School of Population Health

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SEA-LEVEL RISE AND PSYCHOLOGICAL DISTRESS AMONG COASTAL COMMUNITIES: INSIGHTS FROM THE SOUTHWEST COAST OF BANGLADESH

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Abstract

This Doctoral thesis examined the effects of sea-level rise (SLR) on psychological distress in coastal communities of the Asia-Pacific region. First, a systematic review was conducted (Chapter Two) to assess evidence of the relationship between psychological health and SLR in the Asia-Pacific. The systematic review concluded that SLR-induced salinity, erosion, and flooding were associated with resource loss which impacted psychological health experienced as distress, depression, anxiety, and stress. Second, a cross-sectional quantitative study (Chapter Three) examined the effects of SLR-induced environmental stressors on psychological distress among residents of southwest coastal communities of Bangladesh (n = 1200) prior to monsoon season. It was evident that residents of coastal communities in highly vulnerable areas reported greater levels of psychological distress across multiple indicators than those living in less vulnerable coastal communities. A follow-up study conducted eight months after the cross-sectional survey, following monsoon season (4.67% attrition) reported in Chapter Four found that psychological distress was higher in post-monsoon compared to pre-monsoon, and resource loss was a significant predictor of increased psychological distress. The findings contribute direct evidence of resource loss as an underlying factor, underscoring and validating the Conservation of Resources (COR) theory in advancing the understanding of how SLR affects psychological health. In addition, the findings revealed that resilience was generally lower among community members after the monsoon season, and this was particularly noticeable among respondents from moderately and severely susceptible coastal villages. A larger increase in COVID-19 anxiety was found among respondents living in low and moderately vulnerable coastal communities than among those living in highly vulnerable communities. These findings contribute to the body of knowledge on psychological health associated with SLR in relation to the growing threat of climate change and have the potential to inform policy and clinical interventions for coastal communities facing the consequences of climate change globally.

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Author's note

This Doctoral thesis is presented as a hybrid mode that includes papers that have been submitted for publication. As each of these chapters is a standalone manuscript, there is some unavoidable repetition across these chapters and with Introduction and Discussion, particularly when describing background literature, rationale, and discussion. Reference lists have been removed from each standalone manuscript and listed at the end of the thesis.

CHAPTER ONE: INTRODUCTION

1.1. Psychological health and climate change

The impact of climate change on human health is a global concern; and is considered an emerging challenge to psychological health (Charlson et al., 2022; Jones, 2022). While evidence is still limited regarding the connection between climate change and psychological health (Cuijpers et al., 2023), available research indicates that the prevalence of psychological difficulties including distress, depression, anxiety, and stress, is associated with exposure to climate events and environmental changes (Clayton, 2020; Cooper et al., 2019; Gibson et al., 2020; Hieronimi et al., 2023; Lawrance et al., 2022b; Talukder et al., 2021). Investigating the pathways by which climate change, and the resulting environmental stressors, impact psychological health is thus critical.

Climate change, defined by significant alterations in global temperature patterns, extreme weather events, and most notably, an accelerated rate of sea-level rise (SLR), harbors profound psychological impacts (Abijith et al., 2023; Zittis et al., 2022). SLR, a direct consequence of global warming due to increased anthropogenic activities, is characterized by a consistent rise in the world's ocean waters (Bosserelle et al., 2022; Roy et al., 2023). As the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) underscores, this rise exacerbates flooding, coastal erosion, and saline intrusion into freshwater sources, predominantly affecting coastal and low-lying areas (Eslami et al., 2021; McMichael, 2023). These tangible threats, including displacement and loss of livelihoods, trigger stress and anxiety, leading to long-term psychological health disorders (Hayward & Ayeb-Karlsson, 2021; Hrabok et al., 2020). Climate change, through the lens of increasing SLR, presents an enduring psychological stressor that extends beyond the immediate physical threats (Ekoh et al., 2023; Solecki & Friedman, 2021). Despite recent recognition by World Health Organization (WHO), United Nations (UN), and various non-governmental organizations (NGOs), this aspect remains poorly addressed in climate change discourse (MacGregor et al., 2022; Whittingham et al., 2023). As this dissertation delves into psychological health implications of SLR, it aligns with UN's Sustainable Development Goals (SDGs) and the Paris Agreement, reinforcing the need for comprehensive, psychologically informed climate change responses and interventions.

1.1.1. *Direct and indirect effects of climate change*

Climate change incites the psychological effects that are both direct and indirect in nature. The direct effects typically arise from increased exposure to climate-induced hazards that are becoming more frequent, intense, and long-lasting (Cianconi et al., 2020; Patel et al., 2020). Such hazards can result in a significant displacement, causing trauma related to the loss of homes and social networks (McMichael & Lindgren, 2011; McMichael & Shipworth, 2013). The IPCC predicts that, largely due to coastal flooding, shoreline erosion, and agricultural degradation, climate change could displace as many as 150 million people by 2050 (Palinkas, 2020). The indirect psychological effects of climate change are manifested through deterioration of food and water security, destabilization of financial systems, amplified economic risks, and the erosion of social capital (Cunsolo & Ellis, 2018; Ellis & Albrecht, 2017). Poverty and related economic stressors, such as unemployment, are frequently precursors to mental health disorders like depression and anxiety (Patel & Kleinman, 2003). These economic stressors can also undermine the ability of individuals and communities to adapt with climate change (Adger et al., 2003).

Economic pressure can further erode social capital, which includes shared resources or values that facilitate collective action and are protectively related to psychological health (Aldrich & Meyer, 2015; Alston & Whittenbury, 2013; Hikichi et al., 2020; Nakagomi et al., 2020; Villalonga-Olives et al., 2022). Social capital, characterized by community participation and social cohesion, plays a crucial role in community adaptation to climate change risks (Benevolenza & DeRigne, 2019; Hagedoorn et al., 2019). However, a decline in social capital is associated with increased psychological distress (Berry et al., 2011; Noel et al., 2018).

The concurrent dynamics of social capital and social drift significantly shape psychological implications of climate change. Social drift refers to the process where individuals with psychological health disorders are more likely to descend into poverty due to factors like unemployment or high healthcare costs, which can be exacerbated by climate-induced economic strains (Lund & Cois,

2018). On the other hand, social capital, characterized by strong networks, norms, and trust, can mitigate the impacts of social drift by fostering resilience to climate threats (Farooq et al., 2022; Mkungula, 2021). However, climate-induced socioeconomic pressures can erode social capital, undermining its protective effect on psychological health (Farooq et al., 2022; Mkungula, 2021). Therefore, understanding the interplay between social capital and social drift under the influence of climate change offers a comprehensive perspective on the socio-ecological vulnerabilities associated with climate change. This understanding is critical for devising effective climate change adaptation and mitigation strategies that address both the direct and indirect psychological consequences of climate change. By adopting a nuanced approach that acknowledges these intertwined dynamics, this research contributes to the existing body of knowledge, providing valuable insights for policy and community interventions designed to enhance resilience and coping capacities in response to climate change.

1.1.2. *Aspects of psychological health affected by climate change*

Research has found a wide range of psychological health aspects that are impacted by climate change. Depression, anxiety, distress, and post-traumatic stress disorder (PTSD) are frequently examined. For instance, in a cross-sectional survey among Jagatsinghpur residents of India, Kar et al. (2007) found that those affected by cyclones were more likely to experience PTSD, depression, and anxiety. In a qualitative study on the effects of tropical cyclone Aila in affected areas of Bangladesh, Saha (2014) found that Aila survivors reported experiences of psychological trauma and anxiety. In a longitudinal study conducted in Aceh and North Sumatra, Frankenberg et al. (2008) reported that respondents in areas severely damaged by the tsunami displayed the highest levels of posttraumatic stress reactivity. In addition, a qualitative study among the residents of Tuvalu, Gibson et al. (2019) found that financial commitments resulting from land loss due to climate change were linked to greater psychological distress.

Research also distinguishes between concerns about present environmental challenges and concerns that they may lead to future apocalypse scenarios. For instance, according to research by Searle and Gow (2010), the vast majority (98%) of Australian participants believed that lifestyle adjustments, such as reducing water consumption and sun exposure, and unanticipated natural events like hazards were related to climate change. Many people thought that these changes will probably result in more serious socioeconomic problems in the future, like increased food prices, conflicts over natural resources, and massive migration.

Healthcare experts urge the development of solutions to help people deal with their concerns because the perceived harm to a community's psychological health is so large (Charlson et al., 2022; Palinkas et al., 2020). The American Psychological Association published a brochure (Benson et al., 2008) that states:

> Even for individuals who are not immediately and directly affected by climate change, the problem can seem catastrophic, overwhelming, and impossible to control. For people suffering the effects of rising sea levels, droughts or unpredictable weather, the consequences of climate change will undoubtedly cause significant stress. [p. 30]

Hence, psychological health is a universal concern related to climate change challenges. Similar to this, the Australian Psychological Society has created tip sheets that outline typical emotional responses to climate change, strategies for coping with these feelings, and advice on having conversations about the environment that include recommendations to reduce anxiety about the threat of climate change (Reser & Swim, 2011). These resources produced by psychological associations demonstrate the motivation behind the psychology community's concern for climate change problems (Lawrance et al., 2022a; Sanson et al., 2022).

1.1.3. *Assessing research methods*

The relationship between climate change and its consequences on psychological health has been studied using a variety of study methods, including qualitative (Gibson et al., 2020; Hieronimi et al., 2023) and quantitative (Acosta et al., 2016; Pollack et al., 2016) investigations. These studies concentrated on extreme weather events, climate hazards (e.g., cyclones, floods), sub-acute weather events (e.g., droughts), environmental degradation, and other environmental changes (e.g., sea-level rise). Using qualitative approaches, Hieronimi et al. (2023) investigated the psychological well-being of young people in Germany following extreme weather occurrences. During September and October 2021, they conducted nine semi-structured interviews with caregivers and politicians who were supporting and caring for the children and adolescents of a German town affected by flooding in 2016. A content analysis of the interviews revealed that the respondents reported stress reactions connected to their experience of the floods, including extreme fear, helplessness, and tension. A mixed-method study conducted by Gibson et al. (2020) explored psychological health related to climate change among communities in Tuvalu regarded as exceptionally vulnerable to climate change. They conducted face-to-face structured interviews with 100 Tuvaluan participants. Interview data were analysed using descriptive, correlational, and between-group methods, and concluded that participants' distress levels were correlated with stressors connected to climate change. They also claimed that climate change represents a risk to psychological health and obliges decision-makers to consider these risks when conceptualizing climate-related problems or tallying the costs of inaction.

