Progress in Disaster Science 26 (2025) 100423

Contents lists available at ScienceDirect

Progress in Disaster Science

journal homepage: www.elsevier.com/locate/pdisas

Fishers' responses to tropical cyclones in coastal Bangladesh

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ARTICLE INFO

Keywords:
Evacuation behaviour
Fishing communities
Cyclone
SSF guidelines

ABSTRACT

Coastal communities in general have been studied in the context of disaster. However, the specific responses of fishing communities to tropical cyclone events remain relatively under-explored in the disaster science literature. This study investigates fishers' responses to tropical cyclones and various factors that impact behavioral decisions on whether to go to a cyclone shelter. The findings suggest that fishers' coping mechanisms involve securing daily necessities through their initiatives, reliance on kinship relations and obligations, diversification of livelihoods, intensification of fishing, and engagement in social networking and environmental management. The findings suggest that approximately half of the participants refrained from seeking refuge in cyclone centres for various reasons. Crucially, the socio-economic and occupational status of fishing communities significantly influenced their reluctance to comply with evacuation orders. Recognizing non-compliance with evacuation orders is a leading factor in cyclone-related human fatalities and addressing and mitigating non-compliance is essential. Integrated and comprehensive approaches, including cross-sector cooperation, will be needed for effective disaster risk management strategies within small-scale fishing communities.

1. Introduction

Globally, approximately 40 million people are employed in capture fisheries, of which about 90 % are small-scale fishers [1], thus making this sector the ocean's largest employer [2]. Small-scale fisheries (SSF) are are essential not only for economic production but also for people's food, livelihood security, and quality of life [3,4]. Nevertheless, SSF are often described as being associated with the processes of poverty, marginalization, vulnerability, social exclusion, exploitation, discrimination, and impoverishment that occur in different forms and combinations in this fishing context [3,5]. Fishing is a high-risk occupation, with a large number of accidents at sea, particularly during extreme weather events [6,7]. SSF operates in small boats, uses lower motorboat capacity, and employs smaller fishing gear; therefore, carrying out fishing operations is often associated with higher vulnerabilities due to technical failures or natural hazards [8,7]. SSF communities are particularly vulnerable to global climate change due to their high dependence on natural resources, direct environmental exposure to natural hazards, and limited capacity for geographic relocation [9,10,11]. Small-scale fishers face heightened vulnerability to the repercussions of climate change and cyclonic disasters due to their typical residence in coastal communities, placing them at increased risk in

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https://doi.org/10.1016/j.pdisas.2025.100423
Received 1 February 2025; Received in revised form 5 April 2025; Accepted 15 April 2025
Available online 17 April 2025

terms of personal safety, property damage, and threats to their livelihoods [12,13,14]. These increasingly co-occurring processes of political and socio-economic change or instability weaken the persistence and viability of many SSF [10].

In recent years, small-scale fishers, their importance, vulnerability and viability have attracted much attention as several international development instruments. The Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (SSF Guidelines) [4] have emphasized the sustainable future of SSF. The United Nations General Assembly declared 2022 the International Year of Artisanal Fisheries and Aquaculture, and states have undertaken the pursuit of attaining the United Nations Sustainable Development Goals (SDGs) by 2030 [15]. Within the framework of the 17 SDGs, SDG 14 focuses explicitly on the conservation, sustainability, and utilization of oceans, seas, and marine resources to enhance economic benefits. Small-scale fisheries are pertinent to SDG 14; in particular, SDG 14b emphasizes the access of small-scale artisanal fishers to marine resources and markets.

There is a strong interconnectedness between various SDGs and SSF Guidelines [16,17]. Particularly from food security and poverty eradication perspectives, SSF Guidelines represent the first-ever international instrument dedicated exclusively to SSF [4]. Section 9 of the SSF Guidelines explicitly addresses the adverse impacts of climate change and hazards on small-scale fisheries, emphasizing the need for climate change adaptation, mitigation, emergency response, disaster preparedness, and resilience building. The guidelines encourage countries to formulate concrete policies and strategies in consultation with vulnerable fishing communities. This presents an unprecedented opportunity for the emergence of new forms of engagement and collaboration among stakeholders in the sector, fostering the potential for a novel vision for its development co-created by diverse actors, including the fishers themselves [18]. Vulnerability to disaster undermines the role of small-scale fisheries as suppliers of sustainable livelihoods, health and well-being, food security, and economic development, thus hindering the achievement of the targets of the SDGs [19].

The World Risk Index 2023 ranked Bangladesh ninth in disaster risk among 193 countries worldwide [20]. Around 97.1 % of Bangladesh's land area and 97.7 % of the country's population are exposed to the threat of multiple hazards [21]. Bangladesh's coastal areas are exposed to numerous hazards and are highly susceptible to tropical cyclonic storm surges due to several unique geographical and environmental factors. These include extensive and shallow continental shelves, the funnel-shaped coastline, low-lying coastal areas and islands, the confluence of major river systems, and the country's location within the trajectories of tropical cyclones. The combination of these factors makes the region particularly vulnerable to flooding, erosion, and other associated impacts, posing significant risks to human lives, infrastructure, and livelihoods.[22,23,24,25]. High population density, poverty, social inequality, weak institutional capacity, limited financial resources, and poor infrastructure are likely to exaggerate the vulnerability to disaster [26]. An intense cyclone reaches Bangladesh's coast once every three years [27], many of these cyclones results in substantial human fatalities and the loss of physical assets [13,28,29,25]. The intensity of cyclones in Bangladesh is evident because approximately 53 % of global cyclonic hazard-related deaths and 80–90 % of global losses occur in this country [27,28]. There has been a notable reduction in the number of human fatalities compared to earlier extreme events; most deaths and injuries are still predominantly associated with non-compliance with evacuation orders [30,31,32].

Responding to disasters before, during, or immediately after them, not only mitigates the effects of disaster on human life (e.g. by saving lives) and physical and mental well-being (e.g., by reducing health impacts), but also confirms human dignity and rights [33]. The response to cyclonic disasters by vulnerable people forms an intricate pattern of causes and effects influencing coastal communities learning and viability in the short and long term [34,7]. The 2030 Agenda for Sustainable Development recognizes and reaffirms the urgent need to reduce the risk of disasters. The SDGs and the Sendai Framework for Disaster Risk Reduction set the global policy action to achieve SDGs by reducing the exposure and vulnerability of the poor to disasters and building resilient infrastructure [35]. This poses a significant challenge for achieving the 2030 Agenda so that development and progress are even more dependent on measures to build resilience to disaster [36,37]. Therefore, it is necessary to have a clear understanding of the specific characteristics of the fishing industry and the livelihood context of small-scale fishing communities and their actions at the local scale to ensure an adequate response to disaster and warn of future threats through preventive disaster risk management [7]. In Bangladesh, disaster response studies mainly focus on coastal communities as a whole [28,30,32] with limited research on coastal fishing communities specificlly. Few existing studies on fishing communities address pathways of hazards' transformation into disaster (e.g. [13]), institutional, legal, and policy aspects of disaster management and the relevance of SSF Guidelines in disaster risk management (e.g. [16,38]).With this context and research gaps, this study aims to examine: i) How do the small-scale fishers respond to cyclonic disasters on land and at sea, before, during, and after them? (ii) What are the different factors that influence fishers' behavioral responses to government evacuation protocols? (iii) What are the short-term and long-term responses to the cyclonic-disasters?

This paper starts with an introduction of context and objectives, followed by a description of the theoretical framework. Next, it presents methods that include a description of study sites, data collection and analysis procedures, an in-depth presentation of the findings, and a discussion linking the results to the existing literature. Finally, the study concludes with key insights and implications for policy and practice.

2. Adaptive capacity and responses to cyclonic disaster

Community resilience to weather-related events can be described as the community system's capability to withstand, assimilate, and adapt to the impacts caused by environmental alternations [36]. Adaptive capacity refers to individuals, communities, or systems' capability to adjust or adapt 'by adapting to, moderating the impending harms of, taking compensations or opportunities fashioned by, or coping with the impact of global climate change' [36]. Intergovernmental Panel on Climate Change (IPCC) defined adaptive capacity as "the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" ([39]: Annex II - Glossary - IPCC). Burton et al. [40] define hazard response as the various ways a society acts to minimize the negative effects or maximize the benefits of hazards. This includes immediate actions like response to warnings and evacuations, long-term measures such as building houses on elevated areas . For this study, we explore this form of adaptive capacity by empirically investigating actions and strategies in response to past events of disturbances and change processes [41]. Understanding what fishers use as local and or traditional strategies and knowledge to cope with extreme events is necessary to inform planned and formalized adaptation undertaken by other actors with different aims but in similar contexts [42,43].

Though hazards are common, pressures substantially differ across different communities or members of the same community and within families. Those differences depend on the capacities, contexts, experiences, and capitals of the various families or household members [13]. Similarly, though risks are shared, responses substantially differ across members of the communities. Consequently, the outcomes of adaptive strategies and actions also differ significantly, ranging from barely maintaining societal functions or livelihoods to viable change in an incremental or transformational manner [42,44]. Some adaptive measures (such as intensification of resource exploitation) may entail risks of entrenching vulnerabilities and harming individuals, households, or social groups or ecosystems, which is referred to as 'maladaptation'

[45,46].

