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Change in cyclone disaster vulnerability and response in coastal Bangladesh

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The number of deaths owing to tropical cyclones in Bangladesh has significantly reduced. Category 4 Cyclone Gorky in 1991 and Sidr in 2007 caused 147,000 and 4,500 deaths respectively, whereas Category 1 Cyclone Mora in 2017 resulted in six. Face-to-face interviews with 362 residents, participant observation, and focus-group discussions answer a research question about how change in coastal areas has contributed to this outcome. The study considered institutional approaches of disaster risk management through legal frameworks, administrative arrangements, cyclone preparedness activities, cyclone detection and early warning dissemination, construction of shelter centres, strengthening of various types of coastal embankments, paved roads, and pre-cyclone evacuation. The findings indicate significant improvement in house structures and design, income levels and diversification, education, awareness, individual capacity, poverty reduction, and lowering dependency on agriculture-based earning. Furthermore, the availability of mobile telephones, radio, television, and social media platforms enhanced social connectivity and greater gender equality and empowerment helped to facilitate disaster preparedness, evacuation, and response.

Keywords: cyclone vulnerability, disaster risk mitigation, understanding change

Introduction

Deaths associated with tropical cyclones have reduced remarkably in many high-risk countries, including Bangladesh, which has experienced 50 per cent of all global casualties (Alam and Dominey-Howes, 2015). For example, Cyclone Gorky (Category 4) in 1991 and Cyclone Sidr (Category 4) in 2007 caused 147,000 and 4,500 deaths respectively, whereas Cyclone Mora (Category 1) in 2017 resulted in only six deaths. Along with improvements in tropical cyclone detection and warning signal dissemination, institutional disaster reduction approaches (UNDP, 2004; UNISDR, 2004), risk reduction activities led by national governments, international development partners, non-governmental organisations (NGOs), and community-based organisations (CBOs), as well as increases in people's awareness and capacities are believed to have contributed to this achievement.

Over the past 50 years, disaster research has identified aspects of vulnerability that cause disproportionate deaths in different regions (Khan, 1974; Burton, Kates, and White, 1993; Twigg and Bhatt, 1998; Wisner et al., 2004). Cyclone disaster vulnerability was well studied in Bangladesh in our paper of more than 10 years ago (Alam and Collins, 2010). However, the observable improvements in mortality data necessitate understanding more specifically the nature of changes in cyclone vulnerability to help sustain and replicate this progress.

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This paper explores how disaster vulnerability and local-level actions have changed the disaster propensity of Bangladesh over the past few decades. The findings add substance to disaster studies in this region where local-level vulnerability reduction and response mechanisms are thought to play a significant role (Uddin et al., 2020; Al-Maruf et al., 2021; Alam and Mallick, 2022). This also reinforces how underlying development circumstances provide a platform on which more effective disaster risk reduction (DRR) is enabled.

Framing DRR in relation to disaster vulnerability and response

There has been a continuous improvement in the practice of crisis and disaster management over the past 40 years. Current DRR approaches are based on learning and experiences from the field of crisis and disaster management. In the past they focused on the provision of a timely and effective response to meet the basic needs of the affected community and to achieve the restoration of a normal life after an extreme event (UNISDR, 2004). However, the United Nations Office for Disaster Risk Reduction defines DRR as being 'aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development'.[2]

As such, DRR strategies necessarily are greater than notions of 'naturalness' of disasters (O'Keefe, Westgate, and Wisner, 1976, p. 266), also targeting disaster resilience in a given population (Manyena, 2006). Studies across the globe identify a relationship between DRR and loss reduction (Mechler and Islam, 2013; Shreve and Kelman, 2014), but with structural measures seen as a cost-effective means of DRR (Kenny, 2012). Yet, these can fall short of addressing the pre-existing vulnerabilities of societies or places (Twigg and Bhatt, 1998). The differential effects of hazards on people, their economic activities, and social structures emphasise systems that make people more vulnerable to the effects of disasters (Maskrey, 1989; O'Keefe, Westgate, and Wisner, 1976; Wisner et al., 2004). In this study, we consider progress in cyclone DRR in coastal Bangladesh in terms of vulnerability as part of the whole process of 'underdevelopment' impact (Hilhorst and Bankoff, 2004) that is locational (Cutter, 1996).

The rationale is that where cyclone disaster vulnerability changes in relation to education, knowledge of early warning systems, income, livelihood resilience, geographical location, greater equality, particularly for women, and leadership, different pathways involving the disaster and development nexus exist, with disaster events undermining development gains and development exacerbating disaster (Collins, 2009a). In these contexts, unilineal DRR approaches often fail due to fragmentation, a lack of coordination, resources, and institutional support, and cost inefficiency. The solution is seen as a whole of society, state, and private and third sector approach that can integrate multihazard and development planning processes (Collins, 2009a; Twigg, 2004). This mainstreaming of DRR as a process of integration at all levels of decision-making (Benson,

Twigg, and Rossetto, 2007; Tiepolo and Braccio, 2020) can enable systematic efforts and investment in early warning, infrastructure development, land-use planning, empowerment, access to essential services, poverty reduction, and livelihood improvement. Meanwhile, changes in awareness and capacity can lead to both DRR and the promotion of local-level development (Twigg, 2004). Change that produces well-being among at risk groups of people helps to redefine disaster prevention as 'building up early' to 'offset disaster risk', which further orientates towards the disaster and development paradigm (Collins, 2018).

Assessing cyclone hazard exposure and vulnerability in Bangladesh

A plethora of studies have been conducted on the overlapping areas of cyclone disaster and climate extremes in the coastal region of Bangladesh. Cyclone studies can be divided into six categories: (i) cyclone genesis, frequency, and intensity and their relationship with climate change; (ii) cyclone warning and evacuation; (iii) risk assessment; (iv) indigenous knowledge and adaptation; (v) disaster vulnerability; and (vi) resilience to cyclone disasters. White (1974) led seminal studies of human responses to natural hazards in 14 countries, asking residents what could be done for disaster prevention. Bangladesh was one of the members of the consortium led by Islam (1971), who documented people's survival strategies and the need for coastal embankments and risk mapping of coastal zones. Khan (1974) conducted research on cyclones in 1963, 1965, and 1970, to understand risk perception and people's responses, noting that disbelief in warnings and not taking adequate preparedness due to self-instinct could be identified. Sommer and Mosley (1972) carried out studies of Cyclone Bhola in 1970, to estimate damage and recovery requirements for post-disaster reconstruction. This devastating cyclone also received a different analysis as it accelerated the liberation war in Bangladesh in 1971 (Chowdhury, 2014; Hossain, 2018).

Following Bangladesh's independence in 1971, the first cyclone which caused severe damage and received national-level attention was the Urir Char cyclone in 1985. The cyclone caused more than 11,000 deaths (Murty, Flather, and Henry, 1986) in Sandwip and Urir Char, two offshore islands located on the path of landfall (Siddique and Eusof, 1987). Although the Bangladesh Space Research and Remote Sensing Organization detected a severe cyclone formation on 23 May 1985 and the Bangladesh Red Crescent Society alerted coastal people to the impending event, there was less preparedness and response to it, resulting in both greater exposure and deaths on the two islands. The major reasons for individual-level non-responses include the distance to cyclone shelters, underestimating the severity of hazards, limited knowledge of cyclones, and differences in opinions about evacuation (Siddique and Eusof, 1987).

In the period of independent Bangladesh, Cyclone Gorky in 1991 was the most damaging event, leading to the deaths of more than 147,000 people in coastal Bangladesh (Alam and Dominey-Howes, 2015). An abundance of research was conducted about the

physical characteristics of this cyclone, individual- and household-level vulnerabilities, institutional responses, and recovery processes (Bern et al., 1993; Paul and Rahman, 2006; Alam and Collins, 2010). Haque and Blair (1992) and Haque (1995) analysed climatic hazard warning processes, disaster preparedness, and people's reactions to warnings in relation to Gorky. These studies demonstrated that despite a timely early warning being disseminated, residents did not respond effectively because of a lack of trust in such alerts, fears of theft of property, and limited public cyclone shelters (PCSs), resulting in colossal human losses. Local people's vulnerability to cyclones also encompasses a wider risk landscape, such as boat thefts that can lead to the loss of household livelihoods.