Quantitative studies have further examined the relationship between psychological health and climate change. For instance, in a quantitative cross-sectional survey from 2004 to 2012 using a structured questionnaire, Acosta et al. (2016) focused on typhoon-induced floods and landslides that affected the residents of Infanta and New Bataan in the Philippines. They found that the detrimental effects of typhoons have resulted in a range of psychological health outcomes, including distress, anxiety, fear, loneliness, and loss of hope. In a quantitative cross-sectional survey, Pollack et al. (2016) examined psychological health and risk factors among people living in Vietnam who are frequently exposed to

frequent climatic hazards (e.g., typhoons, floods, landslides). They assessed 1,000 participants (female 56%, median age 42 years) using standardized measures of psychological symptoms with generalized linear models (GLM) and found that risk for psychological health problems (e.g., PTSD, financial stress, depression, anxiety) increased with exposure to hazards (e.g., typhoons, floods, landslides). In a cross-sectional survey among 314 participants in the coastal fishing community of Tamil Nadu in India, Kumar et al. (2007) reported that PTSD, depression, and trauma-related psychiatric disorders were higher among the individuals who were affected by the loss of life and property following a tsunami.

While the field of climate change and psychological health is growing rapidly, it is noted that there are still large knowledge gaps in this field thus require additional research (Charlson et al., 2022; Cuijpers et al., 2023; Jones, 2022). Longitudinal studies on psychological health and climate change are needed to advance evidence and knowledge in this field of study and to strengthen policymaking and health service-setting (Berry et al., 2018; Hayes et al., 2019; Manning & Clayton, 2018). In particular, there is a need for more longitudinal studies investigating psychological health outcomes from climate hazards, including psychological health consequences of direct, indirect, and chronic climate hazards like SLR climate-related events salinity, flooding etc.

Salinity ingress, coastal flooding, and agricultural damage induced by SLR have negative impacts on people's lives by reducing their livelihood options (Ahmed et al., 2019; Corendea et al., 2012; Rabbani et al., 2013). For instance, salinity intrusion is having a cascading effect on health and livelihoods among the coastal populations who are highly exposed to saline-contaminated water through drinking and cooking (Naeen, 2018; Nahian et al., 2018; Rakib, Sasaki, Matsuda, et al., 2019). Among communities exposed to flooding, people affected by flood water in their homes and agricultural lands experience a reduction in their livelihoods through resources loss (Jermacane et al., 2018). Moreover, prior studies have focused on student samples (Searle & Gow, 2010), clinical samples (Budziszewska & Jonsson, 2022), or small community samples (Gibson et al., 2020;

Hieronimi et al., 2023) and state that more large-scale community longitudinal assessments are needed to determine the specific effects of climate change on psychological difficulties. For example, Gibson et al. (2020) interviewed 100 Tuvaluan participants and reported that climate change is a risk factor for psychological health. More specifically, there appears to be a need for additional longitudinal investigations looking at the long-term psychological health effects of climate hazards.

1.2. Conceptual framework

This research is grounded in the Conservation of Resources (COR) theory (Hobfoll, 1989, 2001), enriched by the latest academic discourses, and examines the intricacies of vulnerability to climate change. Within this paradigm, vulnerability is not an esoteric concept; instead, it manifests in the daily experiences of individuals and communities. It emerges from the intertwined interactions among social, psychological, and physical dimensions of a given system. Crucially, the overall vulnerability of a community is a composite of its physical environment, socio-economic structures, and its adaptive capacity, thus emphasizing the necessity to consider these facets collectively in vulnerability assessment.

The climate hazards literature has evolved substantially, broadening the perspective on climate hazards from a strictly physical phenomenon to encompassing the socio-ecological construction of human vulnerability. Climate disasters are now perceived as part of a wider socio-environmental matrix in which societal structures interact with physical hazards to produce vulnerability (Adger, 2006; Kasperson et al., 2022). This has resulted in an intricate understanding of vulnerability, with definitions and indicators that are contingent upon the specific context and scale of investigation. Despite this complexity, vulnerability assessments provide significant value for community resilience building, policy development, risk mitigation, and hazard risk reduction (Almutairi et al., 2020; Birkmann, 2006; Füssel, 2007). Drawing upon this theoretical basis, this research seeks to unravel multidimensional nature of vulnerability to climate change, with a particular emphasis on psychological implications of SLR.

The Pressure and Release (PAR) model (Wisner, 2004), the access model (Ribot, 1995), and Cutter's hazards-of-place (HOP) and hazard resilience of place (DROP) models (Cutter et al., 2003) are a few of the critical theoretical models employed in climate change studies to unravel the complexity of vulnerability. These models, however, have been critiqued for various reasons. The PAR model is criticized for not effectively considering the human-environment system and for its potential inability to translate the impact of dynamic pressures and unsafe conditions at a local level (Birkmann et al., 2013). The HOP and DROP models, on the other hand, have been criticized for their focus on equal weights for social and biophysical indicators, neglecting larger contextual factors and the dynamics of post-hazard recovery (Fekete, 2012).

Incorporating the lenses of political ecology (Robbins, 2019) and political economy (Jessop, 2010) in the discourse of vulnerability can further enhance our understanding of community's vulnerability. Political ecology examines an intricate relationship between societies and their environments, while political economy highlights the importance of economic structures and power relations in shaping vulnerability.

This research adopts a holistic approach to vulnerability, integrating physical, psychological, and socio-economic factors. 'Hazard' is conceptualized as a pre-existing condition, while 'risk' is seen as a function of hazard and vulnerability. This necessitates that vulnerability assessment considers a community's current coping capacity and resilience to future hazards, highlighting the importance of developing effective climate change mitigation and adaptation strategies. Recent research underscores the value of localized, context-specific assessments, as large-scale models can overlook the nuances of localized impacts due to climate warming (Fraser et al., 2020; McNamara et al., 2020; Rafliana et al., 2022).

1.2.1. *Conservation of resources (COR) theory*

The current research builds on the theoretical grounding provided by the Conservation of Resources (COR) theory (Hobfoll, 1989, 2012; Hobfoll et al., 2018) to investigate psychological ramifications

of climate change, focusing primarily on the impact of SLR. The COR theory proposes that individuals experience psychological distress when they perceive a threat to their resources or fail to gain resources despite investment. Within the ambit of this theory, resources are defined as entities, conditions, or states that individuals seek to acquire, maintain, cultivate, and safeguard.

Various empirical studies have applied the COR theory to understand the psychological consequences following natural hazards. For instance, Freedy et al. (1994) utilized the COR theory to examine the psychological distress experienced by adults after the Sierra Madre earthquake and Hurricane Hugo. Their research emphasized the pivotal role of resource loss in inducing psychological distress, overshadowing the influence of personal characteristics or coping behaviors. This finding echoes the theoretical underpinnings of COR, which posits that the loss, or threat of loss, of resources can lead to significant stress and distress. Supporting this theory, a comprehensive systematic review by Benevolenza and DeRigne (2019) documented a positive correlation between resource loss and psychological distress during and following climate-related hazards. They emphasized the crucial role of environmental conditions as triggers for resource loss, substantiating the potential of the COR theory as a conceptual framework to understand the psychological impacts of climate change. Extending this COR theory, Rudolphi et al. (2020) surveyed farmers and ranchers in the Midwest USA, discovering that resource loss resulting from extreme environmental conditions often led to anxiety and depression. Their study presents crucial evidence supporting the applicability of the COR theory in the specific context of climate change, paving the way for this doctoral research.

This research intends to apply insights gleaned from these studies to the specific context of SLR. The existing research substantiates the claim that resource loss, often a consequence of natural hazards, can lead to psychological distress. Therefore, extrapolating these findings, we can postulate similar psychological outcomes for individuals and communities grappling with the realities of SLR. By innovatively applying the COR theory to explore the psychological implications of SLR, this research endeavors to enhance the existing theoretical framework around the psychological impacts of climate

change. It seeks to provide a nuanced understanding of how SLR could compound psychological health issues, thereby offering a significant contribution to the existing literature. Furthermore, this research could inform policy interventions, emphasizing the importance of resource conservation and management in mitigating the psychological impact of climate change.

1.2.2. *At risk populations*

Literature indicates that the most detrimental psychological health impacts occur among people living in communities whose livelihoods are closely tied to natural resources (Berry et al., 2018; Clayton, 2020; Palinkas et al., 2020). This is particularly the case in tropical low- and middle-income countries (Berry et al., 2018; Clayton et al., 2017; Gibson et al., 2019; Islam et al., 2020; Palinkas & Wong, 2020b). For example, coastal communities are ecologically vulnerable because of SLR, which could exacerbate livelihoods (Islam et al., 2020; Pörtner et al., 2022). In a cross-sectional survey among 371 household heads in Bangladesh, Islam et al. (2020) reported that riverbank erosion was related to the loss of homestead land, agricultural land, homestead infrastructure, scarcity of pure drinking water, crops, and livestock. They also found that river-bank erosion had increased poverty, insecurity, helplessness, and psychological problems such as stress. Furthermore, Palinkas and Wong (2020a) summarised the most recent developments in understanding the psychological health effects of climate change based on three distinct categories of climate-related events: acute weather events lasting months or years (such as droughts and long-duration heat waves); subacute weather events lasting days (such as hurricanes, floods, wildfires, and short-duration heat waves); and environmental catastrophes lasting weeks or months. They have found that low- and middle-income nations are especially vulnerable to the negative effects of global climate change and experienced as depression, anxiety, and post-traumatic stress symptoms.

Even within low- and middle-income countries, available evidence indicates that the most detrimental psychological health impacts may be evident among older adults, women, and lower social economic status (Berry et al., 2018; DeVito et al., 2018; Frankenberg et al., 2008; Kumar et al., 2007; Shahjalal,

2021). In a cross-sectional survey of members of a coastal fishing community of Tamil Nadu, Kumar et al. (2007) reported that depression and trauma-related psychiatric disorders were higher among the individuals experiencing income loss following a tsunami. In another cross-sectional survey among one thousand participants in central Vietnam, Pollack et al. (2016) focused on psychological health and climatic hazards (e.g., typhoons, floods, landsides). They found that women had significantly higher rates of generalized anxiety disorder (GAD) and PTSD than men, and greater life impairment related to psychological health problems. They also found that increasing age was associated with increased risk for all psychological health conditions.