By removing individuals from temporarily exposed regions and placing them in safe shelters, evacuation procedures help reduce losses of lives and the other negative effects of disasters such as trauma [47,30]. This often involves evacuation advice or orders by government officials. Evacuation during a cyclonic disaster is a social process. People's decision to go to a cyclone centre depends on the kind of hazard warning/evacuation order (e.g., whether it is formulated in a way that is easily understood, the basic norms and beliefs it transports, or whether it is personalized), and the individual characteristics of the people receiving the warnings (demographic information, knowledge, experience, resources, social networks, cognition) [48,49]. People typically go through a socio-physiological process after receiving a hazard warning, including hearing the warning, understanding the meaning of the warning, personalizing the risk, and eventually deciding to respond to the warning [30,31]. Ultimately, they opt for evacuation using their knowledge, previous disaster experience, and available information. The key determinants that influence a positive evacuation decision during a disaster include a hazard alert system, the reliability of the warning message [50], the perceived personal risk [51,48,52,49], the implementation of the evacuation order, evacuation logistics (such as transportable vehicles and evacuation routes), and evacuation infrastructure (especially cyclone shelters) [30]. Furthermore, people's responses to hazard warnings also include a social component, as the relationships of people with social groups play an important role in determining whether or not to evacuate [47,30].

In Bangladesh, evacuation decisions during cyclones are often delayed until the last moment due to various situational barriers. Distance is a significant situational impediment in evacuation decisions. Despite the proximity of shelters, many people struggle to evacuate

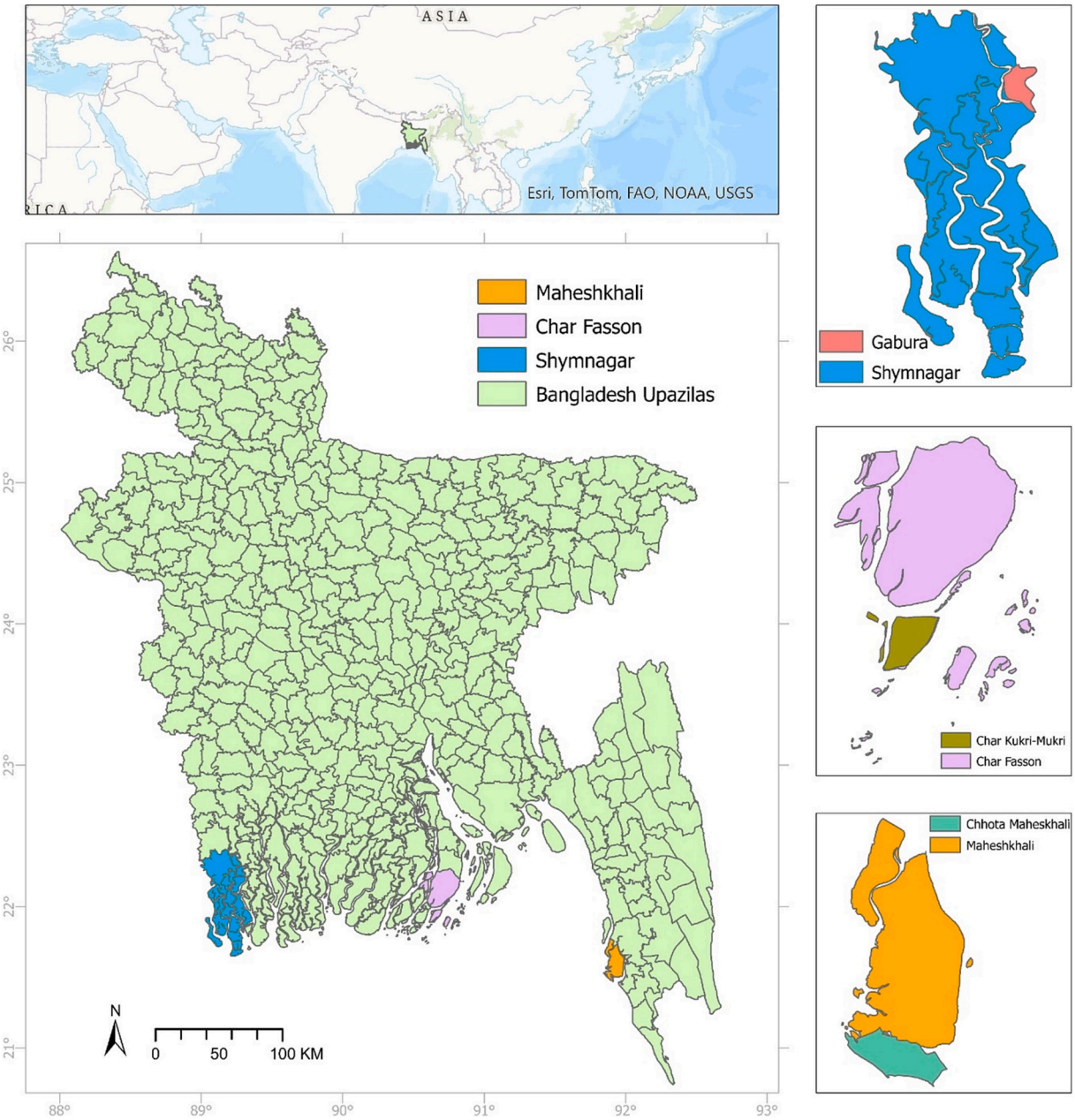

Fig. 1. Map showing the three study sites in coastal Bangladesh: Gabura in Shyamnagar Upazila (Satkhira, southwest coast), Char Kukri Mukri in Char Fasson Upazila (Bhola, central coast), and Maheshkhali Island in Maheshkhali Upazila (Cox's Bazar, southeast coast). Note: Upazila refers to a third-tier administrative region in Bangladesh.

because of poor infrastructure, damaged roads, and unreliable transportation systems. Distrust in warning messages and inefficient communication further complicate evacuation efforts. Socioeconomic factors like illiteracy and poverty limit people's ability to understand or act on warnings. Additionally, cultural beliefs and a "wait-and-see" attitude often lead to risky delays. Vulnerable groups, including the elderly and disabled, face even greater challenges due to inaccessible shelters and insufficient support. These barriers make timely evacuation difficult, even when extreme weather conditions demand urgent action [47,13,28,30,31,52,53]. Given the situational barriers in the context of Bangladesh, people at peril usually choose to evacuate at the eleventh hour or last moment just before landfall, and in extreme weather conditions, it is challenging for them to move to the shelter even though the distance is not huge [13,28]. There are further explanations for why people disregard formal hazard warnings – for instance, the poor physical condition of shelters, the lack of basic facilities, the lack of gender-segregated toilets and shelter, social customs for adult women, and great dependence on the household head [47,30,52], and the lack of or limited opportunities to generate income during and after the cyclone [31]. In some cases, cultural and religious beliefs contribute to avoiding cyclone shelters during catastrophic events [47,54,51,30]. Other important factors related to non-evacuees' perception and attitude include: not understanding the magnitude of the danger, feeling safe at home, and a lack of experience [30,52].

3. Methods

3.1. Site profile and context

This research focuses on three cyclone-prone areas along the Bangladesh coast: the Sundarbans region (specifically Gabura, in the Shyamnagar subdistrict of Satkhira on the southwest coast of Bangladesh); Char Kukri Mukri, a small island situated in the Char Fasson subdistrict of Bhola district on the central coast of Bangladesh; and Maheshkhali Island (Chhota Maheshkhali), located in Cox's Bazar on the south-eastern coast (Fig. 1). Communities in these study areas primarily depend on natural resources for their livelihood and income, such as fishing (harvesting fish, crab, and shrimp). They also depend on shrimp farming, boat operation, petty business, making handicrafts, agriculture, etc. [55,56,57]. The coastal fishing communities in the southwestern region rely predominantly on the Sundarbans mangrove forest for their livelihood sustenance. Their livelihoods are centred around fishing (for fish, crab, and shrimp), gathering wood and non-wood products like Nypa palm, honey, and wax, and shrimp farming. Most island inhabitants on Char Kukri Mukri depend on the estuarine and coastal fishery, with a particular focus on Hilsa shad (*Tenualosa ilisha*) fishing. On Maheshkhali Island, aside from the open sea, the fishing community primarily conducts its fishing activities in the Maheshkhali channel [58].