Studies have also been conducted to understand environmental health problems and local-level survival following Cyclone Gorky (Hoque et al., 1993; Alam, 2003). Hoque et al. (2013) identified water and sanitation as major problems. The findings also noted a lack of environmental health knowledge among affected people and health service professionals (Hoque et al., 1993). Rahman and Bennish (1993) found that despite limitations, coordination was effective among aid agencies and health interventions were able to control the spread of diarrheal diseases and measles. Meanwhile, additional health risks in the region associated with environmental change more widely have been found to be highly varied between different regions in terms of types of environmental hazards (Haque et al., 2013; Nahar et al., 2013; Abedin et al., 2019), cohesive local-level health resilience (Ray-Bennett, 2010), and the propensity for self-care (Edgeworth and Collins, 2006).

The gender dimensions of vulnerability through women's and children's exposure to cyclone disasters have also been explored. Women's reluctance to leave home, their protective instinct to save children and property, and their long clothing and hair, which hinder movement while trying to swim in tidal waves, were identified (CARE, 1991; Caritas Internationalis, 1991; Ohiduzzaman, 1993; Alam and Collins, 2010). Further structural issues, including culture, rights, and representation, have been pinpointed in considering risk reduction. The effects of disasters on individuals depends on age, caste and class, gender, and social status, seen as key in risk mitigation approaches (Ikeda, 1995). Evacuation prior to the landfall of a cyclone warrants power and leadership (Alam and Collins, 2010). To this end, gender dimensions of vulnerability and the right to engage in DRR have been supported by NGOs and international NGOs, including United Nations agencies in various capacities. The current research notes a change in women's roles in disaster preparation, particularly in terms of evacuation practices.

Cyclone Sidr in 2007 was well studied in terms of impacts, warning response, evacuation, health response, relief rehabilitation, and people-led survival strategies, each of these being a potential explanation of fewer deaths (Paul, 2009; Paul and Dutt, 2010; Haq et al., 2012; Uddin and Mazur, 2015). The reasons for this progress were attributed to the Government of Bangladesh's (GoB) disaster management strategies as well as to the physical characteristics of the cyclone, including the duration of the storm and storm surge, the time and location of landfall, and the resilience of the coastal ecology (Paul, 2009). Nadiruzzaman and Wrathall (2015) used ethnographic research methods to reveal that local elites and political power controlled crucial development aids favouring the

comparatively well-off over the structurally poor, resulting in uneven resilience among different social and economic groups.

No Category 4 tropical cyclones have made landfall in Bangladesh since Sidr in 2007. However, two Category 4 cyclones, Fani in 2019 and Bulbul in 2020, directly made landfall in India and affected the southwest of Bangladesh, leading to 10 deaths in each event. Between 2013 and 2017, excluding 2014, four Category 1 cyclones affected the coastal region of Bangladesh: Mahasen in 2013, Komen in 2015, Roanu in 2016, and Mora in 2017; the number of deaths associated with each was less than 50. Studies were undertaken to understand the physical characteristics of these cyclones, their impacts, and the evacuation behaviour of coastal residents (Saha and James, 2017; Akter and Tsuboki, 2021; Rafa, Jubayer, and Uddin, 2021). From a social vulnerability and people-response perspective, the reasons for not moving to the cyclone shelters and non-compliance with warning signals during these tropical cyclones were similarly noted as before (Ibrahim, Rahman, and Rezwana, 2019; Chakma and Hokugo, 2020).

Nonetheless, there remains a lack of evidence-based analysis of the impacts of changes in types of vulnerability and local-level responses to cyclone hazards. The current study sought to provide a more in-depth assessment through participant observations, field visits, face-to-face interviews, and discussions with the residents of some of the most affected areas of coastal Bangladesh.

Aims and objectives of the study

This study endeavours to identify the perceived changes in people's vulnerability and capacities, as well as the improvements of households, NGOs, the private sector, and the GoB that are seen as having affected cyclone disaster survival on the Bangladesh coast. Overall, we seek to determine within what context Bangladeshi coastal people's changes in vulnerability and capacities have contributed to reducing deaths associated with a cyclone disaster? The specific objectives are to:

- examine the perceived changing context of vulnerability to cyclone hazards in relation to local people's experiences on the Bangladesh coast from 1960 to 2021;
- identify the DRR activities, strategies, and interventions of the GoB, the private sector, and NGOs, as recognised by local people living with cyclone disasters; and
- pinpoint which DRR activities, strategies, and interventions of the GoB, the private sector, and NGOs continue to sustain ongoing progress in local-level cyclone disaster risk management.

Methods

To achieve the main aims and objectives of the research and to answer the research question concerning how change in coastal areas has contributed to a significant reduction in cyclone-related deaths, the study applied a mixed-methods approach (Tashakkori

and Teddlie, 2010), collecting data through questionnaire surveys (quantitatively) and focus-group discussions (FGDs), field visits, investigations, and participant observation (qualitatively). Each has its limitations (Gregory et al., 2009). However, mixed methods provide more robust results than relying on solely qualitative or quantitative approaches (Creswell, 2009). In-depth interviews and observations helped us to understand people's responses to and the impacts of a disaster (Phillips, 1997; Norris, 2006), the findings cross-checked with both participant observations and non-participant external interactions with coastal residents.

This study benefitted from the personal account and participant observations of the first author of this paper who was 15 years old at the time of Cyclone Gorky in 1991, living on Sandwip Island. Experiencing high-risk areas of the island afforded an opportunity to take account of people's hazard response processes in daily life. This qualitative personalised data reflection (Lofland and Lofland, 1995) puts a spotlight on experiential social knowledge from within the society.

Although the first author left Sandwip Island in 1991, he continued to visit twice a year up until 2008 and then once every two years up to 2022. He visited affected areas immediately after the major cyclones of 2009, 2013, 2015, 2016, 2017, and 2020 made landfall and conducted field research relating to people's vulnerability and adaptation. During his visits, he took notes on the local environment, residents' lives and changing livelihoods, infrastructures, evacuation during severe tropical cyclones, and changing capacities.

The second author of this paper has visited Bangladesh frequently since 1999 as well as other parts of the world living with coastal disasters. The third, fourth, and fifth authors, meanwhile, have more than 25 years of experience of conducting field-based research with coastal residents in Bangladesh, helping them to hear and to analyse the responses of coastal people.

The research was approved by the Institutional Review Board of the Rabdan Academy in Abu Dhabi, United Arab Emirates, under approval reference RAREC # 0007.

Eleven coastal sites from within the cyclone risk zone[3] of Bangladesh were visited for this study (see Figure 1 in the Supplementary Materials).[4] Of the study sites, five are in Cox's Bazar district:[5] Kutubzome on Moheskhali Island; Samiti Para and Kalatoli in Cox's Bazar city coast; Shamlapur in Teknaf sub-district; Maghnama in Pekua sub-district; and Boro Goph and Durong on Kutubdia Island. The number of respondents from these sites in Cox's Bazar district was 106. Another four study sites are in Chittagong: Sarikait and Magdhara on Sandwip Island; Gandamara in Banskhali sub-district; Alekdia in Sitakunda; and Patenga and Halishahar along Chittagong city coast (see Figure 1 in the Supplementary Materials). The number of respondents from these sites in Chittagong district was 150. As for the other two, Kuakata is in Patuakhali district and Dacope is in Khulna district, where 58 and 48 respondents respectively were interviewed. These areas along the northern end of the Bay of Bengal have experienced higher losses and deaths and are the most cyclone hazard-prone areas of Bangladesh (Alam and Dominey-Howes, 2016). Moheskhali, Teknaf, Pekua, Kutubdia, Banskhali, Sandwip, Sitakunda, Kuakata and Dacope are *thanas*, administrative units in Bangladesh. The selected areas of Kutubzome,

Shamlapur, Kolatoli, Maghnama, Boro Goph, Gandamara, Sarikait, Maghdara, and Sonaichari are *unions* within *thanas*.

