclones, emerging risks except for those top factors and processes include (Tables 4 and 5): economic pressure, forcing them to work during disastrous situations, boat accidents, increase in the severity of tropical cyclones causing trees to fall down, collapse of houses resulting in deaths and injuries and an increase of disabled people. People were killed and injured due to the physical collapse of fragile houses. A number of deaths were also reported when they were fishing at sea when the extreme weather event occurred. The participants at Darianagaor (Cox's Bazar Sadar) reported that two people died during 2017 Mora. Those impoverished persons who work as fishing boat workers often go fishing during the cyclone period. Many people died in this area due to boat drowning or related accidents. They are trapped at sea and cannot return home because of the turbulent weather.

The majority of residents from the entire coastal belt region are in agreement that coastal embankments are the main defence in surviving a storm surge. The respondents in Sandwip Island mentioned that the breakage of the earthen embankment during the Cyclone Gorky 1991 was the main reason for colossal deaths in the low-lying areas close to the coast. In absence of or lack of an embankment, the residents could not survive through a cyclone disaster in the coastal region. The residents stated that earthen embankments which were lower in height were often smashed and damaged during the rainy season in the past. Therefore, block embankment construction has been taking place under the embankment improvement project since 2013. The residents living in high risk areas have been waiting for the coastal embankment to be completed. Those who live close to the sea without coastal embankment cannot eliminate risk of death by TC. The coastal embankment is considered extremely weak at south Kutubzome in Maheskhali. In absence of a strong polder or block coastal embankment, the residents have been living with the fear of destruction and death by TC. Those people who live close to the sea will typically experience more losses than those who live in inner parts of the Islands of Sandwip, Kutubdia and Maheskhali. This coincides with the earlier seminal studies by Cutter [36] which pointed towards geographical locations where vulnerable communities and places are located. Over the years, a number of researchers have contributed to this integrated approach providing examples from a wide range of spatial context [15,37–40].

The residents from eastern and mid coastal regions did not experience a category 4 TC and associated storm surge after 1991 Gorky. The respondents from Maheskhali and Sitakunda uttered that if there were a repeat of the 1991 cyclone, those people who do not move to a shelter centre would die. Khuruskul was heavily affected by the 1991 and 1997 cyclones, however, in the last two decades the residents have only experienced wind associated damage. The residents at north Goramora (Sitakunda) suggested that there were storm surges that had reached the height of the 1991 cyclone and they do not understand future height of storm surge in the region. The participants at Patenga suggest that after the 1991 Gorky, coastal embankment was constructed the storm surge never again reached residential areas which they believe creates a false confidence in the event of a future super cyclone. The residents in the entire coast coincided that if evacuation were not successful, the occurrence of a similar cyclone to the 1991 Gorky could generate huge casualties and immense damage.

The residents often stated that since the 1991 Gorky occurrence, over 30 years ago, those below 35 years old had no experience or knowledge about the possible severity such an occurrence of a cyclone of the same magnitude would produce. Seminal studies on natural hazards evidenced that understanding communities risk perception and preparedness are essential components towards delivering risk reduction [4,41]. Providing examples from volcanic hazards, Johnston et al. [42] suggest that those who directly faced any hazards have higher hazard knowledge and risk perception. In relation to studying earthquake and tsunami preparedness on the Bangladesh coast, Alam [43] suggested that people tended to take precautions for frequently occurring TCs but showed apathy towards earthquake and tsunami, for which they do not have personal experiences. When undertaking risk mitigation approaches, it is important to study communities' hazard knowledge and risk perception [44] because it is unlikely that an individual will participate in disaster prevention activities without any appreciation of the hazard and risk [45]. For such cases, movies on past mega disasters, frequent drills and exercises can lead to enhanced disaster preparedness, understanding and compliance [46].

Some people prefer not to move to cyclone shelters as they feel this will leave their domestic animals and livestock unsafe and vulnerable. These domestic animals and livestock are the main means of living for many coastal residents who prefer not to move to a public shelter centre and are determined to safeguard these, household utensils, properties and houses. The residents at Sarikait reitered that there is no *killa* to safeguard animals and livestock. They added that in the event of TC occurrence, the residents may not experience deaths however they may die economically after the event by losing houses, livestock, crops and trees. One respondent in Maheskhali reported: '*there are still people who are careless about their life and personal safety, and some priotorised purdah over safety and also face indecision what could happen for their houses*.' To this end, approaches in school curriculum and emergency management in Japan and elsewhere called 'zest for living' and 'leaving everything behind to save lives during emergencies' is a strategy and cultural shift that should be further established in Bangladesh [47].