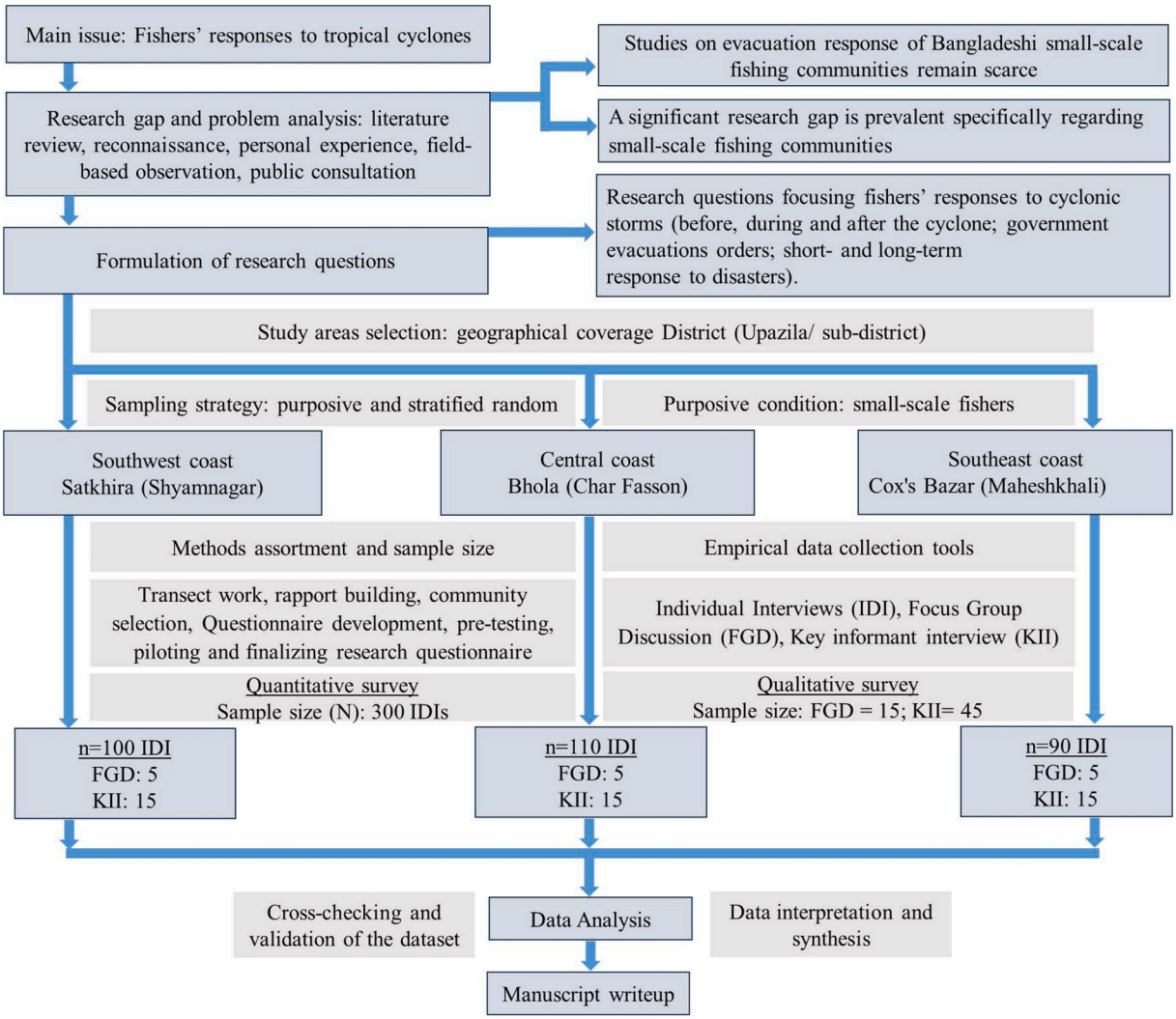

Fig. 2. The flowchart illustrating the methodology used in the research.

3.2. Data collection

Employing various participatory rural appraisal (PRA) methods, the study gathered qualitative and quantitative data. These methods encompassed individual interviews (IIs) using a semi-structured survey questionnaire, focus group discussions (FGDs) aided by a checklist, key informant interviews (KIIs) with experts, and direct field observation (Fig. 2;Table 1). We decided on the sample size based on a combination of factors, including the population size of the fishing communities in the study areas, resource availability, and time constraints. We ensured an inclusive sample by using purposive and stratified random sampling (purposive condition: fishing people- criteria-based purposive scrutinization followed by random selection), ensuring that different related groups, such as small-scale fishers, boat owners, and community leaders, were included. The study populations were selected based on their direct involvement in fishing activities and their exposure to cyclonic events, making them relevant to the focus of our research. This relatively smaller sample size is justifiable as the findings are not generalized for whole coastal communities rather than a specific professional group, where even a small group of people can provide a deeper understanding of perceptions and experiences about specific topics [59,60].

The primary empirical data collection spanned nine months and was divided into three sessions: three months from September to November 2017, a second session from February to April 2018, and a third session of three months from December 2022 to February 2023 at the study sites. The data collection involved 300 individual interviews, with 90 in Maheshkhali, 110 in Char Kukri Mukri, and 100 in Shyamnagar. Additionally, 15 focus group discussions (FGDs) with 5–10 persons in each and 45 key informant interviews (KIIs) with experts were conducted (Table 2).

Table 2
Source of primary data, sample size, study sites, and method.

Area coverage District (subdistrict)	Study sites	Position on Bangladesh coast	Tools/methods and sample size (number)		
			Individual interviews (II)	FGD	KII
Satkhira (Shyamnagar)	Gabura	Southwest	100	5	15
Bhola (Char Fasson)	Char Kukri Mukri	Central coast	110	5	15
Cox's Bazar (Maheshkhali)	Chhota Maheshkhali	Southeast	90	5	15
Total			300	15	45

3.3. Analysis of the data

3.3.1. Qualitative data analysis

The qualitative data collected through interviews and focus group discussions were analyzed using thematic analysis, following the six-step process outlined by [61]. This method involved: (1) familiarization with the data through repeated readings of transcripts, (2) generating initial codes to capture key features of the data, (3) searching for patterns to develop themes, (4) reviewing and refining themes to ensure coherence, (5) defining and naming themes to reflect their essence, and (6) writing up the analysis with illustrative quotes from respondents. This approach allowed for a systematic exploration of fishers' experiences, behaviors, and perceptions related to cyclonic disasters. Thematic analysis was chosen for its flexibility and suitability in identifying patterns of meaning within qualitative datasets. Both inductive and

Table 1
Overview of the study design: methodological approaches, sample size, data collection tools and techniques, and characteristics of the participating fishing communities within the participatory rural appraisal (PRA) framework.

Methods and sample size	Data collection tools/instrument	Arrangement perspectives/settings	Location or place in study areas	Time span/duration and schedule	Characteristics of stakeholders – nature of participants and focal logistical aspects
Observation	Eye observation Cameras	Physical in the field site – in-person, real-time observation	Along three coastal regions of Bangladesh	Continuous Non-participatory	Collecting data by watching and recording behaviour or events in real time. Duly obtaining permission before taking photographs, voice or video recording.
Individual interviews (IIs) $N = 300$	Semi-structured questionnaires	Face-to-face interview. Elucidate the demographic and socio-economic profile of resource users. For a comprehensive breakdown, refer to Table 3 in the results section, which outlines the socio-economic and demographic details of the fishing communities involved.	House/field/local market, with a pre-decided time frame	60–90 min. Preselected time frame by personal communication.	Primary stakeholders are small-scale fishers, including artisanal, subsistence, local, traditional, and capture fishers. These terms encompass various fishing methods and environments, such as inland waters, rivers, estuaries, coasts, mangroves, intertidal zones, and marine areas using small boats or low-tech craft.
Focus group discussions (FGDs) $N = 15$	FGD facilitated by the checklist	Group size of 5–10 people. Engaging a group of people in discussion to gather diverse opinions and insights.	Street shop, tea stall local market, free space on the seaside, and community space	45–90 min session. The preselected time frame after personal communication.	Discussions were held with different groups of primary resource users – SSF fishers. These stakeholders interacted and cross-verified information to capture a comprehensive understanding of resource utilization and the evolving dynamics of the local setting.
Key informant interviews (KIIs) $N = 45$	KII supported the checklist	Face-to-face Interviews that followed a list of questions or topics obtained an overview of key aspects of the local context.	Government offices, Union Parishad (UP) offices, cooperatives, fishers' societies, schools, community clubs, and research stations.	30–60 min period. Pre-scheduled based on personal consultation/ appointments.	Interviews were held with key informants who were expected to have knowledge of local viewpoints and resource systems. These informants included researchers, government officials, local resource managers, NGO personnel, schoolteachers, leaders of fishers cooperatives, and community leaders.

deductive coding approaches were employed. Inductive coding allowed for the emergence of unexpected themes directly from the data, while deductive coding ensured that pre-identified research questions were addressed comprehensively.

3.3.2. Quantitative data analysis

Empirical quantitative data were processed and analyzed using Microsoft Excel and IBM SPSS Statistics® version 21.0. Descriptive statistics were employed to summarize key socio-economic characteristics of the respondents, such as income levels, education, household size, and access to cyclone shelters.

4. Results

4.1. Socio-demographic characteristics

The interviewed fishers in coastal Bangladesh have considerable experience, as their average age (41.57 years) across the study sites spans between 39.63 and 42.78 years. The overall literacy rate among the fishers of the study areas (56.67 %) is lower than the national literacy rate of 77.99 % [62]. Despite the availability of private sanitary toilets, most fishers live in poorly constructed houses made of natural materials, such as Nypa palms, which can be easily damaged or destroyed during cyclonic events. Moreover, a high percentage of fishers in Shymnagar (92) and Maheshkhali (77) use firewood for cooking. At the same time, a large proportion of Char Kukri Mukri (75) depend on plant bark for fuel, indicating their reliance on natural resources for providing fuel (Table 3).

4.2. Cyclonic hazards and damage of fishing communities

Most small-scale fishers in Bangladesh's coastal regions work for fishing teams owned by entrepreneurs who may act as skippers or remain on land. Many fishers have faced various hazards, including cyclones, floods, tidal waves, storm surges, saltwater intrusion, and coastal erosion. Over the last few years, for instance, communities have faced a high number of extreme cyclones and coastal flooding. Between 1985 and 2015, the Bay of Bengal experienced approximately 77 severe cyclonic storms, averaging 3.48 storms per year, with an average wind speed of 175.84 km/h. Over the period from 1975 to 2015, there were around 267 recorded iropical depressions in the Bay of Bengal, with an average of 12.85 events annually [58].