A combination of structured, semi-structured, and open-ended questionnaire surveys and FGDs were conducted between December 2021 and March 2022 to collect data. Prior to the holding of interviews, a list of households was prepared. Households were included on condition of the availability of the head members and their agreement to be participants. Based on this list, 362 interviews were randomly applied for those aged more than 59 years and who had experienced tropical cyclones since the 1970s. These households were living within three kilometres of the Bay of Bengal coast. Earlier studies in this area indicated that people living within this distance of the Bay of Bengal suffered the most in previous cyclones (Alam, 2003).

Of the 362 household heads interviewed, 293 and 69 were male and female, respectively. This reflects the fact that women rarely head households in Bangladesh. Nonetheless, interviewing the heads of households is a way of gaining access to valuable information. Interview questionnaires were pre-tested with 20 participants to check the accuracy and applicability and to rectify any shortcomings noted.

This study complies with the norms of social survey administration, with participant rights being made clear during the entire research process.

The respondents experienced the tropical cyclones of 1970, 1985, 1991, 1997, 1998, 2007, 2017, and 2020 that caused extensive deaths and damage on the Bangladesh coast. Those of more than 59 years of age were selected for both face-to-face interviews and to participate in the FGDs because they could better explain changes in society, underlying reasons for vulnerability, local-level responses, and ways of living in the light of their multiple tropical cyclone experiences. The respondents who were of more than 70 years of age also could recall their memories of the cyclones in 1960 and 1965.

The interview questionnaire was composed of four main parts. The first part included structured questions regarding participants' sociodemographic characteristics, including age, gender, number of family members, type of family, duration of living in current residential place, means of livelihood, present and past house types and plinth patterns, and income and education level. The second part addressed participants' cyclone experiences, deaths and losses due to a cyclone, responses to warning signals, shelter-seeking behaviour in previous cyclones, and reasons for non-evacuation during the last super cyclone. The third part presented questions related to the current and past distance to cyclone shelters, sources of disaster warning information, and agreements or disagreements regarding improvements in road transportation and enhanced mobility in terms of getting to cyclone shelters during the cyclone disaster periods. This included asking whether increases in the number of formal cyclone shelters and the construction of the other types of built infrastructures (that is, mosques, neighbours' houses, and schools) had contributed to people seeking refuge during the cyclone disaster period, levels of trust in different types of information sources, differences in losses by cyclone hazard from one area to another based on physical characteristics (such as distance from the coast, forest, and direction of wind and sea surge), and differences in vulnerability based on

social characteristics, contributing to patterns of deaths during tropical cyclones between 1970 and 2021. This third part addresses why and how people's perspectives of vulnerability to cyclone disasters changed from 1970 to 2021, to understand changes in the effects of cyclone disaster risk management, particularly after Cyclone Gorky in 1991, and what factors could still result in death by tropical cyclone in the region. By knowing about the agents of change, such as income, cultural shifts, and other social factors contributing to cyclone risk reduction, impacts could be built upon still further. The fourth part contained a question regarding the expectations of residents and their suggestions for mitigating losses in future cyclone-related hazards.

In addition to the 362 face-to-face interviews, four FGDs were held in each studied coastal district with inhabitants of more than 59 years of age at a convenient time and in a convenient place for them. At the beginning of each FGD, the event coordinator (that is, the first author) introduced himself to the participants and provided a description of the study's aims and objectives and the discussion topic. Then, the event coordinator detailed the various institutional ethical protocols and received consent from the participants. The data collection assistants facilitated the discussions and took detailed notes. Of the four FGDs, three were conducted among male heads of households who worked in agriculture and fishing or were day labourers or grocery shopkeepers, or were retired, and one was with female household members who were housewives. During each FGD, seven participants were present and the duration of each FGD was 50–60 minutes. The residents presented their overwhelming memories of past tropical cyclone experiences. The preliminary results of the surveys and FGDs were grounded in the local context and were further validated by notes taken during field visits and observations, before generation of the broader evidence-based themes. This helped us to develop clear insights into changes in the socioeconomic and vulnerability contexts, hazard responses, and major improvements in DRR and its agents.

We employed an iterative process to analyse the field data. The responses to semi-structured and open-ended questions were sorted, based on the evidenced-based themes and were analysed in sequence, both manually and automatically, using MS Word and Excel. Furthermore, the average was calculated based on the responses provided by the participants. The findings were presented in the form of a frequency tally, in hierarchical order, according to weight values (see Tables 1–4 and 6). A Likert-type scaling was applied to assess agreement about improvements in infrastructure that led to enhanced warning response and evacuation. The record of the FGDs was transcribed and translated into plain Bengali language and the emerging themes were identified through content analysis (Krippendorff, 2018). From the sub-themes, further broader themes were categorised in accordance with the study's aims and objectives. The broader themes were again corroborated through a variety of data collection techniques, including survey results, field notes, and observations to develop insights with a reasonable basis, acknowledging that respondents' accounts were based on their memories. The derived meaningful results were then interpreted based on the relevant theoretical and development literature and the team's past experiences, including with reference to the studies recorded more than a decade earlier.

Findings and analyses: change in socioeconomic indicators, infrastructure, vulnerability, and local response

Changes in socioeconomic and housing patterns

The gender proportions of the 362 respondents were 81 per cent male and 19 per cent female. The average age was 66.9 years, since we only interviewed respondents of more than 59 years. As for the categories of the respondents by family type, 47 per cent were nuclear (that is, parents and children) and 53 per cent were extended (that is, grandparents, parents, and children or siblings living with spouses and children) family. The average size of the family was 6.5. Approximately 98 per cent of the respondents earned less than BDT 30,000 per month (USD 1 = BDT 87 as of August 2022); income in the range of BDT 0–5,000, 5,001–10,000, 10,001–15,000, 15,001–20,000, 20,001–25,000, and 25,001–30,000 per month was 16.3, 25.7, 32.9, 17.1, 5.3, and 1.1 per cent respectively. The average income of the respondents per month was BDT 13,083. Although literacy rates in Bangladesh in 2022 were 76 per cent, about 51 per cent of the respondents were illiterate, since we only interviewed people over the age of 59. Regarding the remaining 49 per cent, completion of primary (one to five years of schooling), lower secondary (six to eight years of schooling), secondary school certificate, higher secondary school certificate, and graduate were 40.6, 1.4, 2.8, 3.87, and 0.2 per cent, respectively. Approximately 33 per cent of the respondents were farmers and 12 per cent were either retired or unemployed. By occupation, the percentage breakdown of the remaining 55 per cent of respondents were fisherman, day labourer, unemployed, small trader, housewife, fish trader, service sector, remittance, and business, amounting to 13.8, 13.3, 12.4, 10.5, 10.2, 2.5, 1.9, 1.4, and 0.6 per cent, respectively. About 46 per cent of the respondents reported having a second income source. Although the rearing of livestock was not a major occupation of any respondents, 33 engaged in it as a secondary occupation. Forty-two per cent of the respondents had been in their current place of residence for generations. Twenty-four and 19 per cent of them moved to their current place of residence during their grandfather's and father's period, respectively. The remaining 15 per cent moved to their current place of residence by themselves. The average number of houses in a homestead, called a *Bari*, is three. Table 1 presents information on the demographics and socioeconomic characteristics of the respondents.