Literature also indicates why women, the elderly, and poor are more severely affected. Some research suggests that hazards and climate change perpetuate gender inequalities and create security, health, and livelihood risks for women and girls (Frankenberg et al., 2008; Shahjalal, 2021). For instance, Shahjalal (2021) examined climate change effects and climate resilience of women in South Asia through a literature review and found that cultural and societal barriers that restrict women's skills development, including restrictions on education access and property ownership, may limit their ability to implement adaptation strategies for environmental stressors. Likewise, older adults may be more vulnerable to environmental change due to issues related to reduced mobility, limited access to resources like compromised agriculture, dependence on caregivers and health support, reduced availability of freshwater, and limited capacity for evacuation (Berry et al., 2018; DeVito et al., 2018), which may limit their capacity to cope with environmental stressors. It is also evident that psychological disorders were higher among the individuals experiencing income loss following climatic hazards (Benevolenza & DeRigne, 2019; Clayton, 2021; Hime et al., 2018; Kumar et al., 2007). For example, Benevolenza and DeRigne (2019) conducted a systematic review that examined climatic hazard-related experiences and psychological health outcomes in the context of three major hurricanes which occurred in the United States over the past 12 years. They reported that elderly and low-income individuals were more at risk of adverse psychological health outcomes.

1.3. Sea-level rise and psychological health among coastal communities

One of the most concerning facets of climate change is the accelerated rate of SLR. This environmental crisis has seen sea levels increased from 2.5mm per year during the 1990s to approximately 3.4mm per year at present, a figure predicted to result in a SLR of 26 to 77 centimeters by the year 2100 (IPCC, 2022). These changes have profound implications, particularly for the estimated 600 million people residing in vulnerable low-lying coastal zones worldwide (Jevrejeva et al., 2020).

SLR induces various environmental stressors, including coastal flooding, agricultural damage, and salinity ingress (Ahmed et al., 2019; Rabbani et al., 2013). Salinity ingress, for example, can lead to health problems and lifestyle disruptions among coastal inhabitants exposed to saline-contaminated water (Naeen, 2018; Rakib, Sasaki, Matsuda, et al., 2019). Additionally, flooding precipitates property damage, erosion, and loss of crops (Jermacane et al., 2018; Sattler et al., 2018; Yanda et al., 2018), significantly affecting the social dynamics of communities and individuals' psychological health (Cunsolo & Ellis, 2018; Ellis & Albrecht, 2017).

Amid these environmental changes, coastal populations in tropical developing countries, particularly those reliant on natural resources for their livelihoods, are increasingly at risk of experiencing significant psychological impacts (Clayton et al., 2017; Hime et al., 2018). Wade (2022) found that the effects of SLR, including displacement, loss of cultural lands, loss of livelihoods, financial stress, and compromised food and water security, contribute to psychoterratic disorders, a set of psychological health conditions induced by environmental changes. These psychoterratic disorders, including eco-anxiety, eco-paralysis, and solastalgia, have been explicitly linked to SLR (Wade, 2022). Eco-anxiety refers to a persistent fear of impending environmental hazard (Clayton et al., 2017), while eco-paralysis represents a sense of powerlessness or incapacity to mitigate environmental degradation (Doherty & Clayton, 2011). Solastalgia, a term coined by Albrecht et al.

(2007), denotes the distress experienced due to environmental changes impacting one's home environment.

Empirical studies underscore the adverse psychological impacts of SLR. For instance, in the Solomon Islands, Asugeni et al. (2015) reported that almost all participants (56 out of 57) experienced fear and worry due to the negative impacts of SLR. Similarly, Rishi and Mudaliar (2014) found that Indian coastal residents attributed loss of life, property, and other resources to SLR, heightening stress levels. Therefore, there is an urgent need for extensive research into the psychological effects of SLR, with a specific focus on psychological disorders in vulnerable communities. This knowledge can guide the development of necessary interventions to mitigate the psychological ramifications of this global environmental crisis, i.e., SLR.

1.4. Rationale of this study

The overarching aim of this research is to investigate how SLR-induced environmental stressors affect psychological health in coastal communities in the Asia-Pacific region. Currently, there is no evidence in the literature that examines longitudinally this issue in a large-scale. As such, there is a dearth of information regarding how SLR negatively affects psychological health among world's most vulnerable populations. Many researchers recommend empirical work in this space, as diverse communities must increasingly contend with the myriad challenges associated with climate change (Agache et al., 2022; Cuijpers et al., 2023; Cunsolo & Ellis, 2018; Gibson et al., 2019; Hayes et al., 2019). Identifying individuals or communities at risk of psychological distress, depression, and anxiety due to SLR would be of paramount importance to devise targeted interventions. This research examines these issues first among coastal communities in the Asia-Pacific region through a systematic review and then via a longitudinal study conducted across coastal communities of varying levels of environmental vulnerability in Bangladesh.

While SLR affects people globally, the Asia-Pacific region is particularly vulnerable to its adverse effects, where more than half (56%) of the world's seven billion population and nearly two-thirds of

the world's poor live (IPCC, 2022). In 2021, Asia accounted for 40% of global hazard events and 66% of the total number of people affected (IPCC, 2022). Sea-level rise is a pressing and alarming issue for Bangladesh because of the nation's geographical setting, extensive coastlines, high incidence of poverty, and extreme reliance on agriculture (Rahman et al., 2021; Rakib, Sasaki, Pal, et al., 2019). Bangladesh is a sub-tropical country, bordered to the west, north, and east by India, to the south-east by Myanmar, and to the south by the Bay of Bengal with a 710 km long coastline (Ahmad, 2019; CCC, 2022). About 53% of the coastal region is currently affected by salinity (Naeen, 2018), which is mainly the product of climate-induced SLR (Rashid et al., 2014). Additionally, salinity decreases the germination rate of plants which affect livelihoods through slow crop growth (Ashraf et al., 2002; Rashid et al., 2014). Almost every year, natural hazards cause loss of lives and properties and jeopardize development activities along its coastal zone (Pearce et al., 2018). A net reduction of 0.5 million metric ton of rice occurred due to SLR in 2018 and seriously affected local livelihoods (CCC, 2022; Rakib, Sasaki, Pal, et al., 2019). In this region, about 30% of the cultivable land is affected by tidal flooding during the wet season (Dasgupta et al., 2017). Therefore, coastal communities of Bangladesh provide an excellent setting for examining the impacts of SLR on psychological distress.

The theoretical framework of the present research is the Conservation of Resources (COR) theory (Hobfoll, 1989, 2012). Extending prior research that used the COR theory to understand how climate change affects psychological health via resource loss, this research considered the role of resource loss as a mediating factor of the longitudinal effects of SLR on psychological health. In addition, this research considered demographic risk factors, based on the literature that the adverse effects of climate change are experienced most intensely by women, older adults, and those with lower income (Clayton, 2021; DeVito et al., 2018; Islam, 2019; Kumar et al., 2007; Shahjalal, 2021).

1.5. Aims

This research aims to provide new insights into the pathways by which psychological health is affected by climate change induced SLR. Specifically, this Doctoral thesis conducted a large-scale longitudinal assessment of coastal villages in Bangladesh with the aim of identifying and examining some of the ways that climate change affects psychological health. Findings from this research should contribute to the development of a more comprehensive understanding of psychological health challenges, induced by climate change. In addition, a systematic review that is a part of this research endeavour will incorporate the data that have already been discovered regarding the psychological effects of SLR that are found in different disciplines. Through this project, this research also aims to enhance our understanding of factors that may support effective early intervention and treatment at the practitioner and systemic levels.

This research aims to contribute to the efforts towards the integration of psychosocial support in hazard risk reduction policy and calls for accessible clinical interventions for communities affected by SLR amidst the growing threat of climate change. This research is relevant to the priority areas for Health EDRM (Health Emergency and Hazard Risk Management) identified by the World Health Organization Thematic Platform Research Network on Health EDRM: psychological health data management, community risk management, psychosocial management, and health workforce development (Kayano et al., 2019; Lo et al., 2017; Oktari et al., 2022). These areas, therefore, augment calls for psychological health-specific hazard risk management evidence from the World Association for Hazard and Emergency Medicine (Kayano et al., 2019) and the Asia Pacific Hazard Mental Health Network (Newnham, Reifels, et al., 2020). Government policy and funding to address psychological health risks in coastal areas of the Asia-Pacific most vulnerable to SLR will be critical as climate change increases environmental threats. To address the need for evidence to inform policy and practice in this priority area, a series of studies were conducted in this research.

1.6. Thesis organization

The central question of this research is "How is sea-level rise associated with factors of psychological health among vulnerable coastal communities?" To answer this question, this research had the following objectives:

1. To investigate the extent to which SLR is associated with psychological health among coastal communities in the Asia-Pacific (APAC) region;
2. To examine the effect of SLR on psychological health among coastal communities in Bangladesh;
3. To examine the mediating role of resource loss, and moderating roles of socioeconomic status, gender, and age on the relationship between SLR and psychological health; and
4. To longitudinally examine the association between SLR and psychological health.

This research comprised three studies to address the above objectives. Study one (Chapter Two) conducted a systematic review to examine how SLR is associated with psychological health among coastal communities in the Asia-Pacific (APAC) region. Nine electronic databases were used for the systematic review. A total of thirteen studies met the inclusion criteria, representing seven countries (Bangladesh, India, Indonesia, Philippines, Solomon Islands, Tuvalu, and Vietnam). A narrative synthesis was performed to organize, synthesize, and summarize the findings.

Study two (Chapter Three) was a cross-sectional survey examining the effect of SLR on psychological health among coastal communities in Bangladesh. A total of 1200 (50% female, ages 18+ years) participants were randomly selected, in communities stratified by levels of vulnerability to SLR (high, medium, or low). Interviews that supported quantitative data collection were conducted in the pre-monsoon season (06 March to 05 April 2021). Respondents' psychological distress, depression, anxiety, stress, environmental stressors, resource loss, and demographic information were measured. Multilevel mixed-effects models with random intercepts were conducted for data analysis. This study also examined the mediating role of resource loss, and moderating role of age, gender, and income.

Study three (Chapter Four) was a follow-up work of Study two and enabled longitudinal analysis of the association between SLR and psychological health, as well as the mediating and moderating factors. The follow-up study was conducted eight months after the baseline survey in the post-monsoon season. Data collection took place during the COVID-19 pandemic period, and thus, Study three also examined COVID-19 anxiety, to adjust for its effect. In addition, this chapter reported resilience of the coastal communities.

Chapter Five comprises a general discussion of the findings and is the final chapter of this thesis. It addresses overall research aims and describes conceptual and applied insights across the systematic review and empirical studies, and a way forward followed by concluding remarks.