During the cyclone period, due to heavy rain, unpaved roads are immersed in water, becoming slippery removing the capacity for residents to leave their houses by road for shelter amidst heavy wind speed. Heavy cyclonic wind speeds uproot trees and blow the roofs of houses. This debris may block the roads and the residents are also panicked that they may suffer injury or death from the wind-blown materials and electric poles. Sometimes, these types of materials block the road networks and people cannot get to the shelter centre. The respondents from east coast of Sarikait emphasised that the road is not paved, and some residents are not connected by any

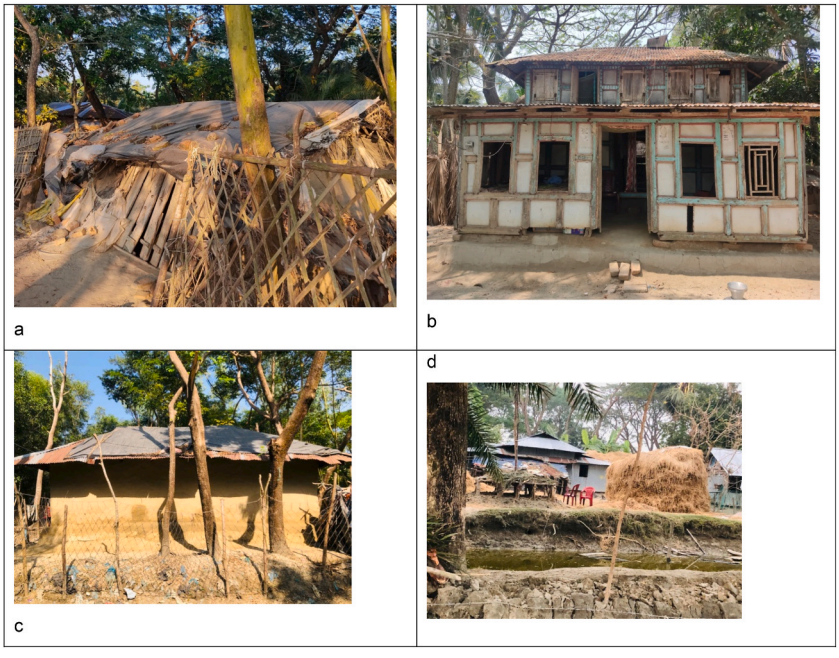

Fig. 2. Fragile houses in the coastal region in Bangladesh a. House at Kutubdia (trees fell down resulting in deaths and injuries; b. house at Kuakata; c. house at Maheskhali; d. house Sandwip.

road network, obstructing and limiting evacuation during the emergency period. In absence of a road network and lack of a cyclone shelter, there will still be casualties in east Sarikait area in the event of a repeat of the 1991 cyclone.

Lack of facilities and problems inside the shelter centre were discussed in great detail as a reason for non-evacuation. Although the number of shelter centres has increased and the distance from the shelters to houses has also minimised, the residents still mentioned the lack of shelter centres, the long distance between shelter centres and their homes. On occasions, the shelter centre is located far from the coast to protect it from coastal erosion, however, the poor live along and close to coastal embankments where limited road networks exist. If they do exist, these are *kutcha* type roads that go under water during cyclonic rain. This type of road becomes wet and slippery and sometimes unserviceable and in need of significant lengthy and involved repair as a result of cyclonic rain.

Space in the public cyclone shelters is generally not adequate to accommodate all the people who live locally. The respondents from North Alekdia suggested that the shelter centre is very far and the road to location is very narrow and does not support rapid or smooth transition. Some residents live a great distance from a shelter centre and do not want to move to the shelter considering that distance and the expenses involved when undertaking evacuation. Cyclonic severe wind uproots trees and removes the roofs of the dilapidated houses which regularly fall into the street obstructing vehicles and people's movement. The residents who live along the coastal embankment in dilapidated houses; who have sick and elderly people, indicated that they cannot evacuate due to the poor road conditions during the emergency period.