The precarious situation of small-scale fishers at sea was highlighted by Cyclone Mora in 2017, which caused the death of 53 fishers from Maheshkhali. Most of the fishers of the studied areas have experienced damage and loss of households and productive assets such as boats and nets, leaving many to live under the open sky or in makeshift housing on embankments. Post-cyclone fishing activities are delayed because boat staff may need more time to be ready to go fishing, and it may be challenging to collect necessary fishing equipment, ice, and logistics immediately after the cyclonic landfall. Furthermore, cyclones have a couple of indirect impacts: fish availability and reduced fish catch in destroyed habitats, dry fish processing field destruction, decreased prices due to market constraints, and disruption to communication and value chain systems, which are affecting the productivity and sales of fishing activities (Fig. 3). Finally, rehabilitation activities such as rebuilding and repairing houses and equipment are costly and time-consuming, further exacerbating the financial difficulties for fishers. Government and NGO support for house reconstruction is insufficient, leading some fishers to resort to high-interest loans, as revealed through key informant interviews.

All studied communities had at least one cyclone shelter within 1.5–2.0 km of their homes. However, accessibility varied widely due to poor infrastructure, inadequate transport, and flooding during storms, which made reaching shelters challenging. Char Kukri Mukri, a remote, low-lying island exposed to cyclones from the Bay of Bengal and Meghna estuary floods, faced severe access issues. One participant shared, "During a cyclone, the roads are flooded, and we have no vehicles. Walking to the shelter takes hours, and it's dangerous with children." In hilly Maheskhali, although awareness was relatively higher due to proximity to urban centers, unpaved roads remained a major barrier. Some avoided shelters altogether due to access difficulties. Shyamnagar, bordering the Sundarbans, frequently experiences major cyclones (e.g., Sidr, Aila, Fani, Amphan). This exposure, combined with protective mangroves, led to higher evacuation rates. Yet, overcrowding remained a key concern: "The shelter is close by, but it gets so crowded that there's no space for my family. It feels unsafe."

Table 3
Socio-economic and demographic profiles of the fishing communities.

Attributes and their summary	Responses (%) multiple options		
	Shymnagar ($n = 100$)	Char Kukri Mukri ($n = 110$)	Maheshkhali ($n = 90$)
Age (average, years)	42.78	42.29	39.63
Sex (Frequency)			
Female	19	21	14
Male	81	89	76
Level of education (average literacy %)	60	58.3	51.3
Illiterate	40	51.7	38.7
Can sign only	17	35.2	19.8
Primary (up to 5 years of schooling)	39	27.5	17.1
Secondary (up to 10 years of schooling)	3	5.5	5.4
HSC (up to 12 years of education)	1	1.1	0
Graduation University (>12–16 years of education)	0	0	0
Housing status (National aver.: 95.85 %) Fishers (%) residing in their own homes (this study)	94.0	80.0	92.2
Roof materials			
Employing natural resources like Nypa palm and weaving Golpata leaves with bamboo slices	61.0	15.5	30.0
Tin or iron sheets	33.0	72.7	72.2
Pucca or concrete	0.0	0.0	3.3
Other (e.g., plywood, polythene)	6.0	2.7	5.6
Wall			
Earthen (clay/mud)	27.0	1.8	24.4
Natural materials, e.g., Nypa palm combined with the bamboo pole	6.0	13.6	14.4
Wooden or wood frame	25.0	28.2	41.1
Tin or iron sheet	37.0	45.5	23.3
Pucca or concrete/bricks/ cement blocks	5.0	0.0	5.6
Other, e.g., polythene	0.0	1.8	2.2
Flooring materials			
Clay/mud or earthen	74.0	70.0	88.9
Bamboo and wood	25.0	20.9	18.9
Pucca or cemented	1.0	0.0	3.3
Fuel source for cooking (multiple options)			
Firewood collection	92.0	55.5	85.6
Buying firewood	37.0	62.7	70.0
Husk/bran	20.0	68.2	51.1
Stems of cereals, dry leaves, cow dung, etc.	58.0	55.5	25.6
Diesel or kerosene	13.0	35.5	36.7
Others (e.g., gasoline, LP gas cylinder)	0.0	0.0	11.1
Toilet facilities			
Use own or utilize a personal sanitary toilet	86.0	76.4	85.6

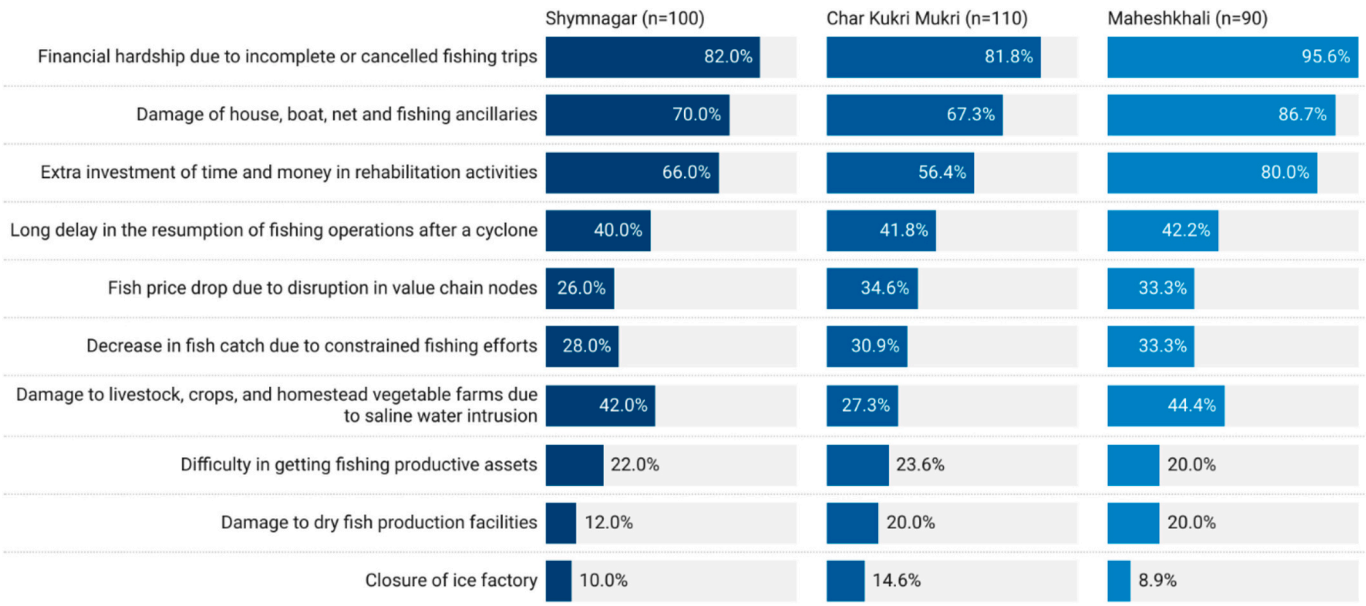

Fig. 3. Fishers' perception (% responses, multiple options) on cyclone impacts on assets, income, and livelihoods.

4.3. Fishers' responses to cyclones: Pre-, during, and post-cyclonic events at sea

Before a cyclone strikes, fishers in the study areas take immediate protective measures to save their lives and boats, such as fixing boat materials with rope and keeping buoys, plastic drums, and banana trees on both sides of the boat. Most fishers of the Sundarbans region (Shymnagar) attempt to return home or look for sheltered, safe places inside the mangrove forest when fishing in the creeks, canals, channels, or rivers. They also share information with other boatmen and discuss the intensity of the cyclone (Fig. 4a). During a cyclonic landfall, fishers engage in various activities such as reducing the load of the boat, removing nets to prevent sinking, and seeking divine help. They also keep their boats oriented toward the direction of the wind, stay together with other boats, and share protective measures. Their most important priority is to save their lives and boats (Fig. 4b). As one fisherman in Char Kukri Mukri said, their main focus during such situations is to seek help from God (Allah) to survive. After a cyclone is over, most fishing people in the studied areas engage in post-cyclone recovery activities such as searching for missing boats and nets, repairing damaged equipment, resuming fishing if conditions allow, and returning to their villages to protect their families and repair their homes (Fig. 4c). One fisher from Maheshkhali shared, *"We know the cyclone is coming, but we have to think about our families. If we don't fish today, what will they eat tomorrow? Sometimes, we take the risk because we don't have any other option."*

4.4. Pre-, during, and post-cyclone recovery activities – When fishers are on land

Before a cyclonic event, fishers on land or in the village perform various activities such as securing their houses with ropes and poles, storing dry food and water, protecting materials, covering the tube well, harvesting crops, and covering the pond with a net. They also watch television to stay updated on cyclone warnings, spread information to neighbours and relatives, prepare to move to a cyclone shelter, and help others do the same (Fig. 4). After receiving orders, many fishers had difficulty leaving their livelihood activities and belongings behind to evacuate to the cyclone centre. However, almost half of the fisher respondents had a positive attitude toward the cyclone warnings and evacuation orders in the study areas. A female respondent from Char Kukri Mukri explained, *"The cyclone shelter is far from my home. Who will take care of my livestock? I am afraid of leaving my house, so I prefer to stay at home and pray to Allah (God)."* Results showed that Maheshkhali had a relatively higher percentage of respondents (54.4 %) taking shelter in the cyclone centre than the Sundarbans region - Shymnagar (51.0 %) and 49.1 % in Char Kukri Mukri (Fig. 4). While 52.2 % of respondents from Maheshkhali, 51.0 % from the Sundarbans region (Shymnagar), and 49.1 % from Char Kukri Mukri stated that they refrained from going to the cyclone shelters despite hearing the hazard warning, thus ignoring the evacuation order (Fig. 5).