CHAPTER TWO: SYSTEMATIC REVIEW

Sea-level rise and psychological distress among coastal communities in the Asia-Pacific region: A systematic review of quantitative and qualitative evidence

2.1. Abstract

Sea-level rise is one of the negative effects of climate change that has gained increased attention both in public and academic arenas. A systematic literature review was conducted to synthesize the current evidence on the relationship between environmental stressors of sea-level rise and psychological health. Nine electronic databases, including Scopus, ProQuest, Health collection (Informit), Google Scholar, CINAHL, and Ovid platform comprises of Medline, PsycInfo, Global Health, and Ovid Emcare, were searched from October 2020 through July 2022. The JBIQARI and NIH checklist was employed for quality assessment. A narrative synthesis was performed. This systematic review identified thirteen studies that met the inclusion criteria. Seven countries were represented in the studies (Bangladesh, India, Indonesia, Philippines, Solomon Islands, Tuvalu, and Vietnam). Ten studies (77%) indicated that exposure to SLR-induced environmental effects (e.g., salinity, flood) predicted psychological distress, depression, anxiety, and stress. Studies often (69%) indicated the role of SLR on people's lives through its negative impact on livelihoods. SLR resulted in a greater degree of loss, especially among more vulnerable coastal communities. Risk factors included loss of life and property, as well as occupation, income, unpredictability, religiosity, catastrophe warning, education, age, and gender. The review provides evidence for an association between sea-level rise and psychological health among coastal residents in the Asia-Pacific region. Limiting the consequences of SLR in coastal communities may have substantial implications for psychological health and livelihoods. Additionally, considering the increased threat posed by climate change, this review revealed risk and resilience factors linked to psychological distress in coastal communities that might be targeted in clinical and health policy interventions.

2.2. Introduction

Climate change is an active phenomenon, and its negative environmental consequences have the potential to cause or exacerbate psychological distress among coastal communities. While climate change affects people globally, the Asia-Pacific region is particularly susceptible to its adverse effects, where more than half (56%) of the world's seven billion people and nearly two-thirds of the world's disadvantaged live (UNDP, 2017). In 2020, the Asia-Pacific accounted for 86% of the world's extreme climatic events and 53% of climate-related deaths occurred in the region (UNDRR & CRED, 2021). Existing studies suggest that climate change has already had a negative impact on the region. Flooding, drought, land erosion, and bushfires are increasing due to rising temperatures, the increasing frequency of weather events, and rainfall variability (Coyle & Van Susteren, 2012; Ellis & Albrecht, 2017; Manning & Clayton, 2018; Sattler et al., 2018). Although both developed and developing countries will be impacted by climate change, developing and least developed countries will be affected disproportionately (Berry et al., 2018).

Researchers have investigated the impact of climate change on psychological health in recent years and have identified it as a substantial risk factor (Ahammed et al., 2019; Berry et al., 2018; Cunsolo & Ellis, 2018; Ellis & Albrecht, 2017; Gibson et al., 2019; Helm et al., 2018; Manning & Clayton, 2018; Rakib, Sasaki, Matsuda, et al., 2019). The most detrimental psychological health impacts are predicted to occur among coastal communities that rely on natural resources for sustenance and livelihoods; in particular, those living in areas most vulnerable to climate change-induced sea-level rise (Hime et al., 2018; Huq et al., 2015; MacDonald et al., 2015; Swim et al., 2011).

SLR is a global phenomenon, which refers to the long-term increase in the average water level of the world's oceans (Becker et al., 2023). SLR caused primarily by two factors related to global warming: the expansion of seawater as it warms, and the melting of ice over land, such as glaciers and polar ice caps (Becker et al., 2023; Prakash, 2021). The rate of SLR has been observed to accelerate in recent years, from 2.5 mm per year in the 1990s to approximately 3.4 mm per year in current times (IPCC,

2022). This has significant implications for coastal communities worldwide, with a predicted SLR of 26 to 77 cm by 2100 potentially affecting the livelihoods and housing security of over 600 million people in low-lying coastal zones (IPCC, 2022; Jevrejeva et al., 2020). This is crucial for coastal regions in Asia and the Pacific because many people reside on low-lying sedimentary landforms in river estuaries (Ashrafuzzaman & Furini, 2019; Guleria & Edward, 2011; IPCC, 2019, 2022; Majumder et al., 2017; Mukherjee et al., 2019). For instance, the livelihoods and residences of about 35 million people in Bangladesh's coastal region are particularly at risk from the effects of SLR (Rakib, Sasaki, Matsuda, et al., 2019; Talukder et al., 2016).

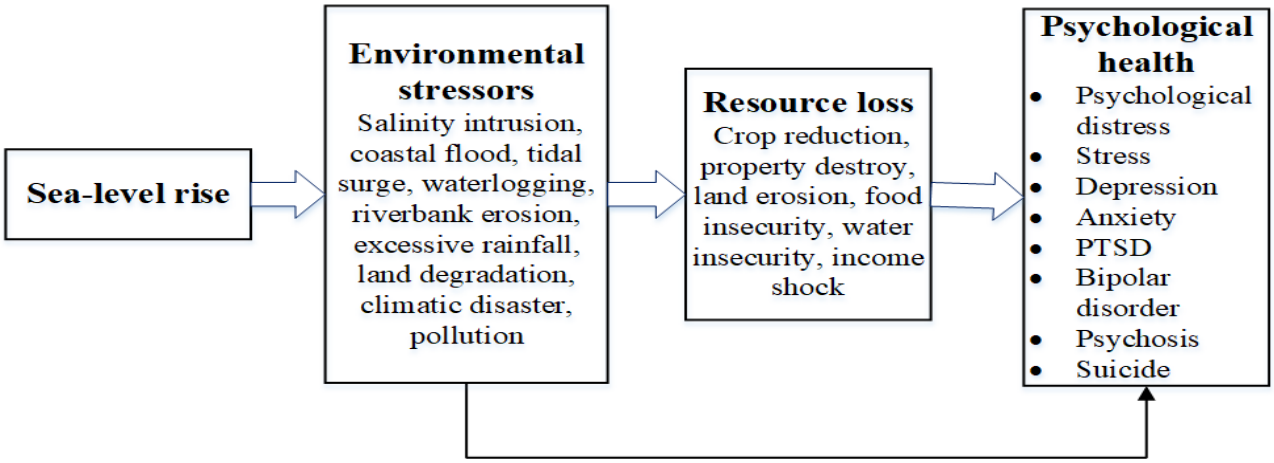
Historical and current sea-level rise and coastal changes have been mapped (e.g., via satellite altimetric data) and sea-level recordings (e.g., by tide gauges), indicating the vulnerability of coastal communities globally (Gutierres et al., 2016). The future effects of predicted sea-level rise have also been modelled; as an example, Hinkel et al. (2014) projected that 4.6% of the global population will be exposed to annual floods associated with sea-level rise. Additionally, by studying 84 developing countries, Dasgupta et al. (2015) reported that during this century more than ten million people (1.28% of global population) are likely to be affected by salinity, agricultural damage, and flooding because of SLR.

Rising sea levels have the potential to change natural landscapes, disrupt food security and water resources, deplete agricultural productivity, and weaken infrastructures that could gradually lead to a reduction of livelihoods (Clayton et al., 2017; Jermacane et al., 2018; Kabir et al., 2016; Khan et al., 2011; Obradovich et al., 2018; Padhy et al., 2015). The detrimental effects of SLR on coastal areas include salinity intrusion, coastal flooding, tidal surge, waterlogging, riverbank erosion, excessive rainfall, land degradation and threats to agricultural productivity (Naeen, 2018; Nahian et al., 2018; Rabbani et al., 2013). For example, salinity intrusion has a cascading effect on health and livelihoods among coastal peoples who are severely exposed to saline-tainted water for drinking and cooking (Naeen, 2018; Nahian et al., 2018; Rakib, Sasaki, Matsuda, et al., 2019). Among communities

subjected to coastal flooding, individuals affected by flood water in their residences and agricultural lands experience resource loss which in turn reduces their livelihood options (Jermacane et al., 2018). These factors in isolation or in combination may result in a loss of personal wealth which has the potential to increase the incidence of psychological distress, anxiety, depression, stress, post-traumatic stress disorder (PTSD), bipolar disorder, and suicide rates (Doran, 2011; Enshassi et al., 2015; Mendenhall et al., 2019). The following model is drawn based on prior findings (Ahmed et al., 2019; Clayton et al., 2017; Corendea et al., 2012; Naeen, 2018; Nahian et al., 2018; Rabbani et al., 2013; Rakib, Sasaki, Matsuda, et al., 2019; Rakib, Sasaki, Pal, et al., 2019), which demonstrate the effect of sea-level rise on psychological health through changes to resource loss (Figure 2.1).

Figure 2.1

Proposed Model of the Effects of SLR on Psychological Health, Resulting from Possible Resource Loss



A loss of resources may increase the risk of psychological distress (Fussell & Lowe, 2014; Jermacane et al., 2018; Kabir, 2018; Lemée et al., 2019; Munro et al., 2017; Zahlawi et al., 2019). According to the Conservation of Resources (COR) theory, psychological distress may be a response to the environment in which there is a risk or genuine resource loss, or a lack of resource gain; resulting from climate change (Hobfoll, 1989, 2001, 2012; Hobfoll et al., 2018; Hobfoll et al., 2015; Zadow et al., 2017). From this perspective, resources are defined as belongings that people strive to protect, retain, obtain, and foster those things that they value, specifically states, objects, and conditions. The COR theory posits that these types of resource loss will result in distress. Freedy et al. (1994) applied

COR theory to predict psychological distress among 229 adults affected by Hurricane Hugo and demonstrated that resource loss was a stronger predictor than coping or demographic variables in predicting distress.

The body of research on the impact of SLR on psychological health is still developing, and it is unknown, if environmental stressors associated with SLR are related to psychological health (Berry et al., 2018; Evans, 2019). Additionally, there is a dearth of information regarding the risk factors that drive psychological distress, depression, and anxiety among coastal inhabitants (Cunsolo & Ellis, 2018). This systematic review aims to synthesize the extant findings in the Asia-Pacific region. Thus, this study endeavors to identify possible links between SLR, resource loss, and psychological distress. This work, therefore, undertook a systematic review of the psychological effects of SLR to inform guidance on, plans for, and responses to environmental stressors induced by climate change.

2.3. Aim and objective

The aim of this review is to investigate the extent to which environmental stressors induced by sea-level rise are associated with psychological distress among coastal communities in the Asia-Pacific (APAC) region. The specific objectives are to:

a) Examine associations between sea-level rise (i.e., environmental stressors, resource loss) and psychological distress;
b) Investigate risk and resilience factors associated with psychological distress.