Out of 362 respondents, approximately 82.32% live in a varied form of dilapidated and *kutcha*-type houses (Fig. 2a, b, 2c and 2d)). These houses are very susceptible to severe wind and storm surge. *Kutcha* houses may be damaged by falling trees and casualties of property, livestock and human life might occur. Poor people cannot rise out of poverty as a key hindrance is the frequent damage annually from extreme weather events. This is further compounded by the time required to rebuild houses depleting any previous monetary savings or the requirement to enter into debt to obtain loans with high interest rates. In 2021, some participants in Maheskhali lost houses and crops because of sudden failure in the coastal embankment. In Sandwip, those people living close to the coastal embankment in dilapidated houses, without an adjacent public shelter centre, may typically experience deaths, property loss and livestock loss.

The findings suggest that for a variety of reasons, the elderly, disabled, females and children could not evacuate following early warning signals. In Maheskhali and Sandwip, it was noted some disabled persons did not have anyone to take assist them to the shelter during the disaster situations. Although the aim is for everyone in the affected region to evacuate for the shelter centre, these with disabilities were left at home. If a storm surge should occur, these particular group would have lost their lives. Along the coastal embankment in Sandwip, the residents noted the presence of sick and elderly people who cannot move along kutcha roads during the emergency period. In some cases, males of family live overseas, leaving children, adolescent girls and females at home. It is difficult for them to move during disaster situations without government led assistance for evacuation. This demands revisiting current approaches and incorporating inclusiveness particularly considering growing female headed households, elderly population and disability in disaster preparedness in the region [48].

The participants reported that migrant workers from the mainland and northern parts of the country work as seasonal workers in the coastal region. For example, in Sandwip, in brick-kilns along the coast, temporary labourers work and reside, who do not have previous knowledge or understanding of cyclones. These temporary residents perceive the cyclones as a low risk event. Similarly, in cross coastal regions, there are many fishing boat workers and fish processing factories, with seasonal workers who reside in dilapidated houses. These labour groups have higher vulnerability due to a lack of social network and housing designed to resist extreme weather events.

The participants across study sites pointed towards a portion of their community members who are really fatalistic, unaware and uneducated and never wanting to leave their houses. The participants stated that households' expenses are currently quite high and it's very difficult to sustain daily life. They stated that some male heads of the households are daily paid workers who would not earn money if they leave their work and seek shelter. The participants at south Putivilla (Kamiterpara) and Kolatali stated that most of the people from this area are fisher. These residents repeatedly reported the deaths of fishermen at sea by sickness and turbulent weather and that boat drowning occurs every year. The residents cautioned that in the event of failure to evacuate from the sea following an early warning signal, many fishermen would die due to a repeat of the 1991 Gorky-like event. The fisher community live close to sea in dilapidated houses. Due to a lack of monetary savings, they cannot stop fishing, even during extreme weather conditions.

The maintenance of law and order is important to ensure the security of property of the residents in disastrous situations. The participants in Maheskhali, Banskhali and Sitakunda suggested that if they evacuate to the public cyclone shelter, they might have experienced theft of their household utensils, livestock and animals. The participants at north Goramora in Sitakunda suggested that they need to move from the western low land coast to eastern mainland for evacuation purposes. In the past, if they did move to the east, fellow local residents stole their belongings. Some residents in Sarikait and Kutubzome mentioned that if they go to the shelter centre during the disaster, they experienced theft by those who had nothing to save and they stayed around to steal. In urban areas, Patenga coast in Chittagong city, the local police led the evacuation with vehicles. The participants at Fulchari para from south Patenga suggested that as it is an industrial zone with many raw materials that could become airborne flying objects, that if residents do not evacuate to the public cyclone shelter and remain there in storm surges, serious accidents might occur may occur from this specific debris type.