The existence of strong houses is one of the major factors behind survival during severe cyclonic winds and subsequent storm surges. Before the current housing, approximately 41 per cent of the respondents had very weak houses made of straw and bamboo, with typically paddy straw for the roof. Currently, only 11 per cent of respondents have this type of house. In the past, only 3.3 per cent of the respondents had semi-brick- and brick-built single-storey buildings, while 17.1 per cent currently live in these or similar structures (see Figure 2 in the Supplementary Materials). Overall, the number of *kutcha* (earthen houses) has diminished (see Table 2). The house plinth is an important feature for a house to remain standing during storm surges. Comparative analysis of current and immediate past house types suggests that the number of houses solely made of mud is less, while the number of brick- and semi-brick-built plinth houses has increased (see Table 2). Notably, in Moheskhali, for example, mud wall houses and tree leafed rooves were dominant types

Table 1. Demographics and socioeconomic characteristics of the respondents

Items/characteristics	Frequency	Percentage
Gender		
Male	293	81
Female	69	19
Type of family		
Nuclear	171	47
Extended	191	53
Education level		
Illiterate	185	51.11
Primary school	147	40.60
Lower secondary school	5	1.38
Secondary school	10	2.76
Higher secondary school	14	3.87
Graduate	1	0.28
Major occupation		
Agriculture	121	33.43
Fisherman	50	13.81
Day labourer	48	13.26
Unemployed	45	12.43
Small trader	38	10.50
Housewife	37	10.22
Fish trader	9	2.49
Service sector	7	1.93
Remittance	5	1.38
Business	2	0.55
Monthly income in BDT		
0–5,000	59	16.30
5,001–10,000	93	25.69
10,001–15,000	119	32.87
15,001–20,000	62	17.13
20,001–25,000	19	5.25
25,001–30,000	4	1.11
30,001–35,000	2	0.55
35,001–40,000	2	0.55
40,000+	2	0.55

Items/characteristics	Frequency	Percentage
Duration in current place of living		
We moved our household here	53	15
My father (if female, my husband's father) moved his family here	71	19
My grandfather (if female, my husband's grandfather) moved his family here	86	24
My family (if female, my husband's family) has been here since before my grandfather	152	42
Number of houses in a *bari*		
1	82	22.65
2	105	29.00
3	71	19.61
4	55	15.19
5	22	6.61
6 and above	27	7.46

Source: authors.

Table 2. Changes in house and plinth types

House type	Current		Before current house type	
	Frequency	Percentage	Frequency	Percentage
Tin/wood	135	37.29	85	23.48
Tin/bamboo	99	27.35	87	24.03
Semi-brick-built	49	13.54	9	2.49
Straw/bamboo	41	11.33	148	40.88
Tin	13	3.59	10	2.76
Brick-built single storey	13	3.59	3	0.83
Tin/mud	7	1.93	–	–
Polythene/mud	3	0.83	2	0.55
Brick-built multiple storey	2	0.55	–	–
Tin/straw	–	–	9	2.49
Straw (paddy)/mud	–	–	9	2.49
Total	**n=362**	**100**	**n=362**	**100**
Plinth types	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Mud	299	82.60	335	92.50
Brick-built	42	11.60	11	3.04
Mud and *pucca* (built)	21	5.80	16	4.42
Total	**n = 362**	**100**	**n = 362**	**100**

Source: authors.

of structure that have reduced in number in the past two decades. Surprisingly, in this area, there are still houses made of mud and plastic (see Figures 2, 3c, and 3d in the Supplementary Materials). Similarly, in Dacope, there are houses still constructed of straw and bamboo.

Improvements in shelter centre, road transportation, and other shelter-seeking infrastructure during disasters

Before Cyclone Gorky in 1991, there were limited PCSs; the respondents used to take refuge in the inner areas of the settlement, higher places, and mosques. Responses indicated that they consider this distance to be currently one kilometre on average, and that before the construction of the existing shelter this was approximately four kilometres. Of the 362 respondents, about 18 and 55 per cent live within 500 metres and one kilometre of the cyclone shelter respectively. With rising infrastructural development, residents in some areas rely heavily on varied sheltering places (VSPs), including a neighbour's strong house, mosque, temple, educational and health institutions, and other governmental buildings. For example, residents who live close to Patenga and Khuruskul coast reported that there are no PCSs but that there is a lot of built infrastructure in which to take refuge during cyclone emergencies. Specific reasons why people use VSPs include a PCS at Kalatoli being submerged in the sea. The area had gone through very high infrastructure development as a tourism destination; developed house buildings, hotels, and motels were used as VSPs during the previous cyclone warning. Meanwhile, there were never any PCSs in Khuruskul but there is a well-structured mosque and temples and health centres nearby that served as VSPs during the previous warning. The participants in Patenga do not have clear knowledge of PCSs and mostly refer to health buildings and other types of offices used for sheltering during past cyclones.

Improvements in road, transport systems, and other built infrastructure facilitates emergency evacuation

There are continuous improvements in road types from *kutcha* (earthen) to *pucca* (paved). In some areas, paved roads were constructed only a few years ago. In response to a question about whether the improvements in road transportation enhanced mobility to PCSs during the cyclone disaster period, approximately 94 per cent of the respondents either strongly agreed or agreed, using a Likert scale measurement (see Figure 3 in the Supplementary Materials). Only five per cent had a neutral position and one per cent disagreed in response to the same question. In the past, road transport was mostly earthen and much narrowed in the entire coastal region. The participants on Sandwip Island suggested that the road in the area was of *Ail* type (like the thin boundary of a crop land), which has been paved in the past three decades. In the areas where roads are still of *kutcha* type, the respondents disagreed that there had been improvements. In the southeast coastal region, namely Chittagong and Cox's Bazar, where the entire road systems have been paved, the residents either strongly agreed or agreed with the question.

In response to a question about whether the increases in the number of PCSs and the construction of other types of built infrastructure (mosques, neighbour's houses, schools) had contributed to people seeking refuge during the cyclone disaster period, 95 per cent of respondents either strongly agreed or agreed (see Figure 3 in the Supplementary Materials). Only four per cent were neutral about the question, opining that there were no shelter centres close by or problems inside the shelter prevent them from visiting.

Trust in cyclone warning information provided by information and communications technology

In response to a question about whether respondents believe the information provided by information and communications technology (ICT), such as radio, television, and mobile devices, about cyclone warnings, 94 per cent either strongly agreed or agreed. Only six per cent took a neutral position, because they are either superstitious about it or not aware of the early warning signal delivered through ICT or consider the information provided not to be accurate.

Inter-related physical infrastructural and socioeconomic characteristics of vulnerability to cyclone hazards

The respondents identified a combination of physical and social characteristics that make them prone to a cyclone disaster. These include closeness to the sea, agriculture- and fishing-based livelihoods, wind direction, low and high land, location of shelters, storm surge height, poverty, house type, and transport facilities. There are interlinkages between the physical (distance from the coast, low land) and socioeconomic characteristics of disaster vulnerability. For example, the residents at south Putivilla and Battali Bazar in Kutubzome on Moheskhali Island are very poor; most of them are workers engaged in daily labour, including as rickshaw pullers and fishing and transport workers. They also live on low land, which makes them highly susceptible to cyclone disasters. Furthermore, the residents at Alekdia in Sitakunda said that in relation to exposure and vulnerability, relevant factors were differences in storm surge height, wind speed and direction, geographical location, angularity of the coast, embankment and road type, land height, density and type of afforestation, occupation, and poverty.

The respondents were asked to explain the social characteristics of vulnerability in the light of both their past hazard experiences and losses. They identified 10 interlinked perceived social characteristics that make them vulnerable to cyclone disasters: fragile housing; livelihoods in at-risk places; lack of road and transportation; lack of embankments; lack of cyclone shelters; nearshore housing; poverty; disbelief in warnings; carelessness; and temporary house and settlement in embankment area (see Table 3). Since the participants lost their houses and livelihoods frequently during past cyclone disasters, they ranked these two items as the most vulnerable elements (see Figure 4 in the Supplementary Materials).

The respondents at Darianagar in Cox's Bazar Sadar reported that two people died due to the severe winds during Cyclone Mora in 2017, resulting in the collapse of houses.

Table 3. Perspectives on the social, behavioural, and economic characteristics of vulnerability to cyclone hazards

Reasons for vulnerability	Frequency	Percentage
Fragile housing	232	29.94
Livelihoods in at-risk places	121	15.61
Lack of road and transportation	108	13.94
Lack of embankments (or embankment was not high enough)	79	10.19
Lack of cyclone shelters	55	7.10
Nearshore housing	47	6.06
Poverty	39	5.03
Disbelief in warnings	31	4.00
Carelessness (paying less attention to the cyclone hazard)	27	3.48
Temporary house and settlement in embankment area	19	2.45
Increasing number of elderly population members	17	2.19
Total	**n=775**	**100**

Source: authors.