2.4. Methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2015). The review synthesized qualitative, quantitative, and mixed-methods peer-reviewed evidence (Beaglehole et al., 2019; Lan et al., 2020; Rubio-Aparicio et al., 2018). The review protocol was registered with PROSPERO (registration no. CRD42020207494).

2.4.1. *Systematic review*

Eligibility criteria

The criteria for including studies in this systematic review were carefully crafted to align with the study's objectives: to evaluate the effects of SLR and associated climate change phenomena on the psychological health of coastal communities in the Asia-Pacific region. The structure of these criteria is grounded in the widely employed PICOS (Population, Intervention, Comparison, Outcomes, Study design) framework, a comprehensive approach recognized in scientific research (Iniesta-Sepulveda et al., 2017; Morgan et al., 2018).

The first inclusion criterion stipulated that the studies must focus on coastal communities in the Asia-Pacific region. These areas are particularly pertinent because of their high susceptibility to SLR and related climate change hazards. Secondly, the studies must investigate environmental stressors or climate-related hazards linked to SLR or broader climate change. This encapsulates a broad spectrum of impacts, including but not limited to, salinity intrusion, coastal flooding, agricultural damage, riverbank erosion, land degradation, pollution, and climatic hazards such as cyclones, hurricanes, storms, tornadoes, tsunamis, and landslides. Although SLR is the primary concern of this review, the inclusion of other climate-related hazards provides a more rounded perspective of the potential effects on psychological health. The third criterion requires studies to analyze the incidence or prevalence of specific psychological health conditions or indicators as outcomes of the aforementioned climate-related impacts. These include depression, anxiety, psychological distress, stress, PTSD, bipolar disorder, psychosis, other psychiatric disorders, suicide, or resilience. The fourth criterion mandates that the studies can be of any design - qualitative, quantitative, or mixed methods. This inclusion allows for an extensive and comprehensive review of the available literature. Lastly, the studies must be available in full text, in English, and must present primary data.

To provide clear distinction and avoid confusion, secondary sources of information such as review articles, conference abstracts, and commentary pieces were not considered for this review. They do

not provide primary data, which is crucial for this review. Although the eligibility criteria were comprehensive enough to include a wide variety of climate change-related impacts, the main focus remained on studies related to SLR-induced impacts.

Search strategy

This review retrieved studies by searching nine electronic databases starting from October 2020 to July 2022 (assigned by the database alert): Scopus, ProQuest, Health collection (Informit), Google Scholar, CINAHL, and Ovid platform including Medline, PsycInfo, Global Health, and Ovid Emcare. Key concepts, subject headings (MeSH), and keywords were used for searching. Additionally, for identifying additional works retrieved articles' reference was tracked (Rother et al., 2020).

Study selection

To conducting a comprehensive and unbiased systematic review, a well-structured and rigorous process was implemented to ensure the selection of the most relevant studies. The initial step involved a broad search of the pertinent literature, following which all potential articles were imported into an EndNote library (version X9.2) for further scrutiny. The initial screening phase involved a review of both the title and abstract of each article to ascertain its relevance to the research objectives. This preliminary screening was carried out by the primary researcher, who is a PhD candidate well-versed in the field. This initial screening was designed to exclude studies that did not fit the predefined inclusion criteria, based on the information presented in their titles and abstracts.

The next phase entailed a full-text review of the remaining articles by two independent researchers: the primary PhD candidate and a second researcher, also a PhD candidate. This collaborative and independent review approach aimed to enhance the reliability of the study selection process and minimize any potential bias. Any discrepancies or disagreements arising during this phase were resolved through thorough discussion aimed at reaching a consensus. If the two initial reviewers could not reconcile their differences of opinion, a third reviewer, a faculty member well-versed in the research topic and systematic review methodology, was engaged to make the final decision on the

article's inclusion or exclusion. This multi-tiered and collaborative process not only ensured a thorough and unbiased selection of studies but also bolstered the overall quality and validity of the systematic review.

2.4.2. *Data extraction*

A data extraction form was developed following the Cochrane Handbook for Systematic Reviews of Interventions (Aromataris & Munn, 2020) and JBI Manual for Evidence Synthesis (Higgins et al., 2020). This work extracted the following information from each of the articles: study design, data collection procedure, sample characteristics, sea-level rise impact and measure, psychological health measure(s), psychological outcomes, and risk or resilience factors.

2.4.3. *Quality assessment*

Each article's quality was evaluated independently by the researcher and another PhD candidate (r =.95); any discrepancies were resolved by the research panel. This study used the Joanna Briggs Institute Qualitative Assessment and Review Tool (JBIQARI) for assessing qualitative and mixed-methods studies (Higgins et al., 2020). Each study was given a low, medium, or high quality assessment based on the study's design, methodology, integrity, confounders, potential selection bias, summarising, and reporting of the results. After being added together, these ratings reflect quality as follows: 8 to 10 (excellent quality), 5-7 (medium quality), and 4 points (low quality). This study employed the National Institute of Health (NIH) checklist for quantitative studies (Kamara et al., 2018). The researcher rated a study's quality as 'good' if it fulfilled 10 to 14 requirements of the NIH reliability and validity checklist, 'fair' if it met 5 to 9 requirements, and 'poor' if it met fewer than 4 requirements. Both the JBIQARI and NIH checklists are recommended tools for evaluating the quality of the existing studies (Kamara et al., 2018; Mangin et al., 2016; Ward et al., 2018).

2.4.4. *Data synthesis*

A narrative synthesis was performed to organize, synthesize, and summarise the findings considering a variety of study approaches of the included studies (Guise et al., 2014; Schwarz et al., 2019). First,

the researcher read extensively through the findings of the selected studies and made notes on relevant information. The researcher then categorized pertinent data features and summarized major findings from each study that addressed SLR and psychological health.

2.5. Results

2.5.1. *Overview of eligible studies*

After screening abstracts and full-text, thirteen articles were identified as eligible for the systematic review (refer to Figure 2.2). Table 2.1 outlines study characteristics for the final samples. Seven countries were represented: Bangladesh, India, Indonesia, Philippines, Solomon Islands, Tuvalu, and Vietnam. Studies were conducted between 2007 and 2022. Six studies were quantitative, three used qualitative methods, and four studies employed mixed methods. Three studies (20%) were based on longitudinal designs, while most studies (80%) employed cross-sectional methods. The quality of quantitative studies assessed using the NIH checklist ranged from ‘fair’ to ‘good’ with 67% of studies rated as ‘good’. Qualitative and mixed studies evaluation via the JBIQARI ranged from ‘medium’ (57%) to ‘high’ (43%).

Figure 2.2

PRISMA Flowchart of the Selection of Study

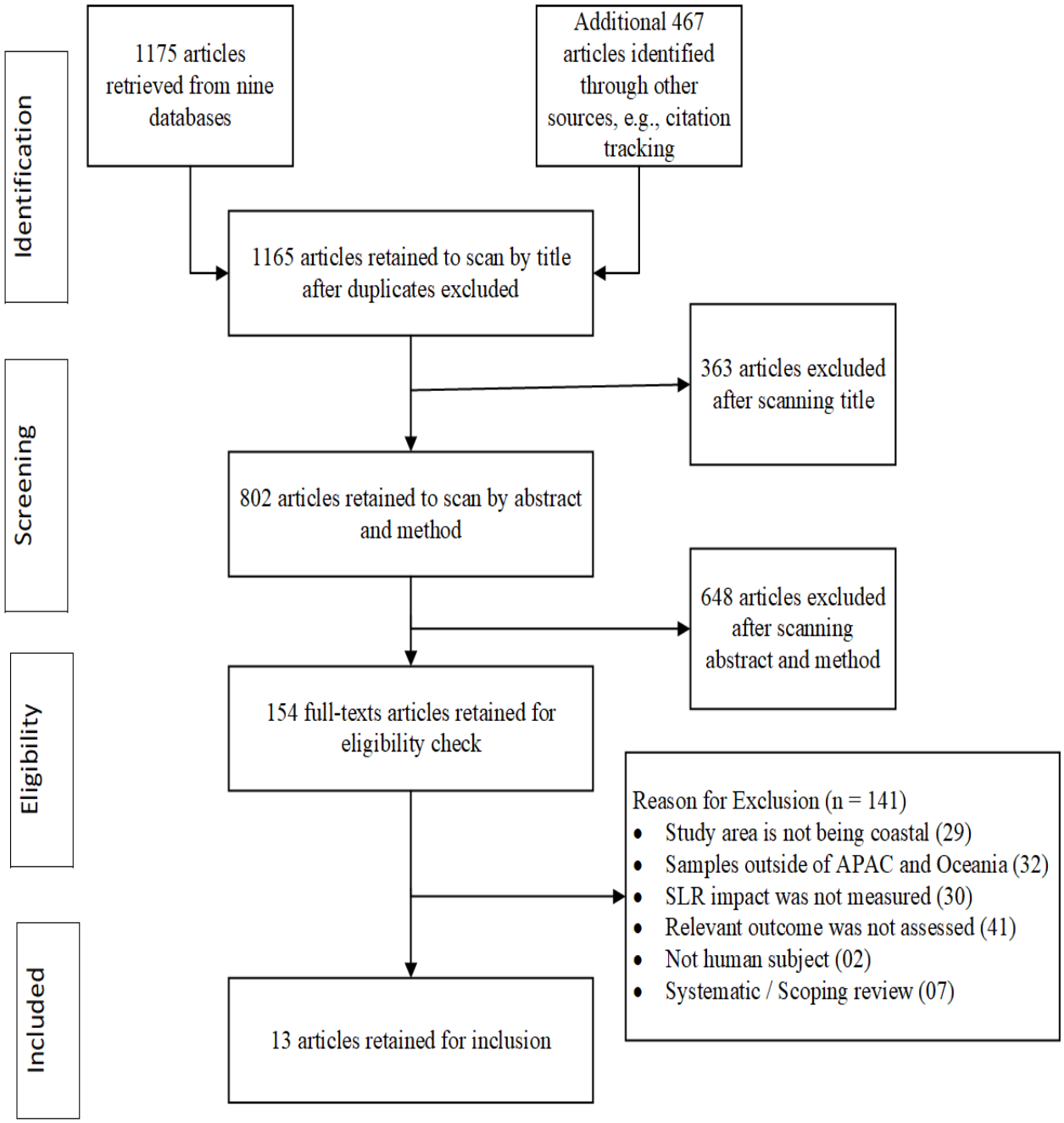


Table 2.1

Summary of Original Research (n = 13)