4. Conclusions

This study answers how deaths occurred as a result of tropical cyclones in the past and factors that might still contribute towards deaths from identified cyclone hazards. The identified factors and reasons that still might cause deaths by TCs have importance for

formulating cyclone disaster mitigation policies, particularly in the areas of nexus of disaster and development. The findings indicate that there have been improvements in housing structures and design, warning responses and evacuation to public cyclone shelters and informal cyclone shelter centres. At the utmost, the findings identified that the community resides and works in hazardous places (places at risk) which without effective coastal embankments strategies which contribute towards deaths by TC occurrence in the future. If there were no established and adequate embankment coverage, astronomic tide and TC associated sea surge will devastate the area. Coastal embankment is considered the main strength for combatting the effects of TCs. For this reason, the participants' reflection is that it would require strengthening current progress in constructing block embankments and on time periodical maintenance of them to sustain lower deaths and damage associated with TCs on the Bangladesh coast.

The field visit in coastal Bangladesh in 2022 and subsequent findings implies that the residents who are living in remote areas are still at great risk from cyclone disasters. Due to the lack of recent experience of the 1991 Gorky-like cyclone, if the residents from eastern and mid coastal areas were to experience a cyclone of similar magnitude, the event might cause great damage and casualties due to limited perception, knowledge and understanding. The residents still deter to move to public cyclone shelters mentioning a variety of reasons including lack of a safe refuge place (*Killa*) for domestic animals, shortage of public shelter centres, space problems and facilities in shelter centres, unpaved roads being damaged or slippery during the cyclone period and lack of transportation to move to the shelter centres. The residents often prefer to stay in their own homes or take refuge in adjacent reinforced buildings and infrastructure. In synthesising the results surrounding key factors of cyclone disaster deaths, the study recommends that there is still significant room for improvement and growth in facilitating emergency evacuation and shelter centre management. In considering the enormous financing requirements, long-term goals need to be strategical developed for individual-level disaster-resilient housing development.

Apart from the repeat of a 1991 Gorky-like TC event and physical infrastructure including the construction of coastal embankments, public cyclone shelters, transport and vehicles, the findings imply that undertaking inclusiveness, education, poverty alleviation, and evacuation and awareness campaigns in the remote locations are all required. Evidence generated from the coastal Bangladesh areas suggests that poverty, livelihood, and limited access to resources increases exposure to natural hazards, especially in the remote areas [49]. There has been a paramount emphasis from the International Decade for Disaster Risk Reduction (1990–1999) to the latest 'Sendai Framework for Disaster Risk Reduction (2015–2030)', the participation of all parties including NGOs, governmental organisations and community based organisations coming together to integrate disaster risk reduction in their regular development agendas [50]. As such, the study suggests enhancing inclusiveness including disaster risk reduction interventions in remote and inaccessible locations where marginal communities still live at risk of cyclone hazards. To sustain current progress in cyclone disaster risk management and to address identified factors that still may cause deaths by tropical cyclones, this study recommends enhancing risk reduction interventions and strategies to be implemented in partnership between individual, community, private sectors, non-government organisations (NGOs) and public sectors on coastal Bangladesh. Despite identifying comprehensive factors and reasons for cyclone disaster deaths in Bangladesh, the author maintains a cautious optimism and suggests that further studies should be conducted considering larger sample sizes, to be analysed through in-depth statistical analysis.

Ethics statement

The Institutional Review Board of the Rabdan Academy has approved community survey in Bangladesh coast (RAREC $\neq$ 0007, date: November 15, 2021).

Data availability statement

The data that supports the findings of this study is available on request from the corresponding author. The data is not publicly available due to privacy or ethical restrictions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] E. Alam, D. Dominey-Howes, A new catalogue of tropical cyclones of the northern Bay of Bengal and the distribution and effects of selected landfalling events in Bangladesh, Int. J. Climatol. 35 (6) (2015) 801–835.
[2] E. Alam, N.S. Ray-Bennett, Disaster risk governance for district-level landslide risk management in Bangladesh, Int. J. Disaster Risk Reduc. 59 (2021), 102220.
[3] A.A.-M. Khan, Perception of cyclone hazard and community response in the Chittagong coastal area, Orient. Geogr. 18 (2) (1974) 85–94.
[4] I. Burton, R.W. Kates, G.F. White, The Environment as Hazard, second ed., The Guilford Press, New York, 1993.
[5] J. Twigg, M. Bhatt, Understanding Vulnerability: South Asian Perspective, Intermediate Technology Publications, London, 1998.
[6] B. Wisner, et al., At Risk: Natural Hazards, People's Vulnerability and Disasters, Routledge, London, 2004.
[7] Standing GoB, Orders on Disaster. Ministry of Disaster Management and Relief (MoDMR), Governemnt of the Poeple's Republic of Bangladesh, GoB), Dhaka, 2010, p. 239.
[8] M. Faruk, S.A. Ashraf, M. Ferdaus, An analysis of inclusiveness and accessibility of Cyclone Shelters, Bangladesh, Procedia Eng. 212 (2018) 1099–1106.
[9] C.P.P. Cyclone, Preparedness Programme (CPP), the Ministry of Disaster Management and Relief, the Government of the People's Republic of Bangladesh, 2022 [cited 2022 23 July 2022]; Available from: http://cppvolunteer.info/.