To guard against cyclone-associated sea surges, the participants identified three types of infrastructure: paved roads, strong coastal embankments, and cyclone shelters. This infrastructure developed by the GoB is lacking in some highly disaster-prone areas, particularly those close to the coast. Respondents from different areas explained the varying characteristics of social vulnerability in terms of the practicalities of their situation. The areas with strong block embankments are more resilient than those without them. Those poorer people who live closer to coastal embankments without proper road connectivity are more vulnerable than other people. A participant at Battali Bazar in Moheskhali pointed out that 'there is no block embankment, only a low earthen embankment. Sometimes sea surge enters in the area and washes away everything, including cows, goats, and livestock'.

The FGDs suggest that people died because of temporary and makeshift houses along the embankment. There were no good road networks connecting the house and the PCSs. In some areas, a PCS is still very far away. People failed to evacuate from that type of remote area during emergency periods because the road network was either broken or submerged in rainwater. For example, participants in east Sarikait underscored that there are too few PCSs for the size and density of the population. The road is narrow and of *kutcha* type, or even no road network is available to connect some houses. People who live a long way from a PCS do not want to move to a shelter given the distance and expense involved. The participants at south Putivilla on Moheskhali Island and north Sonaichari in Sitakunda suggested that the people of that area are very poor and that houses and roads are of *kutcha* type, making them vulnerable to severe tropical cyclones. Because of chronic poverty, these residents are compelled to live in at-risk areas and cannot move elsewhere for a better living. The participants from Sutarkhali at Chalna indicated that

there are no PCSs within four kilometres of their houses. The participants from Gaimtali at Kolatoli and Samiti Para in Cox's Bazar stated that some residents live temporarily on government land where they are not permitted to construct permanent infrastructure, resulting in them living in temporary houses for generations. This type of housing faces a high level of damage due to cyclonic winds every year. Seashore housing, disbelief in warnings, and carelessness were highlighted by some respondents in the coastal belt. The participants at north Sonaichari suggested that poverty is the main reason for vulnerability. Owing to poverty, they were compelled to live on cheaper low land close to the coast. The residents from Kuakata in Patuakhali indicated that some people are careless and tend to disobey warning signals. Meanwhile, a family accompanied by an elderly and disabled person faced difficulties in moving to a PCS.

Exposure characteristics of cyclone risk

The respondents identified five perceived characteristics of physical susceptibility due to past experiences and varying cyclone losses in one area to the next: proximity to the sea; wind direction and sea surge; forest coverage; low and high land; and the slope and the direction of the land. Of the physical characteristics, distance from the coast is the most vital in terms of exposure to sea surge. The houses directly alongside and close to the coast suffer more devastation than those further inland, because they experience the highest wind speeds and greatest sea surges; this is particularly pronounced in the absence of mangroves. The participants at north Sonaichari and Alekdia in Sitakunda said that the area within three kilometres of the coast is affected by sea surge, damaging crops and *kutcha* houses. Participants at Sandwip confirmed that the direction of wind and storm surge is the main factor that defines which area is more affected. Overall, the participants from the southeast coast indicated that if the wind flows from a south-westerly direction, Cox's Bazar city, Moheskhali, and Kutubdia face extreme cyclonic effects. These areas were impacted by the tropical cyclones that occurred in 1991, 1998, 2007, and 2017. In the low-lying *Char* (a newly emerging land with low habitation and sometimes subject to tidal inundation) of Sandwip Island, people live close to the embankment and sea and experience a loss of crops and vegetation to saltwater every year. Usually, it is very difficult to grow crops, trees, and vegetation in the *Char* area due to saltwater intrusion.

The participants from Sarikait on Sandwip Island reported that if the direction of the wind is easterly and south-westerly, the damage to housing is greater. The people living in low-land areas experience more direct wind and sea surge as compared to the inner area of comparatively high land. Participants at Muradpara said that if the wind flows from the east or southwest, it causes more devastation. Areas with more trees are better protected from wind and storm surge. The respondents indicated that trees, particularly mangrove forests, work as a defence against severe wind and storm surge. In Moheskhali, coastal afforestation called *parabon* has been working as a wall against sea surge. The participants at Maghdara noted that where the land is lower, the speed of the surge is higher, causing more damage to houses. The participants from east Sarikait suggested that the houses on low land experience more devastation. For instance: 'The area near to [the] sea

without coastal embankment experiences more disaster losses than [the] inner area'. The participants at Chawkatali underlined that: 'it is low land without embankment, extensive damage occurs in that area. The closer to [the] sea, there are less road networks, fewer shelter centres, and other built infrastructure in Sandwip Island'. The participants at Samiti Para, Cox's Bazar, also indicated that the problem is the low land area, emphasising that 'we get in a panic if [the] wind flow is from the western side because it brings water quickly'.

The participants from Naiapara at Shamplapur pointed out that it is comparatively high land there and that although its distance from the coast is less than 200 metres, the area has never been highly inundated. The residents further explained that to the south, namely at Baharchara, Himchari, and Kalatoli, there are low-land areas that experienced death, loss, and damage during Cyclone Gorky. The intermediate area between these two is medium high land that suffered moderate losses in previous cyclones. The responses of the participants and subsequent field observations at Shamplapur suggest less possibility of death by storm surge in the inner marine drive owing to its geographical location and height. However, fishermen living adjacent to the coast are affected, highlighting the context-specific nature of exposure factors.

Perceived changes in cyclone disaster losses from 1970–2021

The respondents were asked to explain why and how losses owing to a cyclone disaster changed between 1970 and 2021 (see Table 4). To understand variation of loss over time, we presented the timing of cyclones as six periods based on major disaster occurrences and losses in terms of family deaths, illness because of disease, physical injury, housing damage, and lost businesses, crops, poultry, and domestic animals, including cows, buffaloes, sheep, and goats. The respondents extended the sector and types of losses to include those related to commercial and subsistence fishing, disruption of daily income, mental health and well-being, damage due to wind, breakdowns of coastal embankments and roads, salinisation, household belongings, tree damage, and overall human suffering. Notably, the participants could not recall a complete account of losses occurring before the 1991 cyclone. Nevertheless, they significantly recognised family deaths, injuries, illnesses, damage to housing, and the crops, poultry, and domestic animals lost in the period between the cyclones of 1970 and 1991 (see Table 4). In the past, residents were completely dependent on agriculture, poultry, and domestic animals to make a living, but currently there are multiple income sources. Before the 2000s, deaths and illness caused by tropical cyclones were the major concern, but economic losses are now paramount. Human suffering, mental health problems, and income losses, including increased non-workdays during the cyclonic season and business and commercial fishing losses, were more pronounced after the 1997 cyclone.

Overall, respondents from the eastern coast of Bangladesh reported no deaths due to storm surge but increased winds and resultant damage in recent decades, in particular in reference to the 1997 cyclone. Participants at Patenga confirmed that the area was not heavily affected by storm surge owing to a new block embankment, but there was severe

Table 4. Perceived changes in losses by cyclone disasters from 1970–2021

Types of losses	Cyclone 1970	Cyclone 1985	Cyclone 1991	Cyclone 1998	Cyclones 2007–09	From cyclone 2013
Deaths in family	105	34	164	1	10	1
Illness from disease	118	28	150	3	8	11
Physical injury	92	26	114		8	1
Housing damage/destroyed (*kutcha* type)	121	39	195	26	60	29
Crop losses	112	68	138	48	58	55
Business losses	43	16	86	44	69	62
Fish project damage	41	14	56	31	63	64
Livestock (including commercial ones)	53	10	94	40	52	32
No work (difficulties in going fishing)/income lost, leading to economic pressure (debt as well)	–	–	–	37	35	42
Mental health problems	–	–	16	9	8	7
Wind damage, trees fall down (Shamlapur)	–	–	–	57	55	65
Breakdown in coastal embankment	–	–	–	23	31	43
Human suffering	–	–	–	23	28	49
Household belongings	–	–	–	23	22	24
Water salinisation	–	–	–	12	22	21
Damage to roads	–	–	–	–	–	–
Tree damage	–	–	–	17	22	27

Source: authors.

sustained wind damage to *kutcha* houses. At Shamlapur in Teknaf, participants' concerns were more about deaths caused by falling trees and houses. The participants from the east coast confirmed that while several major cyclones (the events of 1970, 1991, 2015, and 2017) affected the region, they have not experienced anything like Cyclone Gorky over the past three decades. However, they had been experiencing economic pressures owing to high tidal surges and occasional storm surges, affecting embankments, agricultural crops, salt farms, and fish projects in the area, such as salt farmers at Pekua. Furthermore, high wind speed and torrential rainfall due to a cyclonic depression caused a loss of income among daily workers, forcing them to live on previous savings and to borrow money at high rates of interest.