Respondents cited several reasons for not following the evacuation order, including poor and fragile physical conditions at the centre, inability to realize the imminent danger, concerns about theft or stealing, fear of losing livestock and poultry, scepticism about the warning, and poor accessibility of the cyclone centre. The presence of nearby concrete structures such as mosques, temples, schools, and government offices provides a sense of security and is a viable option in emergencies. Furthermore, the lack of separate spaces and toilets for women was mentioned as another constraint (Table 5). Feeling secure at home, especially in hilly surroundings or areas with dam structures, forests, and mangrove bioshields, contributes to the perception of safety during cyclonic events. Fatalism, rooted in the belief that divine intervention will protect them, also influences decision-making. These factors, combined with previous negative experiences, deter fishing communities from seeking refuge in public shelters during cyclones. Negative past experiences with cyclone shelters also influenced evacuation behaviour across all sites. In Maheshkhali and Char Kukri Mukri, respondents frequently cited concerns about theft and damage to property as reasons for non-evacuation. A fisher from Maheshkhali shared, *"Last time I went to the shelter, I returned home to find my livestock missing. I can't take that risk again."* Female respondents in Char Kukri Mukri expressed additional concerns about privacy and safety in cyclone shelters. One woman stated, *"There are no separate toilets for women in the shelter. It's embarrassing and unsafe for us."* This lack of gender-sensitive facilities deterred many women from seeking refuge during cyclonic events, as some key informants stated. Decision-making constraints due to the absence of a household head and fear of theft during evacuation were also mentioned as deterrents. Some respondents had a false sense of security or did not understand the severity of the cyclone, while others did not trust the intensity of the exemplary signals. Social stratification was also mentioned, with influential members occupying more space in cyclone

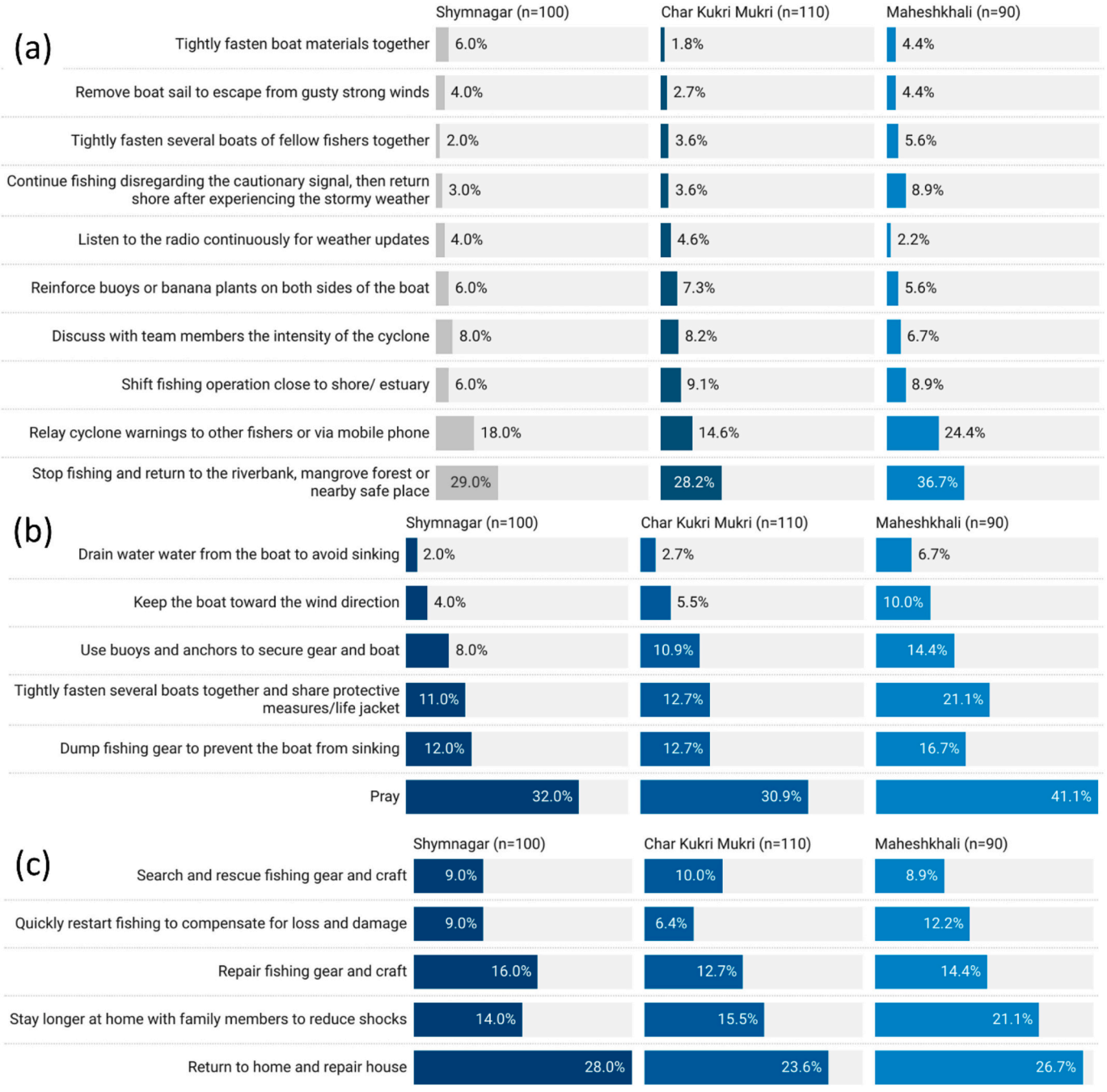

Fig. 4. Activities of small-scale fishers in the study areas: before, during, and after cyclonic events (% responses, multiple options), (a) pre-cyclone preparations, (b) actions taken during the cyclone, (c) post-cyclone recovery efforts.

shelters. (Table 4).

The problems with cyclone shelters include a lack of space and separate rooms for men and women, overcrowding, inadequate sanitation and health services, insufficient food and drinking water supply, poor structural and hygienic conditions, and a lack of electricity facilities. Many respondents reported these issues, including a leader of a fisher organization who noted that cyclone centres have limited capacity. More than a third of respondents had to return home due to overcrowding. These problems and insufficient repair and maintenance of old shelters discourage people from using them (Fig. 6).

During a cyclonic event, fishers on land or in the village focus on saving their lives and protecting their resources from damage. They may stay home or in adjacent areas, pray to God, and support family members. Depending on the severity of the cyclone, fishermen may also help neighbours and free livestock and poultry during a cyclonic attack. When in a cyclone shelter, fishers pray and pass the time anxiously (Table 5).

Some fishers may climb trees or tie themselves to branches with ropes to escape high water levels. After a cyclone has passed, fishers take different actions, such as repairing their homes, sanitary latrines, animal sheds, boats, and nets. They also clean up tube well water and care for the sick while collecting relief materials provided by the government or NGOs. Starting work for the fishing team can be challenging, and not all boat staff are immediately available. However, most fishers in the study areas attempt to gather the necessary materials for fishing operations as quickly as possible after the cyclone (Fig. 7). A fisherman from

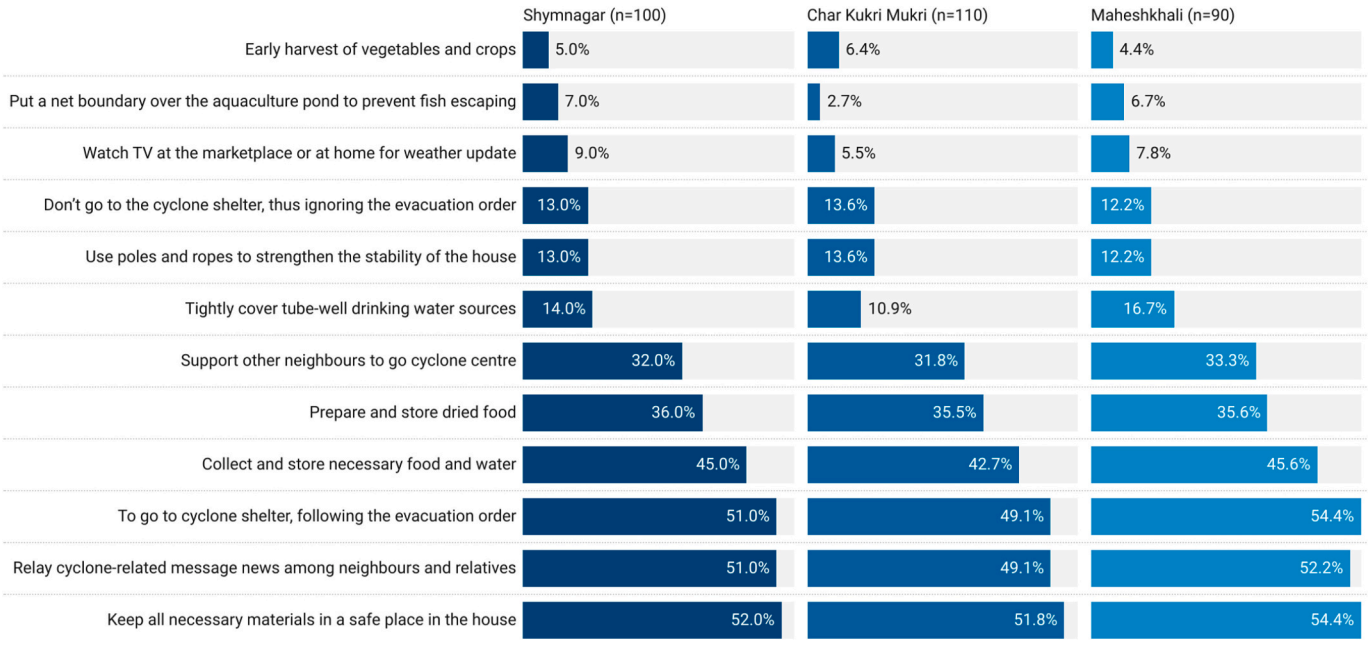

Fig. 5. Pre-cyclone preparatory activities and evacuation responses by fishers on land (% responses, multiple options).