[10] M.A. Islam, Human adjustment to cyclone hazards: a case study of Char Jabbar, in: G.F. White (Ed.), Natural Hazards: Global, Regional and Local, Oxford University Press, New York, 1974.
[11] T.S. Murty, R.A. Flather, R.F. Henry, The storm surge problem in the Bay of Bengal, Prog. Oceanogr. 16 (1986) 195–233.
[12] A.K. Siddique, A. Eusof, Cyclone deaths in Bangladesh, May 1985: who was at risk, TGM (Trop. Geogr. Med.) 39 (1987) 3–8.
[13] C.E. Haque, D. Blair, Vulnerability to tropical cyclones: evidence from the April 1991 cyclone in coastal Bangladesh, Disasters 16 (3) (1992) 217–229.
[14] C.E. Haque, Climatic hazards warning process in Bangladesh: experience of, and lessons from, the 1991 April cyclone, Environ. Manag. 19 (5) (1995) 719–734.
[15] E. Alam, A.E. Collins, Cyclone disaster vulnerability and response experiences in coastal Bangladesh, Disasters 34 (4) (2010) 931–954.
[16] Ohiduzzaman, M., Socio-economic and environmental effects of the 1991 cyclone in coastal Bangladesh : a local level analysis. MURP Thesis, Department of Urban and Regional Planning, in Department of Urban and Regional Planning. 1993, Bangladesh University of Engineering and Technology (BUET).
[17] A.M.R. Chowdhury, et al., The Bangladesh cyclone of 1991: why so many people died, Disasters 17 (4) (1993) 291–304.
[18] CARE After the Storm, Bangladeshi Response to the Cyclone. CARE, Cooperation for American Relief Everywhere) -Bangladesh, Dhaka, 1991.
[19] Caritas, Cyclone-91: in Memorial, Caritas-Bangladesh, Dhaka, 1991.
[20] B.K. Paul, et al., Cyclone evacuation in Bangladesh: tropical cyclones Gorky (1991) vs. Sidr (2007), Environ. Hazards 9 (1) (2010) 89–101.
[21] B.K. Paul, Factors affecting evacuation behavior: the case of 2007 cyclone Sidr, Bangladesh, Prof. Geogr. 64 (3) (2012) 401–414.
[22] B.K. Paul, Why relatively fewer people died? The case of Bangladesh's Cyclone Sidr, Nat. Hazards 50 (2009) 289–304.
[23] F.B. Ibrahim, M.M. Rahman, N. Rezwana, Non-response to early warning: a comparative study of three recent cyclones in Bangladesh, Dhaka Univer. J. Earth Environ. Sci. 8 (1) (2019) 53–60.
[24] C. Swarnali, H. Akihiko, Evacuation behavior: why do some people never evacuate to a cyclone shelter during an emergency? A case study of coastal Bangladesh, J. Disaster Res. 15 (4) (2020) 481–489.
[25] C. Bern, et al., Risk factors for mortality in the Bangladesh cyclone of 1991, Bull. World Health Organ. 71 (1) (1993) 73–78.
[26] S.K. Saha, H. James, Reasons for non-compliance with cyclone evacuation orders in Bangladesh, Int. J. Disaster Risk Reduc. 21 (2017) 196–204.
[27] E. Alam, B. DelGrosso, Tropical cyclones: experiences from Bangladesh and the United States, in: Routledge Handbook of Environmental Hazards and Society, Routledge, 2022, pp. 73–87.
[28] B.D. Phillips, Qualitative methods and disaster research, Int. J. Mass Emergencies Disasters 15 (1) (1997) 179–195.
[29] F.H. Norris, Disaster research methods: past progress and future directions, J. Trauma Stress 19 (2) (2006) 173–184.
[30] M.S.H. Mondal, T. Murayama, S. Nishikizawa, Assessing the flood risk of riverine households: a case study from the right bank of the Teesta River, Bangladesh, Int. J. Disaster Risk Reduc. 51 (2020), 101758.