Participants from Baraghop (Kutubdia) and Alekdia (Sitakunda) noted that when high tide water or sea surge inundate, it takes longer for the water to recede, affecting crops and health. While the shipyard industry along the Sitakund coast is beneficial to some businessmen and migrant workers, it causes further water logging and consequent crop

damage. Participants at north Alekdia pointed to storm surges that enter the ponds, killing the fish, whereas those from north Sonaichari referred to crop damage every year due to waterlogging, although there have been no cyclone deaths since 1991.

Major improvements in cyclone disaster risk management before and after Gorky

The respondents were asked to explain the major improvements in cyclone disaster risk management in this area before and after Gorky in 1991. They identified 28 perceived challenges and subsequent improvements, which are divided into six categories: (i) individual house- and infrastructure-related; (ii) improvements in cyclone detection, warning, and dissemination; (iii) community and gender dimensions; (iv) income and education; (v) urbanisation and facilities; and (vi) activities by the local community and engagement by the private sector, NGOs, and the GoB (see Table 5). The change resembles a complex of coastal embankment improvements alongside increases in income, education, availability of information by ICT, NGO activities, and risk awareness. The GoB and foreign countries have financed the continual construction of new shelter centres, embankments, hospitals, and school infrastructure, which have facilitated safe refuge during cyclone disasters. More dry and processed food is available now and improvements in food processing and packaging afford residents safe storage in normal and disaster periods. Hence, the residents of Patenga indicated that there was now less reason to stay home to protect stored foods and grains. The participants from north Goramora (Sitakunda) reported that NGOs train women in how to make hair knots, since loose hair is one of the reasons for women drowning during a storm surge. Some NGOs also facilitate loans that can help to provide multiple income opportunities.

Table 5. Perspectives on major improvements in cyclone disaster risk management after Gorky

Challenges before the 1991 cyclone	Improvements after the 1991 cyclone
Individual house- and infrastructure-related	
Residential houses were mostly *kutcha*—made of earthen plinth and mud	Residential house infrastructure improved through the use of strong materials
There were no embankments in the area or they were destroyed earthen embankments	Embankments with concrete blocks
There was no road transport or weak and narrow earthen roads that become slippery during rain	Improvements in road transport
There were no cyclone shelters or they were limited in number or more distant from the house	More cyclone shelters
There was less built infrastructure (that is, mosques, schools, and colleges)	Increases in built infrastructure (that is, mosques, schools, and colleges)
Improvements in cyclone detection, warning, and dissemination	
There were no or inaccurate warnings and the residents did not receive information or did not trust the warnings	Improvements in cyclone detection and warning dissemination and increased trust in the warnings

Limited technology, mobile telephones, televisions, Facebook, and means of making quick connections	Strong and frequent connectivity via mobile, radio, and social media platforms (Facebook, Messenger Chat, WhatsApp, and others)
Lack of volunteers and limited announcements by megaphone	More volunteers, especially social media groups working at the community level as a major presence
Limited work by NGOs, CBOs, and government institutions on awareness and evacuation	More NGOs, CBOs, and government institutions working on awareness and evacuation issues
Community and gender dimensions	
Orthodoxy and low levels of risk perception/interpretation among residents	Local resident's awareness and belief in warnings increased
Inability to make decisions on safe evacuation due to the lack of genuine information and facilities	Comparatively easy decision-making based on available information sources
Orthodoxy about women's roles and religious dogmatism	Orthodoxy about women's roles and religious dogmatism reduced
Women being unaware and not having sufficient power to make decisions on preparedness and evacuation	Increases in women's education and empowerment to make decisions on preparedness and evacuation
Income and education	
Heavy dependence on agricultural activities, which are more prone to cyclone disasters	Number of people entirely dependent on agriculture decreased after an increase in multiple income sources
Poverty rate high	Acute poverty relatively decreased and local-level resistance to hardship increased
Low education, resulting in a lack of awareness and a low sense of security	Higher education rate, resulting in more awareness and a higher sense of security
Owing to poverty, people devoted to domestic animal safety and dependencies	Number of poor reduced and less dependence on domestic animals
High birth rate	Birth rate controlled
Urbanisation and facilities	
Mostly rural areas with limited infrastructure	Urbanisation and facilities have increased
No electricity or only limited to urban centres	The majority of the area is covered by electricity
Lack of transportation for evacuation	More transportation
Lack of hospital and health facilities	More hospitals and health facilities
Activities by the local community and engagement by the private sector, NGOs, and the GoB	
Limited NGOs, CBOs, and government institutions available to work on DRR and related development issues	More NGOs, CBOs, and benevolent local community investment in disaster awareness and related relief
Limited financial and logistics help from the local community	Cash and house construction support increased from within the community
Limited coastal afforestation work	Coastal afforestation decreased in some areas but increased in others
Lack of supply of drinking water	Deep tube well installed by the GoB, with Pond Sand Filters supplied by NGOs

Source: authors.

Contribution of increased income to cyclone DRR

Financial solvency through improved economic activity has directly contributed to DRR over the past three decades. Respondents said that rising incomes have contributed to reductions in cyclone deaths, injuries, and losses. With rising incomes individuals can construct a built house or move to a safer place that is less exposed to high-risk open coastline, next to embankments or outside the embankment in the *Char* area. In Sandwip, every household has at least one person who receives remittances from overseas, which helps with upgrading houses over the course of a lifetime. In the past, crop-based agricultural activities were largely unprofitable and at risk due to saltwater intrusion during high tide periods. Continuous maintenance of the embankment and the use of constructed block embankments by the GoB prevents water intrusion. Consequently, farming activities and income rises have increased confidence. More income sources, including trading, means that people can shift from agricultural to non-agricultural activities that are less sensitive to tidal water or storm surges. Economic improvements have also resulted in a sense of human security. In some areas, financial solvency has enabled people to construct built roads at their own expense, which in turn enhances mobility and access to PCSs or adjacent built infrastructures when there are increased hazards.

Cultural influences on cyclone DRR

Open-ended questioning about cultural change in relation to the previous identified constraints concerning women's decision-making and clothing was performed in the context of some nuclear families beginning to address women's rights. Discussions with residents in Moghnama and Sandwip suggested that responsibility for maintaining the family's basic needs depended on females because males are either busy at work or stay in another area or an overseas country for employment. This leads to women making sole decisions both in normal and emergency periods. In these circumstances, housewives can make the decision themselves to leave houses during the early warning period, with interviewees also referring to it as part of the understanding that 'women are leaders inside the house'. There have also been significant improvements in education for women and women have been emerging as significant in family decision-making processes. Women can increasingly talk to the male heads of household about decision-making, including for evacuation preparedness, and clear suggestions were forthcoming that male attitudes have moved much more towards accepting female opinions.

During Cyclone Gorky in 1991, it was well reported that many people died owing to *sarees*, the long clothing worn by women across their entire body. Many women now have improved clothing: instead of a *saree*, they wear clothing in three pieces. In Sandwip, male respondents said that they allow women to leave early and that women can make decisions about disaster preparation and evacuation using information from mass media sources. The residents in Magdhara and Patenga suggested that women are accessing radio, television, and social media and that this supports evacuation decisions. The residents at Sarikait indicated that orthodoxy and indifference vis-à-vis disaster preparedness were less among both males and females. Women do not feel hesitation or shame

in going outside and they are more aware of their personal and family safety both during disasters and in daily life. A FGD at Banskhali revealed that there are more women in employment and earning money. The involvement in income generation raises the profile of women in terms of their decision-making and power at the household level. In Shamplapur, a site close to Cox's Bazar, the impacts of tourists on female dressing, attitudes, psychosocial well-being, and culture were considered to be visible. However, in contrast, respondents at Moheskhali reported little improvement in women's awareness and that the overwhelming majority of women (75 per cent) depend on male decision-making. In addition, many women there still wear full *sarees*.