Table 4
Reasons for not complying with an evacuation order.

Reasons for not complying with an evacuation order	Fishers' responses (%, multiple options)		
	Shymnagar (*n* = 100)	Char Kukri Mukri (n = 110)	Maheshkhali (n = 90)
Lack of awareness about cyclone intensity and evacuation order	41.00	42.73	40.00
Longer distance of cyclone shelter location	21.00	22.73	26.67
Inadequate facilities and previous unfavourable experiences	37.00	24.55	43.33
Availability of nearby concrete structures for taking shelter	11.00	4.55	17.78
Fear of burglary of household assets	31.00	21.82	35.56
Sense of social exclusion	6.00	1.82	14.44
Little trust in the intensity of the cyclone and cautionary weather signal	16.00	10.91	16.67
Have a sense of security and feel safe at home due to protected surroundings (e.g. dam, mangrove forest)	32.00	20.91	26.67
Fatalism	23.00	17.27	30.00
Not having past deadly experience	4.00	6.36	5.56

Shyamnagar recounted, *"During cyclone Sidr, the water level rose very quickly. We lost everything – our boat, our nets, and our home. It was a terrifying experience that I will never forget."*

4.5. Socio-economic factors affecting the evacuation behaviour

Several key informant interviews and focus group discussion revealed interconnections between socioeconomic status and evacuation responses. Better-off households are more capable of disaster response as they live in better-protected locations and concrete-structured houses and even get better access to cyclone shelters (e.g. more space or secluded space). Some well-off fishers even temporarily move to further inland safer areas. Some key informants reported locations of cyclone areas, which are usually selected and built up in well-connected areas to better off and powerful households. In contrast, most fishing households live in the seafront areas, far from cyclone cyclones, as these are located in the center location of areas. Again, fishing is often considered a 'lower caste,' and fishing communities are situated at the lowest position in the social ladder position, which often serves as a barrier for fishers to evacuate to cyclone centers with other communities. Women and older adults also feel less comfortable evacuating due to restricted mobility capacities and the lack of specialized facilities (e.g. lack of privacy, overcrowding, and insufficient gender-segregated facilities) in the cyclone centers.

4.6. What steps are taken to cope, adapt, and overcome the cyclone-induced loss and damage?

In the short term, the government and NGOs provided relief programmes, and some respondents used their savings or obtained loans from fishing patrons or microcredit organizations to cover daily expenses. Some temporarily switched to land-based occupations or migrated elsewhere to work. For example, about 40.0 % of respondents in Maheshkhali, followed by 30.91 % in Char Kukri Mukri and 26.0 % in the Sundarbans region (Shymnagar), temporarily migrated to other places to seek employment and participate in diverse income-generating activities such as driving vans, pulling rickshaws, and engaging in daily labour (Table 6). Loans from fishing patrons (*Dadonder*) or microcredit organizations, usually at a high interest rate, were utilized by many fishing households, especially women. Many fisher households started planting fruits and vegetables in their homestead areas in the Char Kukri Mukri (23.64 %), the Sundarbans region - Shymnagar (22.0 %), and Maheshkhali (20.0 %) study areas (Table 6).

In the long term, some fishers became involved in homestead plantation or coastal afforestation programmes, and some of them received capacity-building training in disaster risk reduction, tried to decrease expenses and increase savings, and invested in child education. For instance, many participants in Char Kukri Mukri (17.3 %), the Sundarbans region - Shymnagar (17.0 %) and Maheshkhali (15.6 %) have witnessed and/or engaged in coastal afforestation efforts, such as supporting the natural regeneration and growth of salt-tolerant plants, and the planting of trees along roads and embankments by government or

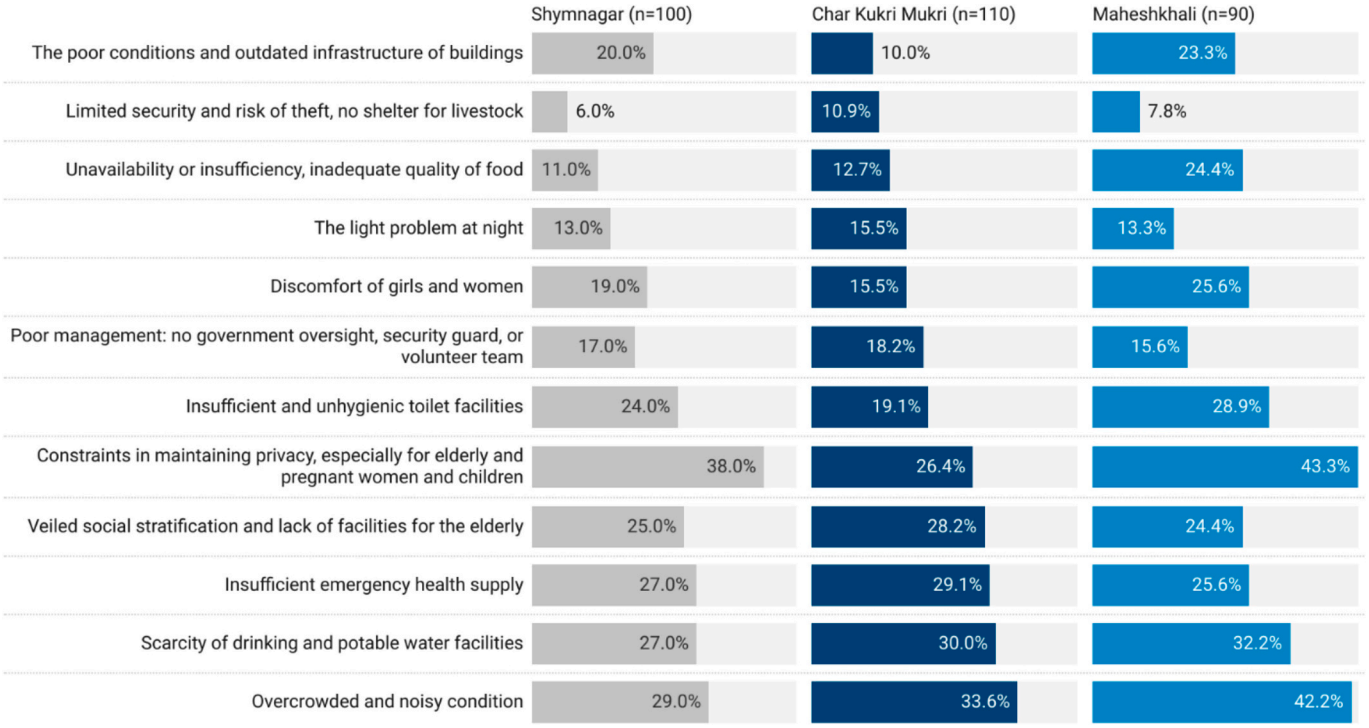

Fig. 6. Fishers' opinion on the suitability of multi-purpose cyclone shelters (% responses, multiple options).

Table 5
Activities during cyclonic landfall when fishers stay on land.

Fishers' activities during cyclone landfalls	Fishers' responses (%, multiple options)		
	Shymnagar (n = 100)	Char Kukri Mukri (*n* = 110)	Maheshkhali (n = 90)
Pray	97.00	96.36	97.78
All family members stay together	59.00	59.09	56.67
Mental support for the family members	52.00	57.27	53.33
Help neighbours with the necessary support	21.00	21.82	18.89
Let livestock and poultry free for moving to a safer place	55.00	53.64	58.89

non-governmental organizations (NGOs) (Fig. 8). The involvement of family members, primarily women, in fishing and post-harvest fish processing was also evident in the study areas. Many fishers were interested in child education to prepare a better future for the next generation. A key informant from the Sundarbans region (Shymnagar) said: *"People have now become more interested in educating their children, as they observe that educated people are more capable of gaining opportunities of alternative occupations and capacity building for better livelihoods."* They also undertake several other interventions, such as modifying the structure of their homes and boats to withstand stronger winds and higher waves. For instance, modification of the roof structure – redirecting the wind force or allowing it to pass more quickly – raising the floor of the house, using more durable housing materials like steel, iron, concrete, or cement blocks, introducing cement pillars in place of wood, etc., modification of the livestock sheds, and modification of boat structures were evident in the study areas. Fishers expect the government to take several measures to reduce disaster risks, including increasing relief facilities, enhancing coastal protection, improving cyclone shelter amenities, developing salinity-tolerant technologies for crops, vegetables, fish, and rice, and implementing education and awareness programs (Fig. 8).