Author (Year)	Study site	Study period	Study population	Study design	Sample characteristics	Exposure	Outcomes	Assessment methods	Findings	Risk or resilience factor	Quality rating
Acosta et al. (2016)	Philippines	2004 and 2012	Residents of Infanta and New Bataan	Quantitative: cross-sectional survey	Stratified random sampling. 249 households	Typhoon-induced floods and landslides	Psychological distress, anxiety, fear, loneliness, loss of hope, self-pity	Open-ended questions using conjoint analysis/ choice models, measurement scales were not reported	Fear (53%), anxiety (41%), and self-pity (40%) were significantly higher among typhoon-affected communities.	Preferences on adaptation assistance were household (53%), livelihood (11%), agriculture (13%), and others (23%)	Good (NIH Checklist)
Asugeni et al. (2015)	Solomon Islands	Not reported	Residents of East Malaita	Mixed methods: cross-sectional survey	Purposive sampling. 57 participants from 6 villages, male (54%), married (62%)	Self-reported exposure to SLR	Psychological health, perceptions of SLR on individual, family, community level worry and actions	Closed and open-ended questions, measurement scales were not reported	Nearly all participants reported that SLR was causing worry (98%) and negative effects on psychological health (95%) within the community. More than half (58%) identified negative effects of worry on their communities.	Themes identified in qualitative data comprised: the physical impacts of climate change, worry about the future, adapting to SLR, and government action.	Medium (JBIQARI)
Frankenberg et al. (2008)	Indonesia	2004 to 2006	SUSENAS respondents in coastal areas of Aceh and North Sumatra	Quantitative: longitudinal study	Purposive sampling. 25778 respondents, 15+ years, 97% follow-up survey	Tsunami produced loss and damage	Posttraumatic stress reactivity, post-traumatic stress disorder	Posttraumatic stress reactivity (PTSR) scale, PTSD Checklist-Civilian Version, NASA's Moderate-resolution imaging spectroradiometer (MODIS) sensor	PTSR scores were highest for respondents in heavily damaged areas and declined over time. Female and younger age were significant predictors of PTSR. Exposure to traumatic events, loss of kin, and property damage were significantly associated with higher PTSR scores.	Proximity to coastline, exposure to traumatic events, loss of family and friends, and loss or damage of property were strongly related to PTSR	Good (NIH Checklist)

Gibson et al. (2019)	Tuvalu	2015	Residents of Tuvalu	Qualitative: exploratory study	Snowball Sampling. 39 residents, 16 key informant, 23 lay residents, 18+ years, male 48%, employed 44%, married 48%	Self-reported exposure to climate change (e. g., SLR, sea-surface temperature, coral bleaching, ocean acidification and extreme rainfall)	Psychological distress and associated impairment	Semi-structured interviews, inductive thematic approach	Determinants of distress included climate change, urbanization, and land shortage, among other factors. Distress was resulting from climate change, drought, extreme temperatures, and increased variability of weather patten.	Socio-cultural, transgressions, collective support systems, financial obligations to family and community were associated with distress	High (JBIQARI)
Guleria and Edward (2012)	India	2006	Coastal community of Tamil Nadu state, south-eastern of Indian peninsula	Qualitative: case study	Stratified sampling. 9 villages in 3 districts, focus group discussion (5-12 persons), key informant (6-10 persons)	Coastal hazards (i.e., cyclones, floods, landslides, earthquake, salinity, and shoreline erosion) based on loss of lives and property during tsunami in 2004	Coastal community resilience	Integrated approach, meteorological, hydrological, geological, and geo-morphological data, participatory vulnerability assessment, hazard risk vulnerability and capacity	Coastal population (80-90%) depends on fishing as a means of livelihood which makes them vulnerable. Community development, coastal and hazard management processes and activities were needed to build coastal community resilience towards coastal hazards.	Coastal resource management, society and economy, risk knowledge, emergency response, hazard recovery were resilience elements to affected community	Medium (JBIQARI)
Islam et al. (2020)	Bangladesh	2018	Southern coastal community of Bangladesh	Mixed methods: cross-sectional survey	Multi-stage sampling. 371 household heads, male 88%, mean age	River erosion	Socio-economic and psychological vulnerability,	Vulnerability index, concurrent data analysis technique using triangulation	Losses due to river-bank erosion were homestead land (55%), land (53%), homestead infrastructure (52%), scarcity of pure	Innovative production, formatting self-help groups, entrepreneurship	High (JBIQARI)

					45, married 54%, fishing 36%, day labourer 22%, illiterate 65%		community resilience		drinking water (41%), crop (30%), and livestock (29%). River erosion has increased poverty (70%), insecurity (64%), helpless (63%), and psychological problems such as stress (71%).	development, priority basis livelihood options, use of indigenous knowledge and skill-based coping strategies were the elements of resilience	
Kar et al. (2007)	India	2000	Sea-side residents of Jagatsinghpur	Quantitative: cross-sectional survey	Cluster sampling. 447 participants, female 50%, age 7-17 years (mean = 12.9 & SD = 1.83)	Sea tide sweeping inland and cyclone with heavy loss of life and property	Post-traumatic stress disorder (PTSD), depression, anxiety	A checklist based on the International Classification of Psychological and Behavioural Disorders (ICD-10-DCR)	Significantly more children (43.7%) in high exposure areas reported PTSD than those (11.2%) in low exposure areas ($p < 0.001$). Depression was significantly associated with PTSD.	High exposure, lower educational level, and middle socio-economic status significantly predicted the outcome of PTSD	Good (NIH Checklist)
Kumar et al. (2007)	India	2005	Coastal fishing community of Tamil Nadu	Quantitative: cross-sectional survey	Purposive sampling. 314 participants, age 18–76 years (mean = 35.8 & SD = 14), female 51%, married 79%	Tsunami-affected communities	PTSD, depression, and trauma-related psychiatric disorders	Harvard Trauma Questionnaire, DSM-IV	The prevalence of PTSD was 12.7% among the individuals that sought help from psychiatrists available during the study, 48.9% were diagnosed with major depressive disorder and 31.9% with PTSD.	PTSD symptoms were higher among individuals with no household income, women, and those injured during the tsunami	Fair (NIH Checklist)
Pollack et al. (2016)	Vietnam	2013	People living in central Vietnam coast	Quantitative: cross-sectional survey	Purposive random sampling. 1000 participants, female 56%, 18+ years, median age 42	Natural hazards e.g., typhoons, floods, landsides	Financial stress, depression, anxiety, PTSD, somatic syndrome,	Post-traumatic diagnostic scale (PDS), Chronic financial stress scale, PHQ-9, GAD - 7, Somatic-	Moderate to high levels of financial stress were reported by 30% (n=297), 22.7% (n=227) in one or more psychological health problems, and 22.1% (n=221) reported moderate	Age, gender, financial stress, and traumatic events were risk factors for all mental health problems. Education	Good (NIH Checklist)

					years, married 83%		alcohol dependence, self-perceived physical health	syndrome checklist -90-R, alcohol dependence (ICD 10), self-perceived physical health (SF-36)	to severe functional impairment. Financial stress was the strongest predictor of psychological health problems. Increased risk for psychological health problems with traumatic exposure to a major storm.	was a protective factor	
Rishi and Mudaliar (2014)	India	Not reported	People living in coastal cities of Mumbai, Chennai, Daman, and Pondicherry	Quantitative: correlational study	Multistage purposive sampling. 150 respondents, female 51%, age 18-45 years	Coastal hazards, e.g., flood, SLR, salinity, land inundation, storms, cyclones	Climate stress and emotional concerns, coping and adaptation, subjective well-being	Climate change perception inventory (CCPI), climate change awareness (CCA), climate stress and emotional concern (CSEC), coping/ Adaptation institutional accountability (IA), coastal subjective well-being (CSWB)	Results indicated a good level of climate change awareness and subjective wellbeing among coastal people. Respondents were found to be experiencing a moderate amount of climate stress and were unable to fully cope with stressors.	CSWB is predicted by emotional anxiety, resource stress and climate variability and IA (institutional accountability)	Fair (NIH Checklist)
Saha (2014)	Bangladesh	2010	South-western coastal residents of Bangladesh	Qualitative	Stratified sampling. 3 villages, 14 focus group discussion, 5 with young (18–30 years), 7 with adult (31–59 years),	Tropical cyclone Aila 2009	Psychological trauma, anxiety	Measurement scales were not reported	Aila survivors possessed anxiety and psychological trauma.	Extreme weather, hazard-prone location, insufficient public services, high salinity, damage of biodiversity, loss of human lives and animals, shattering livelihood options,	High (JBIQARI)

					2 with elderly (60+ years)					and damage of assets and infrastructures were considered as predominant factors of vulnerability	
Sharifuzzaman et al. (2018)	Bangladesh	2013 to 2014	Coastal fishing community of Hatiya Island	Mixed methods: cross-sectional survey	Cluster sampling. 18 villages, 360 participants involving in survey, 47 focus group discussion, 29 key informant, 18 field observations, female 25-30%	Vulnerable to tropical cyclones and storm surges	Resilience	Analytic hierarchy process (AHP), self-explored interviewed, measurement scales were not reported	Certain livelihood assets (e.g., ability to make decision on fish selling, social harmony) enhance resilience of fishing community to climate change by as much as 20–40%. moderate role in building resilience of other livelihood assets (e.g., education, embankment, credit).	Community resilience enhanced by livelihood assets (e.g., nets and boats ownership)	Medium (JBIQARI)
Uddin et al. (2020)	Bangladesh	2014 to 2015	Coastal community of Patuakhali	Mixed methods: cross-sectional survey	Stratified cluster sampling. 300 household heads interviewed, 8 focus group discussion, 20 key informant, 5 case studies	Cyclone and storm surge hazards	Community resilience attributes	Measurement scales were not reported	Coastal community resilience was significantly depended on economic base, occupations, and respective contexts of vulnerability.	Coastal community resilience was significantly depended on economic base, occupations, and respective contexts of vulnerability	Medium (JBIQARI)

2.5.2. *SLR and psychological distress*

Detrimental effects of SLR on psychological health were reported in 77% (10 out of 13) of the studies (refer to Table 2.2, Column 1). For example, Acosta et al. (2016) reported that typhoon-induced floods and landslides that affected the residents of Infanta and New Bataan in the Philippines have resulted in a range of negative psychological outcomes, including distress, anxiety, fear, loneliness, and loss of hope. Among the residents of East Malaita in the Solomon Islands, Asugeni et al. (2015) reported that perceptions of SLR affected worry among nearly all participants (98%). In a cross-sectional survey among 314 participants in the coastal fishing community of Tamil Nadu, Kumar et al. (2007) reported that PTSD, depression, and trauma-related psychiatric disorders were higher among the individuals who were affected by the loss of life and property following a tsunami.