The participants acknowledged the existence of social groups, benevolently supported youth activities, and social media-based groups that participate in disaster preparedness, evacuation, and relief. Communication and connectivity were reported locally as being enhanced through social media and mobile telephones, helping to change attitudes. People were coming forward to help each other during disaster periods and spreading any information they received about cyclone early warnings. For example, Mostaq Ahmed, a local person aged 41 years, helped to evacuate more than 100 people during the 1997 cyclone and then again during the 2008 cyclone aided by a support network. Respondents at south Putivilla in Moheskhali reported that locals are very poor and young people go to other areas for jobs, engaging in limited social activities there. The participants from east Soloshahar stated that many of the richer people from both overseas and in-country help disaster-affected people, while residents in Moghnama pointed out that socially influential people had got involved in awareness activities and supporting the poor.

Suggested loss mitigation and enhanced risk reduction for future cyclonic hazards

When asked about what more should be done for DRR in the area, suggestions related to more being needed in the areas of policy and facility development, infrastructural improvement, poverty reduction and income support, development, and social safety nets (see Table 6). These suggestions were linked to existing socioeconomic and geographical contexts at the sites visited. The most apparent suggestions included sustaining block embankments and enhancing road networks and shelter centres (see Figure 4a in the Supplementary Materials). Without strong embankments, the residents cannot grow crops and rear free-range animals in low-lying areas. The residents view the development of coastal embankments with roads as a feasible project for disaster risk management (see Figure 4b in the Supplementary Materials), with the height of the embankments and roads needing to stay above the height of the high tides and possible storm surges. Increases in multipurpose PCSs with sanitation and improved road networks will be needed for successful evacuation prior to a potential future super cyclone (see Figure 4c in the Supplementary Materials). Residents who practise agriculture and rear poultry and animals for a livelihood suggested constructing a *killa*, an earthen mound, to save their poultry and animals during storm surges (see Figure 4d in the Supplementary Materials). For example, residents from Sandwip Island suggested constructing a *killa* in low-lying *Char* areas where free-range livestock are being reared.

Table 6. Recommendations for mitigating losses due to future cyclone hazards

Recommendation	Frequency	Percentage
Completion of coastal embankment using concrete edge and block	260	10.82
More shelters with capacity and sanitation facilities for women	247	10.28
Improving the road network because there is still a *kutcha* road in highly populated areas (see Figure 4c in the Supplementary Materials)	244	10.15
Assisting with the construction of brick-built houses for all people, including disaster-resilient housing for fishers and poor people	152	6.33
The construction of *killa* for livestock	112	4.66
Continuing current awareness-raising activities and disseminating information to everybody	88	3.66
Cyclone shelter locations placed with consideration to residents living in high-risk areas	73	3.04
Mobile network coverage enhanced because people do not get information from mobile communications if there are network problems	66	2.75
Arranging vehicles to move people to cyclone shelters, especially the disabled and children	65	2.70
Electrification of the area	65	2.70
There should be a government policy to encourage and design disaster-resilient housing	65	2.70
The Cyclone Preparedness Programme needs to be extended to at-risk areas	64	2.66
Sufficient water, food, medicine, and other first aid at shelter centres	63	2.62
Enhanced microphones and loud-speakers to evacuate people	61	2.54
Increasing afforestation programmes in the coastal zone, as in Paraben in Moheskhali (see Figure 4e in the Supplementary Materials)	59	2.46
Enhancing social safety nets to improve disaster resilience	53	2.21
Monitoring cyclone formation and warning in advance about the possible occurrence of a Gorky-like cyclone	53	2.21
Prohibit in law settling along the embankment	44	1.83
Door-to-door evacuation, sending people away directly while at their home	47	1.96
Frequent maintenance of the embankment and roads to protect crops and salt farms	46	1.91
Compensation for economic losses	43	1.79
Improving health facilities	43	1.79
Government support for livelihoods during the high cyclonic season	38	1.58
Responsibilities of local government representatives to be fulfilled	35	1.46
Income-generation activities for local people	34	1.41
Sewerage improvement	33	1.37
Fixing appropriate prices for crops and salt that may lead to economic improvement of marginal groups	33	1.37
Emergency evacuation, response, and relief efforts that provide food, medicine, and financial support and that maintain cleanliness	33	1.37

Recommendation	Frequency	Percentage
Improved hygiene and a lower density of people in shelter centres	27	1.12
Cyclone shelters that are also tourist centres	25	1.04
Relocating vulnerable settlements away from the coast	23	0.96
Enhancing DRR activities adjacent to the sea	22	0.92
Permanent plans for residents who temporarily live on public land	22	0.92
More schools, education, and awareness orientated towards risk reduction	22	0.92
Accelerating and completing existing development projects	22	0.92
Controlling riverbank erosion	21	0.87
Total	**n = 2,403**	**100**

Source: authors.

The respondents also advocated for more schools, mosques, and other types of public centres that serve as shelters during disaster periods, indicating that investment in these would promote shelter seeking by poorer residents who still live in *kutcha* houses. Multi-purpose PCSs along with improvements to elevated stronger roads that are more resistant to rainfall (see Figure 5c in the Supplementary Materials) would increase survivability in times of excess rain and extreme cyclonic depressions, particularly among elderly and disabled people who previously could not be evacuated due to transport limitations. Meanwhile, improvements to mobile networks during high winds and severe rainfall would make getting information from social media more secure at those times.

Residents of three sites referred also to limited disaster preparedness and evacuation activity by elected representatives. Residents from the newly declared urban areas in Moheskhali indicated little progress in cyclone DRR because of the inactivity of the city mayor. Some elected representatives of the sub-district of Moheskhali lived in Cox's Bazar city and it was believed that they did not work for the people. The residents' view was that when non-benevolent people are elected as representatives, they do not work in the local interest. In the absence of monitoring by and pressure from the local administration, they do not want to work. Participants thought that on many occasions, they only support their relatives, known people, and voters. The residents at Patenga indicated that evacuation and preparedness also depend on the active engagement and activities of the local government representatives. As such, local government needs to be neutral and working for the people. A criticism was that the Cyclone Preparedness Programme passed volunteering activities to rich and influential people who then do not work during disaster periods.

The narrow strip from Cox's Bazar city to Teknaf has limited residents but tourism-led infrastructure development is taking place. The residents at Darianagar in Cox's Bazar suggested that it might be impracticable to construct public shelters along such a long narrow strip with a low population density. However, a public–private partnership involving many types of infrastructure for informal shelters and the repairing of marine drives for people from Kalatoli to Teknaf should bring greater safety.

Owing to a lack of specific policies on house design and construction materials in highly cyclone-prone areas, a disaster-resilient housing policy, including settlement layout and design, should be developed for the coastal region. Furthermore, residents at Kuakata stated that more government support could be provided for those living along the coast (in Moghnama) in relation to resettling in safer places, job opportunities so as to be able to afford appropriate housing, and deep tube wells to procure safe water and hence avoid disease outbreaks in the post-cyclone period. Those below the poverty line expect more poverty reduction strategies, which might promote further advances in DRR.

Discussion and conclusions

This study has addressed a key question about the context within which people's changes in vulnerability and capacity have contributed to reduced mortality and disaster risk along the Bangladeshi coast. From the information gleaned, it appears that a significant reduction in mortality arising from cyclone hazards in the coastal areas of Bangladesh can be credited to people-centred interventions complemented by the efforts of the GoB, NGOs, and the private sector. However, existing challenges in cyclone disaster risk management, including elite capture of public shelter centres, corruption, and ineffective disaster relief, have also been widely discussed (Mallick and Vogt, 2011; Mahmud and Prowse, 2012; Nadiruzzaman and Wrathall, 2015). Based on participant observations, field surveys, and FGDs, the major changes leading to this engagement and impacts included through housing, income, education, hazard and risk perceptions, preparedness, evacuation following warning signals, women's capacity and changing roles, awareness, development campaigns by NGOs, and the construction of embankments, roads, shelter centres, hospitals, and school buildings by the GoB. Thus, the case findings pertaining to cyclone risk reduction in Bangladesh demonstrate the clear interlinkage between DRR and development pathways. These are often referred to as perpetuated in major policy initiatives (UNISDR, 2015) and other disaster and development literature, but are rarely assessed in much detail in terms of major progress. That improvements in overall socioeconomic indicators and infrastructure have led to reduced deaths and losses in the region is highly significant.