5. Discussion

Despite recent improvements in cyclone alert systems, emergency evacuation protocols, and the extensive network of cyclone shelters along the coast of Bangladesh, a notable proportion of individuals facing risks still do not opt to engage in evacuation efforts [47,54,30,52,32]. While the role of cyclone shelter as a best structural mitigation measure is much appreciated [63,64,65], however owing to their apprehension about belongings in general, and the risk of losing their sole source of livelihood by losing productive asset (e.g., fishing boat) many hesitate to opt for cyclone shelters. Instead, a section of fishers may resort to some local response, such as raising the plinth of housing, reinforcing the strength of housing by tightening ropes to other structures or moving to a nearby concrete house of neighbours or mosques. However, these strategies are likely less effective due to the low number of strong houses along the coast [63,65]. The fishers may decide to go to one, if the cyclone event intensifies severely and the warning signals are set in motion. However, by then, due to unfavourable weather conditions, they might find it challenging to cover such a considerably long distance. Additional significant reasons for refraining from seeking refuge in safe locations include the fear of burglary and theft of household possessions, mistrust and misunderstanding of warning information, logistical challenges, the absence of gender-segregated sanitation facilities, limited awareness of the potential danger, a sense of security at home, a lack of experience, the belief that a cyclone will not occur in their area, and the determination to endure the situation [66,30,52,32], or mistrusting the warning [28,65].

The direct quotes from fishers reinforce our findings and provide valuable insights into the complexities of disaster response. As highlighted by one respondent, *"The government tells us to go to the cyclone shelter, but they don't understand our reality. We need food, water, and security for our families."* This underscores the need for disaster management strategies that are tailored to the specific needs and vulnerabilities of fishing communities, as emphasized in the SSF Guidelines [4]. Furthermore, the reluctance to evacuate, as expressed by another fisher

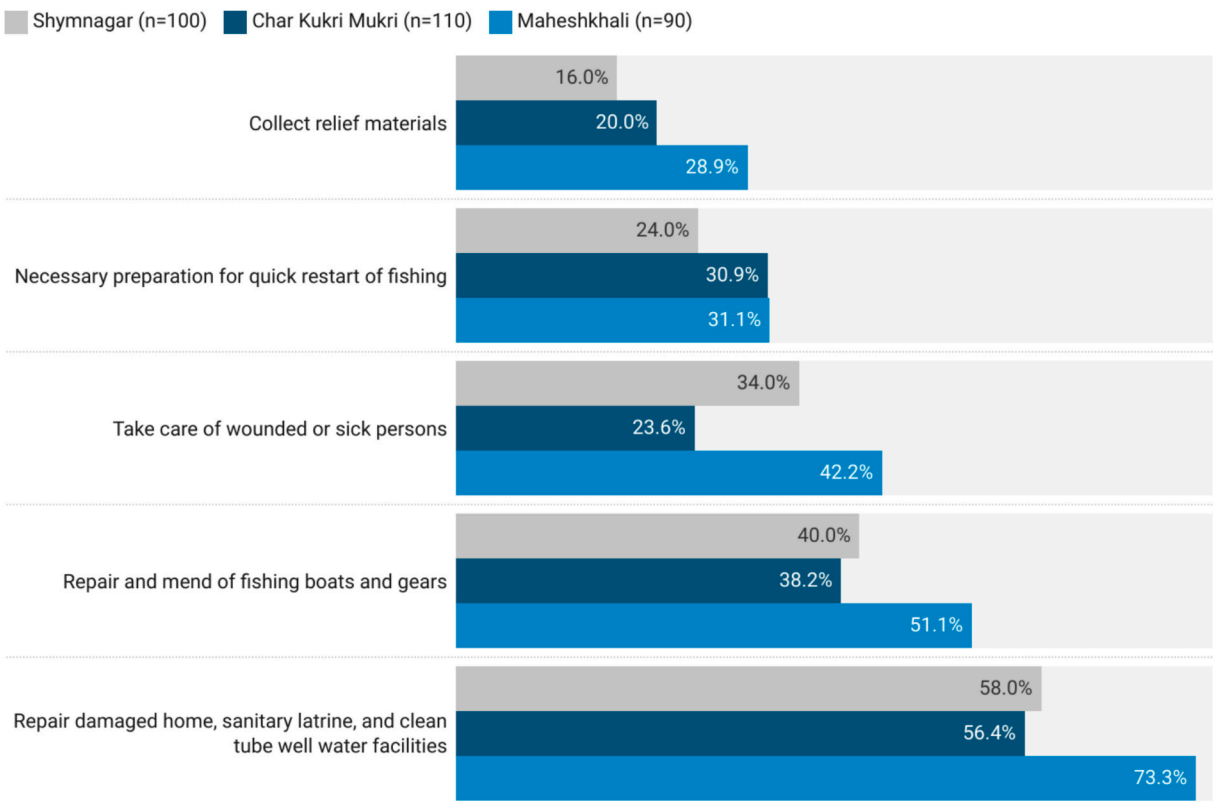

Fig. 7. Immediate post-cyclone recovery activities of fishers on land (% responses, multiple options).

"I have seen many cyclones in my life, and nothing happened to me. I trust on the Almighty.", reflects a combination of risk perception, past experiences, and cultural beliefs, consistent with findings from previous studies [47]. These insights highlight the importance of incorporating local knowledge and perspectives into disaster preparedness and risk communication efforts. Risk perception differences across communities reveal how cultural beliefs and prior experiences shape attitudes toward cyclonic hazards. The reliance on divine protection observed in Maheshkhali aligns with findings from Ayeb-Karlsson et al. [54], emphasizing the need for culturally sensitive risk communication strategies. Understanding these cultural contexts is crucial, as cultural beliefs and practices can significantly influence how communities perceive and respond to risks [67]. Similarly, concerns about overcrowding and privacy among female respondents in Char Kukri Mukri highlight gender-specific vulnerabilities that must be addressed through inclusive disaster management planning. Efforts should focus on integrating local knowledge into formal disaster preparedness programs while addressing socio-cultural barriers that hinder evacuation compliance.

The study indicated that the socio-economic and occupational status of the participants played a crucial role in influencing non-compliance with evacuation orders. Specifically, it was observed that shelters were predominantly occupied by the local elite during disasters, leaving limited space for those who were more marginally vulnerable [64,65]. Social and political marginalization act as a driver of vulnerability to a disaster. Small-scale fishers are often excluded from macroeconomic development planning processes due to their low education level, living in marginal or remote areas, are poorly organized politically, and have no social security [68], which makes it challenging to avoid cope with, or adapt to the impacts of climate change [69]. Coastal residents' occupation and socio-economic status can impede relocating to a cyclone centre, as landlessness, poverty, and a 'lower position' in the social stratification of society lead to fishing often being regarded as a 'lower class' profession [70]. This is consistent with the Pressure and Release (PAR) model [71], which explain vulnerability to disaster arises from the interplay of exposure to hazards and underlying socio-economic and political factors [72].The societal stigma associated with this occupation may contribute to fishers hesitating to seek refuge in cyclone shelters. Additionally, the risky nature of sea fishing and precarious livelihood condition has fostered a sense of fearlessness regarding cyclones among many fishers, could deter them from relocating to cyclone centres.

In such circumstances, addressing structural inequalities is essential for improving evacuation rates and reducing cyclone-related fatalities in fishing communities. These findings underscore the need for targeted interventions that address the socio-economic vulnerabilities of fishing communities. Prioritizing a closely knit network of small public cyclone shelters is recommended over a limited number of large shelters. Several key informants from the study areas shared several suggestions for good practices of disaster management. They suggested that apart from the establishment of new public shelters (located within 1–2 km of residences), there is a need for rehabilitation of current tenants of government and public buildings with specified structural features, including separate facilities for male and female evacuee quarters with sufficient bathrooms and toilets, adequate sleeping space, sufficient lighting, ample storage space, and safe drinking water, and enhancements in logistics (such as the provision of buses, trucks, and motorboats for

Table 6
Coping (short-term) responses employed by fishers in the last five years.

Brief description of short-term coping actions by fishers	Responses (%, multiple options)		
	Shymnagar (n = 100)	Char Kukri Mukri (n = 110)	Maheshkhali (n = 90)
Taking loans for rebuilding houses and productive assets	34.00	41.82	42.22
Expense saving	8.00	12.73	11.11
Buying grocery items on credit	42.00	41.82	42.22
Advanced sale of labour (*Dadan*) to the boat owner	14.00	5.45	13.33
Cut down family expenses	12.00	9.09	20.00
Taking microcredit	38.00	10.91	20.00
Taking relief support from government and non-government organizations	8.00	10.91	11.11
Selling household and fishing assets, including boats, nets, and ancillary equipment	22.00	18.18	28.89
Procuring or repairing productive assets for a quick start of fishing	8.00	9.09	13.33
Longer fishing operations for more income	20.00	10.91	28.89
Temporary migration to cities for alternative income activities	26.00	30.91	40.00
Temporary out-migration for alternative income activities			
A complete switch to another occupation through migration	8.00	5.45	13.33
Taking children out of education and involving them in fishing	12.00	7.27	17.78
Engaging in post-harvest or aquaculture activities, such as collecting PL from riverbanks or restarting fish culture in ponds	36.00	20.00	28.89
Engaging in homestead farming and livestock rearing, such as raising goats and ducks	22.00	23.64	20.00

transporting people and their belongings), separate shelter facilities for livestock, and improvements to coastal road networks and coastal embankment can facilitate timely access to the centres.

Fishers' responses to cyclones at sea are shaped by their understanding of the risk severity and socio-economic capacities, such as perceptions of the severities of the storms, vessel size and target fishery [14]. For the better safety of fishers who stay at sea during extreme weather, some respondent fishers asked for a modern communication system, proper monitoring of the seaworthiness of fishing vessels, adequate safety equipment for all seagoing fishers, and construction of waterborne cyclone centers to rescue fishers who strike at sea during extreme weather conditions. Small-scale fishers remain at risk because of several other context-specific factors [59,13]. Fishers often face extreme weather while still in the bay, which can be deadly or at least force them to abandon their fishing trips, thus incurring financial loss. Risk-taking behaviour among fishers is closely tied to socio-economic pressures.