Exposure to SLR (e.g., salinity, coastal flood) was related to psychological distress, depression, anxiety, and stress. For instance, in a cross-sectional survey among 1000 participants in central Vietnam coast, Pollack et al. (2016) found that moderate to high levels of stress were reported by 30% (n = 297), with 22.7% (n = 227) participants reporting one or more psychological health problems, and 22.1% (n = 221) participants reported moderate to severe functional impairment. They also stated that age, gender, financial stress, and traumatic events were the major risk factors for all psychological health problems and education was a protective factor.

Many studies (69%) indicated the role of SLR on people's lives through its negative impact on their livelihood options (Table 2.2, Column 2). In a qualitative study on the effects of tropical cyclone Aila in affected areas of Bangladesh, Saha (2014) found that salinity intrusion significantly led to loss of lives, and damage to biodiversity, livelihoods, assets, and infrastructure. Saha also noted that Aila survivors reported psychological trauma and anxiety. SLR-induced salinity was also associated with resource loss. For example, in a cross-sectional survey among 371 household heads in the southern coastal community of Bangladesh, Islam et al. (2020) reported that losses due to riverbank erosion was homestead land (55%), land (53%), homestead infrastructure (52%), scarcity of pure drinking

water (41%), crop (30%), and livestock (29%). They also stated that river erosion has increased poverty (70%), insecurity (64%), helplessness (63%), and psychological problems such as stress (71%).

Table 2.2

Summary of the Studies (n = 13)

Author (year)	Detrimental effect of SLR on psychological health	SLR-induced salinity impact on resource loss/livelihood options	SLR resulted in greater level of psychological distress among more vulnerable community
Acosta et al. (2016)	Yes	Yes	Yes
Asugeni et al. (2015)	Yes	Yes	
Frankenberg et al. (2008)	Yes	Yes	Yes
Gibson et al. (2019)	Yes		Yes
Guleria and Edward (2012)	Yes		Yes
Islam et al. (2020)	Yes	Yes	Yes
Kar et al. (2007)		Yes	Yes
Kumar et al. (2007)		Yes	Yes
Pollack et al. (2016)	Yes	Yes	Yes
Rishi and Mudaliar (2014)		Yes	Yes
Saha (2014)	Yes	Yes	Yes
Sharifuzzaman et al. (2018)	Yes		Yes
Uddin et al. (2020)	Yes		Yes

Most studies (92%) found that SLR resulted in greater level of loss among more vulnerable communities (Table 2.2, Column 3). For instance, in a cross-sectional survey among the seaside Jagatsinghpur residents of India, Kar et al. (2007) found that people inhabiting sea tide sweeping inland areas, thus more vulnerable, were more likely to experience post-traumatic stress disorder (PTSD). Children (43.7%) in more vulnerable areas reported significantly more PTSD than those (11.2%) in less vulnerable areas. In addition, high vulnerability as well as lower educational level were significantly associated with higher levels of PTSD in this population. In a longitudinal study among the respondents in coastal areas of Aceh and North Sumatra, Frankenberg et al. (2008) reported that posttraumatic stress reactivity (PTSR) scores were highest among respondents in areas damaged severely by tsunami, although PTSR scores declined over time. Furthermore, in this

population, the proximity to the coastline, exposure to traumatic events, female gender, younger age, loss of family and friends, and loss or damage of property was significantly associated with high PTSR scores.

2.6. Discussion

This review synthesized evidence across coastal populations in the Asia-Pacific region and demonstrated an association between the environmental impacts of sea-level rise and psychological health difficulties. Specifically, the findings indicate potential for sea-level rise to cause or exacerbate distress, depression, anxiety, and stress through resource loss as depicted in Figure 2.1.

In relation to this review's first objective, the association between sea-level rise and psychological distress was reported in 77% of the studies reviewed. These findings were obtained in studies conducted in seven Asia-Pacific countries (Bangladesh, India, Indonesia, Philippines, Solomon Islands, Tuvalu, and Vietnam) examining different ways in which SLR affects psychological health. For example, exposure to SLR was assessed through coastline proximity, typhoon-induced flood, landslides, and psychological health was assessed as distress, depression, anxiety, and stress. The current findings synthesize and highlight a growing body of evidence that demonstrates a clear link between sea-level rise resulting from climate change, and psychological distress among coastal communities. For instance, it was found that coastline proximity, kin loss, and property damage were significantly associated with distress, depression, and trauma and that women reported significantly higher scores than did men (Frankenberg et al., 2008).

Addressing the review's second objective, it was identified that risk and resilience factors associated with psychological distress in coastal communities. Specifically, consistent with Figure 1, a large majority (69%) of the studies indicated adverse impacts of sea-level rise through reductions in livelihood options (Asugeni et al., 2015; Islam et al., 2020; Saha, 2017). The findings specified that environmental stressors (e.g., salinity, flooding) affect resource loss, such as reductions in agricultural products (e.g., crop yields), destruction of properties, and erosion of land and indirectly impact food,

water, and income security (Frankenberg et al., 2008; Kar et al., 2007; Kumar et al., 2007). These impacts may vary between communities as well as at the individual level (Gibson et al., 2019; Islam et al., 2020; Sharifuzzaman et al., 2018; Uddin et al., 2020). In vulnerable communities that have a greater resource loss due to the ongoing effects of sea-level rise, people whose livelihoods are heavily tied to natural resources (such as fishing and farming) are at elevated risk (Clayton et al., 2017; Hime et al., 2018). Resource loss thus exacerbates levels of psychological distress, depression, stress, and anxiety (Acosta et al., 2016; Frankenberg et al., 2008; Gibson et al., 2019; Islam et al., 2020) providing further evidence to support the Conservation of Resources Theory (Hobfoll, 1989, 2012).

In addition to these findings that pertain to two aims of the study, this review also found elevated levels of loss in more vulnerable communities. Characteristics of vulnerable communities included exposure to sea-level rise (e.g., salinity), lower educational levels, and lower socioeconomic status, and these factors predicted depression across studies reviewed conducted in Bangladesh, India, Indonesia, Philippines, Tuvalu, and Vietnam. This review also identified that depression was associated with age, occupation, income, and loss of life and property. For example, a moderate level of climate-induced anxiety was reported due to resource loss, and significant gender differences were found with women reporting higher anxiety than men (Rishi & Mudaliar, 2014). Individuals living in hazard-prone areas possess higher anxiety, and financial stress was the strongest predictor (Pollack et al., 2016; Searle & Gow, 2010). Salinity-induced resource loss creates anxiety among coastal communities (Saha, 2014). Resource loss (e.g., loss of life, property) is causing psychological distress, anxiety, and fear among hazard-stricken people in coastal areas (Acosta et al., 2016).

2.7. Implications and research gaps

The findings of this review are relevant to the five major priority areas for Health EDRM (health emergency and hazard risk management) identified by the World Health Organization Thematic Platform Research Network: psychological health data management, community risk management, psychosocial management, research methods and ethics, and health workforce development (Kayano

et al., 2019; Lo et al., 2017; Oktari et al., 2022). These priority areas support the World Association for Hazard and Emergency Medicine (Kayano et al., 2019) and the Asia-Pacific Hazard Mental Health Network's requests for psychological health-specific hazard risk management (Newnham, Dzidic, et al., 2020). When climate change increases the likelihood of environmental dangers, government policy and funding to address psychological health concerns in coastal areas of Asia-Pacific most exposed to sea-level rise will be crucial.

A unique contribution of the current systematic review is that it synthesized evidence from the literature that environmental stressors of sea-level rise in coastal areas included salinity intrusion, coastal flooding, and threats to agricultural productivity and its detrimental impacts on psychological health experienced as psychological distress, stress, anxiety, and depressive symptoms. It explores the association between sea-level rise and psychological health among coastal communities in the Asia-Pacific region which recommended by APCMHD (Asia-Pacific Community Mental Health Development) project (Ng et al., 2009). This review is also helpful for policymakers to make a long-term plan of local and national psychological health services to ensure sustainable and effective programs for future SLR hazard management. Furthermore, this study also identified risk and resilience factors associated with psychological distress in the coastal communities that can be targeted for policy and clinical intervention in response to the Sendai Framework for Hazard Risk Reduction 2015-2030 (Kayano et al., 2019).

The negative consequences of climate change, such as sea-level rise, which have been threatening human health, is gaining increased attention both in public and academic arenas (Berry et al., 2018; Brennan et al., 2022; Gibson et al., 2019). Empirical research on the psychological health of individuals living in coastal communities, likely to be the most affected by SLR, is nascent (Berry et al., 2018; Evans, 2019) and evidence of the relationship between environmental stressors of sea-level rise and psychological health has not been synthesized. The current systematic review addresses a significant gap in the body of knowledge on psychological health associated with sea-level rise in

relation to the growing threat of climate change. Although many researchers recommend empirical work in this space, as diverse communities must increasingly contend with myriad challenges associated with climate change (Berry et al., 2018; Brennan et al., 2022; Evans, 2019). Identifying individuals or communities at risk of psychological distress, depression, and anxiety due to sea-level rise would be of paramount importance to devise targeted interventions. Thus, further research is needed for contributing to the body of knowledge on psychological health associated with SLR in relation to the growing threat of climate change.

2.8. Limitations

Several limitations should be noted. Primarily, the focus was limited to the Asia-Pacific region, which excluded potentially relevant data from other regions, vulnerable to SLR. This geographical limitation highlights specific policy targets for the Asia Pacific region, butt limits the development of a comprehensive global perspective. Moreover, the study considered only articles written in English, possibly leaving out important findings reported in other languages, especially in regions where English isn't the primary language.

Additionally, the review only included peer-reviewed articles and excluded unpublished studies, creating potential for publication bias. The focus of the review was narrow, overlooking studies that did not explicitly link sea-level rise to psychological health and resilience, or those using non-validated symptom-based measures. This could possibly exclude relevant indirect effects. Furthermore, the review did not include a systematic bias assessment for the association between sea-level rise and psychological health effects. This could limit the reliability of the conclusions drawn from the review. These limitations should be considered in the future research to provide more inclusive and comprehensive insights.