[31] E. Alam, Landslide hazard knowledge, risk perception and preparedness in Southeast Bangladesh, Sustainability 12 (16) (2020).
[32] R. Seidler, et al., Progress on integrating climate change adaptation and disaster risk reduction for sustainable development pathways in South Asia: evidence from six research projects, Int. J. Disaster Risk Reduc. 31 (2018) 92–101.
[33] A.E. Collins, in: T. Binns (Ed.), *Disaster And Development*. Routledge Perspectives on Development, Routledge, London and New York, 2009, p. 285.
[34] J. Twigg, Disaster Risk Reduction: Mitigation and Preparedness in Development and Emergency Programming, Overseas Development Institute (ODI), 2004.
[35] R.K. Mall, et al., Disaster risk reduction including climate change adaptation over south Asia: challenges and ways forward, Int. J. Disas. Risk Sci. 10 (2019) 14–27.
[36] S.L. Cutter, Vulnerability to environmental hazards, Prog. Hum. Geogr. 20 (4) (1996) 529–539.
[37] M. Degg, Earthquake hazard, vulnerability and response, Geography 78 (2) (1993) 165–170.
[38] D.M. Liverman, The vulnerability of urban areas to technological risks: an overview of US and European experience, Cities 3 (2) (1986) 142–147.
[39] D. Ahmad, M. Afzal, Household vulnerability and resilience in flood hazards from disaster-prone areas of Punjab, Pakistan, Nat. Hazards 99 (1) (2019) 337–354.
[40] E. Alam, M.S. Khan, R. Salam, Vulnerability assessment based on household views from the Dammar Char in Southeastern Bangladesh, Nat. Hazards 113 (1) (2022) 329–344.
[41] G.F. White (Ed.), Natural Hazards: Local, National, Global, Oxford University Press, New York, 1974.
[42] D.M. Johnston, et al., Volcanic hazard perceptions: comparative shifts in knowledge and risk, Disaster Prev. Manag. 8 (2) (1999) 118–126.
[43] E. Alam, Earthquake and tsunami knowledge, risk perception and preparedness in the SE Bangladesh, J. Geogr. Nat. Disasters 6 (1) (2016) 1–7.
[44] J.C. Gaillard, C.J.L. Dibben, Volcanic risk perception and beyond, J. Volcanol. Geoth. Res. 172 (3–4) (2008) 163–169.
[45] S. Wegscheider, et al., Generating tsunami risk knowledge at community level as a base for planning and implementation of risk reduction strategies, Nat. Hazards Earth Syst. Sci. 11 (2) (2011) 249–258.
[46] K. Amini Hosseini, Y.O. Izadkhah, From "Earthquake and safety" school drills to "safe school-resilient communities": a continuous attempt for promoting community-based disaster risk management in Iran, Int. J. Disaster Risk Reduc. 45 (2020), 101512.
[47] K. Kitagawa, Continuity and change in disaster education in Japan, Hist. Educ. 44 (3) (2015) 371–390.
[48] M.R. Hasan, M. Nasreen, M.A. Chowdhury, Gender-inclusive disaster management policy in Bangladesh: a content analysis of national and international regulatory frameworks, Int. J. Disaster Risk Reduc. 41 (2019), 101324.
[49] M.A. Seddiky, H. Giggins, T. Gajendran, Impact of Non-DRR NGOs' interventions for community-based DRR mainstreaming in Bangladesh, Int. J. Disaster Risk Reduc. 77 (2022), 103088.
[50] M.A. Seddiky, H. Giggins, T. Gajendran, International principles of disaster risk reduction informing NGOs strategies for community based DRR mainstreaming: the Bangladesh context, Int. J. Disaster Risk Reduc. 48 (2020), 101580.