Many fishers continue fishing in rough weather out of desperate need to earn money or due to pressure from influential boat owners. Thus, disaster risk is also an issue of power and poverty [38]. One respondent explained, *"If we don't fish today, we won't have food tomorrow. Sometimes we take risks because we have no other choice."* This sentiment highlights the precarious economic conditions that compel fishers to prioritize immediate survival over safety. Small-scale fishers may only be able to afford the least costly response. Before, during, and after incidents, Bangladeshi fishers respond to cyclone hazards, exhibiting local knowledge of mechanisms that involve securing daily necessities through individual initiatives, reliance on kinship relations and obligations, and engagement in social networking, working together to rebuild or restore devastated infrastructures such coastal embankments [66,73]. Similar strategies have also been described in some other global contexts, such as the Philippines [74]. Many of these strategies may help them with their immediate survival before another disaster strikes. Fishing communities in Bangladesh suffer several shocks within a short period amid existing pressures; thus, the pace of change due to several 'blows' often outstrips their coping capacities [70].

Managing disaster risk and climate change adaptation effectively demands systematic and integrated approaches, emphasizing cross-sector collaboration. Thus, the viability of small-scale fishers is related not only to the access to resources they depend on but also to support from different government and non-government sectors. For example, government bodies responsible for disaster management, public health, and local government are intricately related in delivering different civic services, which is vital for communities' well-being in the aftermath of cyclones. The linking or sharing of information, resources, activities, and capabilities by all stakeholder organizations can achieve jointly a far more viable outcome for the communities that could not be achieved by

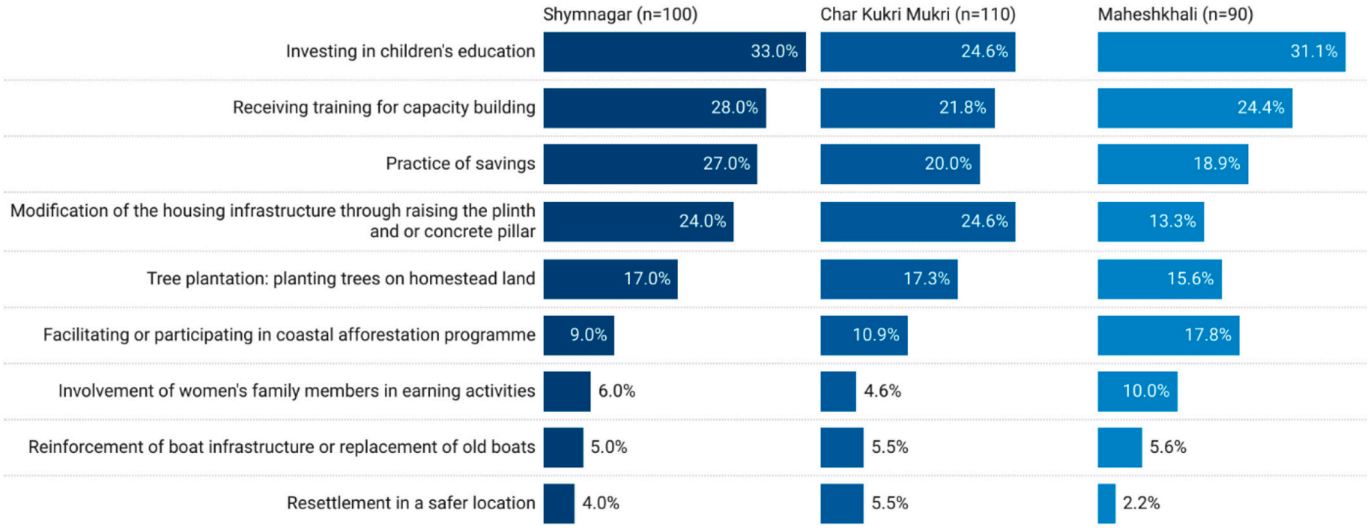

Fig. 8. Long-term adaptation (good practice) actions (% responses, multiple options) by fishers in the last five years to mitigate loss and damage due to cyclonic events.

one sectoral organization separately [75,23]. We argue that implementing the SSF Guidelines would create an enabling environment for cross-sectoral collaboration. The Guidelines delineate the strategies and responsibilities of government and other stakeholders to ensure the social, economic, and ecological aspects of sustainability of any fishery system. The Guidelines also suggest roles for all stakeholders – governments, small-scale fishers and their organizations, civil society organizations, research and academia, the private sector, and donor agencies – in fostering collaboration (cf. [23]). This call for interconnectedness is particularly relevant for Bangladesh. Though Bangladesh has received worldwide recognition for establishing a Comprehensive Disaster Management Program that confirms disaster risk reduction as an integrated component of national fiscal planning [73], still the significant gap in the institutional framework for disaster risk management is happned due to the lack of functioning partnerships [23,16].

For disaster risk management, the Guidelines suggest that SSF should be targeted for broader disaster preparedness and response and recovery initiatives by the state, employing the principles of the continuum of relief creation and "building back better". States should also consider securing access to funds for climate change adaptation, services, and technology that is culturally relevant and accessible to small-scale fishing communities. Following the Guidelines, any fishery management efforts should integrate safety at sea as a component. To this end, they should ensure the enactment and implementation of national legislation consistent with the FAO, ILO, and IMO international guidelines for fishery and sea safety work in SSF. There is a need for maritime safety awareness and training programmmes for all seagoing fishers and for a monitoring programmmes to consider all sea accidents and increase compliance with safety regulations. All fishers should have access to emergency rescue information and emergency detection systems for rescue at sea. Access to more precise information on cyclone risks will likely motivate fishers toward better compliance with evacuation orders. Special support given to small-scale fishing communities is likely to make them less vulnerable to economic shocks and thus make them risk-averse when fishing in unfit weather conditions (Section 9.2). This arrangement will only be possible through integrated and holistic approaches such as intersectoral collaborations (Section 9.3) [4].

6. Conclusion

The responses for coping with or adapting to climate-induced disasters, particularly tropical cyclones, are predominantly influenced by the prevailing socio-economic conditions and community risk perceptions. Consequently, community responses to an imminent tropical cyclone are intricately linked to their member's respective occupations and are often dictated by their socioeconomic status, coping strategies, and adaptive capacity. Understanding the context-specific vulnerability of communities to tropical cyclonic disasters and their responses to disaster risks is crucial for devising effective disaster response strategies. While numerous studies have explored the vulnerabilities of coastal communities in Bangladesh to disasters, there needs to be more research on the vulnerabilities of fishers, both within the national context and on a broader regional and global scale. While small-scale fishers have many reasons similar to other coastal communities for going or not going to cyclone shelters in tropical cyclones, some of the reasons are specifically related to their occupational and social status. Thus, 'one-size-fits-all' is not an appropriate strategy for small-scale fisheries. Despite their special needs for disaster risk management, the concerns of small-scale fishers are often overlooked in disaster management policies at any level: national, regional, or global. However, considering the important roles that small-scale fishers play, particularly in developing countries, in achieving SDGs, disaster preparedness strategies will likely be incomplete without addressing small-scale fishers' vulnerability. With adopting the 2030 Agenda for Sustainable Development, member states also pledged to ensure that "no one will be left behind", including small-scale fishers.

The study focuses on three specific sites, which may limit the generalizability of findings to other regions or fishing communities. It also primarily relies on self-reported data, which may introduce recall bias. Nevertheless, this study contributes to disaster science by exploring the behavioral responses of small-scale fishers in coastal Bangladesh to cyclones, highlighting their coping mechanisms and socio-economic factors influencing evacuation decisions. Understanding the response of fishers and the constraints to the viability of responses is key to effective mitigation and adaptation enabling policymakers to design tailored evacuation and emergency plans [59] to support fishers and their ability to make viable decisions for their health and safety [14]. While this research provides valuable insights into the dynamics of disaster response within fishing communities, further exploration is needed to fully understand the short-term and long-term impacts of cyclonic disasters on these communities. Specifically, future research could investigate the long-term livelihood trajectories of fishers following disasters, the effectiveness of current disaster relief and recovery programs, and the potential for integrating local knowledge into formal disaster management plans. Additionally, studies could explore the specific gendered impacts of cyclones and the role of social networks in facilitating disaster recovery. Addressing these gaps will contribute to more effective and equitable disaster risk reduction strategies for small-scale fishing communities in Bangladesh and similar contexts.

CRediT authorship contribution statement

Mohammad Mahmudul Islam: Writing – original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Mohammad Mosarof Hossain:** Writing – review & editing, Visualization, Software, Methodology, Formal analysis. **Sabrina Jannat Mitu:** Writing – review & editing, Data curation. **Johannes Herbeck:** Writing – review & editing. **Mohammad Mojibul Hoque Mozumder:** Writing – review & editing. **Petra Schneider:** Writing – review & editing, Validation. **Abdullah Al Zabir:** Software, Data curation. **Md. Mostafa Shamsuzzaman:** Writing – review & editing. **Svein Jentoft:** Writing – review & editing, Validation, Supervision.

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.

Mohammad Mahmudul Islam reports financial support was provided by The Social Sciences and Humanities Research Council (SSHRC) of Canada. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

This work was supported by the Social Sciences and Humanities Research Council (SSHRC) of Canada (Grant Number: 895-2020-1021) under the project Vulnerability to Viability (V2V): Global Partnership for Building Strong Small-Scale Fisheries Communities. We thank four anonymous reviewers for their very useful feedback.

Data availability

Data will be made available on request.

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