The findings show in terms of cyclone disaster mitigation that, importantly, mortality reductions can be sustained and overall losses minimised through combined development and risk reduction actions that are heavily grounded at the local level. The findings are consistent with, and help to advance further, key ideas that underpin DRR and disaster- and development-related approaches more widely. Specifically, they confirm that mitigation strategies must be technically appropriate and locally grounded and governed, and that anticipatory and long-term investment to 'build up' societal well-being in at-risk locations generates a more sustainable process of prevention. While research, policy, and practice sources have long advocated for strengthening prevention through a vulnerability-facing approach that includes local perceptions and ideas about risk, the impact evidence base in highly exposed low-income settings need not remain more anecdotal or under-reported. The case of improved cyclone coping in coastal Bangladesh is evidenced by returning to our evaluation of years earlier in drawing these conclusions.

Resilient societies are promoted within the Hyogo Framework for Action 2005–2015 and the subsequent Sendai Framework for Disaster Risk Reduction 2015–2030, although more durable case studies are needed. Some of the first community-based risk and resilience committees established optimal processes and principles for local engagement in various parts of the world,[6] focusing on early warning and early action (Collins, 2009b); this approach is now more typical and part of the evolution of people-centred perspectives being promoted worldwide. However, assumptions about the application of 'community' in local actions in disaster risk and development work requires care (Titz, Cannon, and Krüger, 2018) and cannot be a panacea. The coastal Bangladesh example demonstrates the crucial interdependence of local-level actions within an institutionally supporting environment. Without the latter, it is doubtful whether mortality rates would have reduced so significantly there. Caution is also required in assuming a linear pathway to future progress, with much uncertainty now surrounding the expected forthcoming intensification of cyclone- and other climate-related hazards through hitherto unexperienced climate change impacts (Pörtner et al., 2022).

The physical characteristics of cyclone hazard exposure and aggravating land-related factors combine with societal characteristics. Where cyclone-related fatalities and losses have seen improvement, there has been associated vulnerability reduction and repositioning of power relationships. This has been critical to the forward steps identified. It is evident that interlinked societal characteristics accrue higher benefits than solely changes in agriculture, business, remittances, and working in service sectors. The residents constructed strong houses and invested in the education of family members; quality of life enhancing a sense of self security and well-being (Nahar et al., 2013) and encouraging preparedness for an upcoming cyclone hazard. This is in part contrary to our earlier studies in the area when forms of superstition and dogmatism were noted by coastal people in their own analysis of the situation (Alam and Collins, 2010).

Owing to improvements in accurately detecting cyclones, information dissemination, and education and awareness, enhanced, inter alia, by the availability of radio and social media platforms, there is also notably now increasing trust in satellite-based warning signals. Rapid change in the availability of information communication technology through radio, television, and social media, as well as DRR activities by the GoB, development partners, NGOs, and the private sector, have boosted human security in the region. It is notable too that previously, there had been evidence that coastal residents demonstrated fatalistic attitudes towards cyclones, causing deaths (Haque and Blair, 1992).

The high level of ownership of cellular telephones and the rapid and frequent flow of information through television, radio, and social media platforms, with 44.7 million people using Facebook, have led to enhanced social connectivity and education vis-à-vis disaster preparedness and safer evacuation following warning signals. Moreover, education, access to information, and increasing employment opportunities over the years have empowered women to be more significant decision-makers in normal and emergency periods. Nonetheless, the extent of this empowerment still has major limits; participants explained that 'women are leaders inside the house'. Women's clothing and hair have been noted as contributing to higher deaths among this group in cyclones in the 1960s,

1970s, and 1990s (Islam, 1971; Haque and Blair, 1992; Alam and Collins, 2010), but this is now seen as less of a contributor to mortality data.

The GoB with technical and funding assistance from its development partners has been continuously establishing and updating disaster management policies, acts, rules, and strategies in line with its commitments to and follow up with the Hyogo Framework for Action 2005–2015, the Sendai Framework for Disaster Risk Reduction 2015–2030, and the SAARC (South Asian Association for Regional Cooperation) Comprehensive Framework on Disaster Management (2006–15). Over the past two decades, the GoB has undertaken a comprehensive risk reduction approach, in contrast to its earlier conventional relief responses. However, it is clear that policy development and changes in risk management did not alone contribute to vulnerability reduction and capacity among the residents who live in this high-risk region. Our findings indicate that gradual socioeconomic changes, improvements in education and awareness, and livelihood changes contributed to DRR. Although the role of the GoB and other agencies led to infrastructural development, particularly block coastal embankments, roads, and public shelter centres, local shifts in society and culture in the face of disaster risk were also part of the change. This viewpoint is further reinforced by the fact that the majority of expectations and recommendations of participants regarding mitigating losses in future cyclonic hazards involve longer-term development interventions, empowering individuals to contribute to improving well-being and the means of earning a livelihood in the region. The identification of critical factors that have sustained the success of cyclone disaster risk management, particularly through building up the resilience of coastal people (Paul, 2009; Uddin et al., 2020), is important in pinpointing what might be further sustained and replicated elsewhere.

Despite perceived improvements in DRR across multiple sectors and aspects of life, the study participants and the authors maintain a cautious optimism rather than proposing a panacea using the case analysis presented. There were also signs of improvement in the past five decades, following Cyclones Bhola in 1970 and Gorky in 1991, but these were insufficient to offset adequately the impacts of what followed. And there were challenges to warning response, evacuation, and relief following the cyclones that occurred after 1991 (Paul, 2009, 2012; Saha and James, 2017; Islam et al., 2021). We propose, therefore, that to achieve sustainable human security with respect to disasters in the region, and elsewhere, ongoing monitoring and evaluation and endogenous understanding of disaster vulnerability and response implementation locally are required across multiple aspects of life in such a highly exposed region facing compounded climate, disaster, and development risk.

The main limitation of this study is that it is heavily dependent on consultations with 362 local residents of more than 59 years of age. Yet, a more rigorous and long-term study can be developed using this lead, which attracts participants from among local government personnel, NGOs, CBOs, and national-level policymakers, and which is less time-dependent.

Finally, the lessons learnt in dealing with cyclone disaster risk management in Bangladesh over the past 50 years might be usefully applied to similar settings elsewhere.

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Data availability statement

The data that support the findings of this study are embedded in the paper and available in the supplementary material of this paper.

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[2] See https://www.undrr.org/terminology/disaster-risk-reduction#:~:text=Disaster%20risk%20reduction%20is%20aimed,the%20achievement%20of%20sustainable%20development (last accessed on 21 September 2023).

[3] According to BUET and BIDS (1993), the risk zone extends from the coastline (seacoast or riverbank) to an inland limit up to which surge water can reach. The high-risk area includes a strip of land within the risk zone extending from the coastline up to a limit where the depth of storm surge inundation may reach one metre. The latter criterion was selected based on the experiences of survivors during past storm surge inundations. It has been reported by people in this area and observed by the authors that an adult could force their way through water if its depth remains below waist height.

[4] All supplementary materials can be found online in the Supporting Information section at the end of the article.

[5] There are 64 districts in Bangladesh. A district is the second largest administrative unit, and it is considered a vital unit of government administration, consisting of several *thanas*. A *thana* comprises several unions, and several villages form a union. A typical village in Bangladesh contains between 30 and 500 households (BBS, 2020) .

[6] The Disaster and Development Network has explored the meaning of risk, resilience, and security through this approach in a number of case studies in different parts of the world.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.