2.9. Conclusion

This review highlights direct association between sea-level rise and psychological health among coastal communities in the Asia-Pacific region. The environmental effects of SLR on coastal areas included salinity intrusion, coastal flooding, and threats to agricultural productivity, which in turn had detrimental impacts on psychological health experienced as psychological distress, stress, anxiety, and depressive symptoms. SLR-induced salinity was associated with many types of resource loss which directly or indirectly impacted psychological health. Future research should investigate individual and community levels instead of being restricted to the investigation of associations between adverse exposures and psychological health problems that can be targeted in policy and clinical intervention.

CHAPTER THREE: CROSS-SECTIONAL SURVEY

Association between sea-level rise and psychological distress among coastal communities: A quantitative survey and conditional process analysis

3.1. Abstract

Climate change-induced sea-level rise (SLR) has significant effects on salinity ingress, flood risk, and agricultural damage with critical implications for population health and livelihoods. This is the first large-scale quantitative investigation of SLR-induced environmental stressors on psychological health in coastal communities. A total of 1200 participants were randomly selected and surveyed across coastal communities in Bangladesh. In each of the three communities assessed as having high, moderate, or low environmental vulnerability status, 400 (50% female, ages 18+ years) were interviewed during the pre-monsoon season (March to April 2021). Respondents' psychological distress, depression, anxiety, stress, environmental stressors, resource loss, and demographic information were collected. Coastal community members of areas highly vulnerable to sea-level rise were more psychologically distressed than people living in moderately or lower vulnerable coastal communities. A similar pattern was evident for depression, anxiety, and stress. The effect of environmental stressors on psychological health measures was mediated by resource loss. Older people and women were more affected by environmental stressors. Consistent with the focus on psychosocial support in the Sendai Framework for Hazard Risk Reduction, the findings of this study call for persistent attention to psychological health needs, and accessible services in communities facing rising sea levels.

3.2. Introduction

Sea-level rise (SLR) is a critical indicator of climate change, with significant implications for planetary and human health. It is now widely agreed that climate change is a major risk factor for poor psychological well-being in areas exposed to rapid environmental deterioration (Rakib, Sasaki, Pal, et al., 2019). The most detrimental psychological health impacts are predicted to occur among those communities whose livelihoods are heavily tied to natural resources (Clayton et al., 2017;

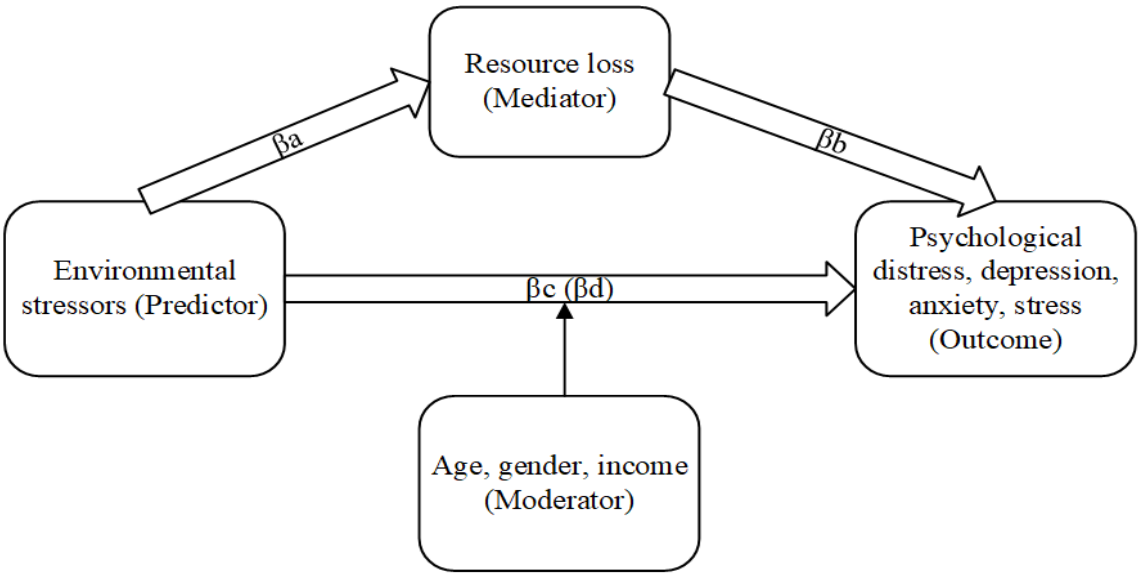
Gibson et al., 2019). In particular, coastal communities that rely on natural resources for sustenance and livelihoods; located in areas most susceptible to climate change induced SLR, are at elevated risk (Hime et al., 2018).

In the 1990s, globally, the sea level rose at a rate of 2.5 mm per year, while at present the level is approximately 3.4 mm per year (IPCC, 2022). SLR of 26 to 77 cm is estimated by 2100 due to an accelerating rate of climate (IPCC, 2022). The livelihoods of nearly 600 million people who live in low-lying coastal zones worldwide may be affected (IPCC, 2022). This is particularly important for Asia's coastal areas where large populations live in mega-deltas, such as the low-lying sedimentary landforms at river estuaries of the Ganges-Brahmaputra (IPCC, 2022).

Environmental stressors resulting from SLR such as salinity ingress, coastal flooding, and agricultural damage have negative impacts on people's lives by reducing their livelihood options (Ahmed et al., 2019). For example, salinity intrusion has a cascading effect on health and livelihoods among the coastal populations that are highly exposed to saline-contaminated water through drinking and cooking (Rakib, Sasaki, Matsuda, et al., 2019). Among communities exposed to flooding, people affected by flood water in their homes and agricultural lands experience a reduction in their livelihoods through resource loss (Yanda et al., 2018). Agricultural damage resulting from SLR includes a reduction in crop yields; destruction of properties and infrastructure, and erosion of land (Cunsolo & Ellis, 2018; Yanda et al., 2018). Indirect impacts can include changes to food, water, and income security that may have the potential to weaken the social fabric and health status of communities (Cunsolo & Ellis, 2018; Ellis & Albrecht, 2017). These impacts may vary at the community level as well as at the individual level (Ahmed et al., 2019; Sattler et al., 2018). Communities that have greater levels of loss related to the ongoing effects of SLR, and people whose livelihoods are heavily tied to natural resources (through fishing and farming) are at elevated risk (Clayton et al., 2017; Hime et al., 2018).

Figure 3.1

A Model of the Association Between Environmental Stressors and Psychological Distress, Mediated by Resource Loss and Moderated by Age, Gender and Income



where βa = Beta coefficient of the predictor → mediator, βb is beta for mediator → outcome, βc is coefficient for predictor when mediator is in equation, and βd is coefficient for predictor when mediator has not been entered.

This study model postulates that a loss of resources is a mechanism through which the risk of environmental stressors affects psychological distress (refer to Figure 3.1) (Munro et al., 2017; Zahlawi et al., 2019). The conceptual model of this study incorporates elements from the Conservation of Resources (COR) theory, which proffers that the environmental threat to or actual resource loss, or a failure to gain resources, can engender psychological distress (Hobfoll, 2012). Resources, in this context, encompass tangible and intangible assets of personal, social, or economic value, the threat of loss which can lead to increased stress and distress. This theory has been corroborated in numerous contexts. For instance, Freedy et al. (1994) applied the tenets of the COR theory following Hurricane Hugo, establishing a strong positive relationship between resource loss and psychological distress, more potent than the influence of demographic characteristics or coping strategies. A similar thread was observed by Rudolphi et al. (2020), in their study involving farmers and ranchers in the Midwest USA, where resource loss was significantly associated with symptoms of anxiety and depression. Adding to this body of knowledge, this study extends implications of the COR theory within the specific context of sea-level rise. As SLR threatens the livelihoods and

physical infrastructures in coastal communities, it is postulated that it leads to an escalating cycle of resource loss, in turn inducing increased psychological distress.

This research further posits that the psychological impact of such environmental stressors is not uniform across all demographic segments but is modulated by factors such as income level, gender, and age. The model suggests that particularly vulnerable groups - older adults, women, and individuals from lower socioeconomic backgrounds - may bear a disproportionate brunt of the psychological distress associated with SLR. Support for this assertion comes from multiple sources; for example, Kumar et al. (2007) reported higher incidences of depression and trauma-related disorders among individuals who experienced income loss following a tsunami. Literature also indicates that hazards and climate change perpetuate gender inequalities and create security, health, and livelihood risks for women and girls, with significant psychological health implications (Shahjalal, 2021). Likewise, older individuals may be more vulnerable due to issues related to reduced mobility, dependence on caregivers and health support, and limited capacity for evacuation (Berry et al., 2018; DeVito et al., 2018). Therefore, this research takes the COR theory as a conceptual tool to understand the psychological distress that can arise from SLR, and the differential impacts based on socio-demographic factors, offering a nuanced and comprehensive understanding of the psychological health implications of SLR in the era of escalating climate change.

While SLR affects people globally, the Asia-Pacific region is particularly vulnerable to its adverse effects, where more than half (56%) of the world's seven billion population and nearly two-thirds of the world's poor live (IPCC, 2022). In 2021, Asia accounted for 40% of global hazard events and 66% of the total number of people affected (IPCC, 2022).

SLR is a pressing and alarming issue for Bangladesh due to its geographical setting, high incidence of poverty, and high dependence on agriculture (Rakib, Sasaki, Pal, et al., 2019). Approximately 53% of the coastal region in Bangladesh is currently affected by salinity, largely the product of climate induced SLR (Rakib, Sasaki, Matsuda, et al., 2019). Almost every year, natural hazards cause the loss

of lives, immense property damage and jeopardize development activities along the coastal zone (Rakib, Sasaki, Matsuda, et al., 2019; Rakib, Sasaki, Pal, et al., 2019). The coastal populations are at extreme risk of health hazards, including exacerbation of existing psychological health risks and suffering (Rakib, Sasaki, Pal, et al., 2019). Therefore, Bangladesh provides an important setting for investigating the current model to understand the impacts of SLR on psychological distress.

3.3. Aim and hypotheses

The aim of this work was to examine the effect of SLR-induced environmental stressors on psychological distress, the mediating role of resource loss, and moderating roles of income, gender, and age (Figure 3.1). Specifically, this study examined the following processes and mechanisms. First, people of the coastal communities who live in areas most susceptible to SLR and rely greatly on natural resources for sustenance and livelihoods would report higher levels of psychological distress than those living further from the coast. Second, environmental stressors result in the loss of resources, which increases the risk of psychological distress, depression, anxiety, and stress. Third, the most detrimental psychological health impacts are predicted to occur among residents of the coastal communities with lower income, women, and older adults.

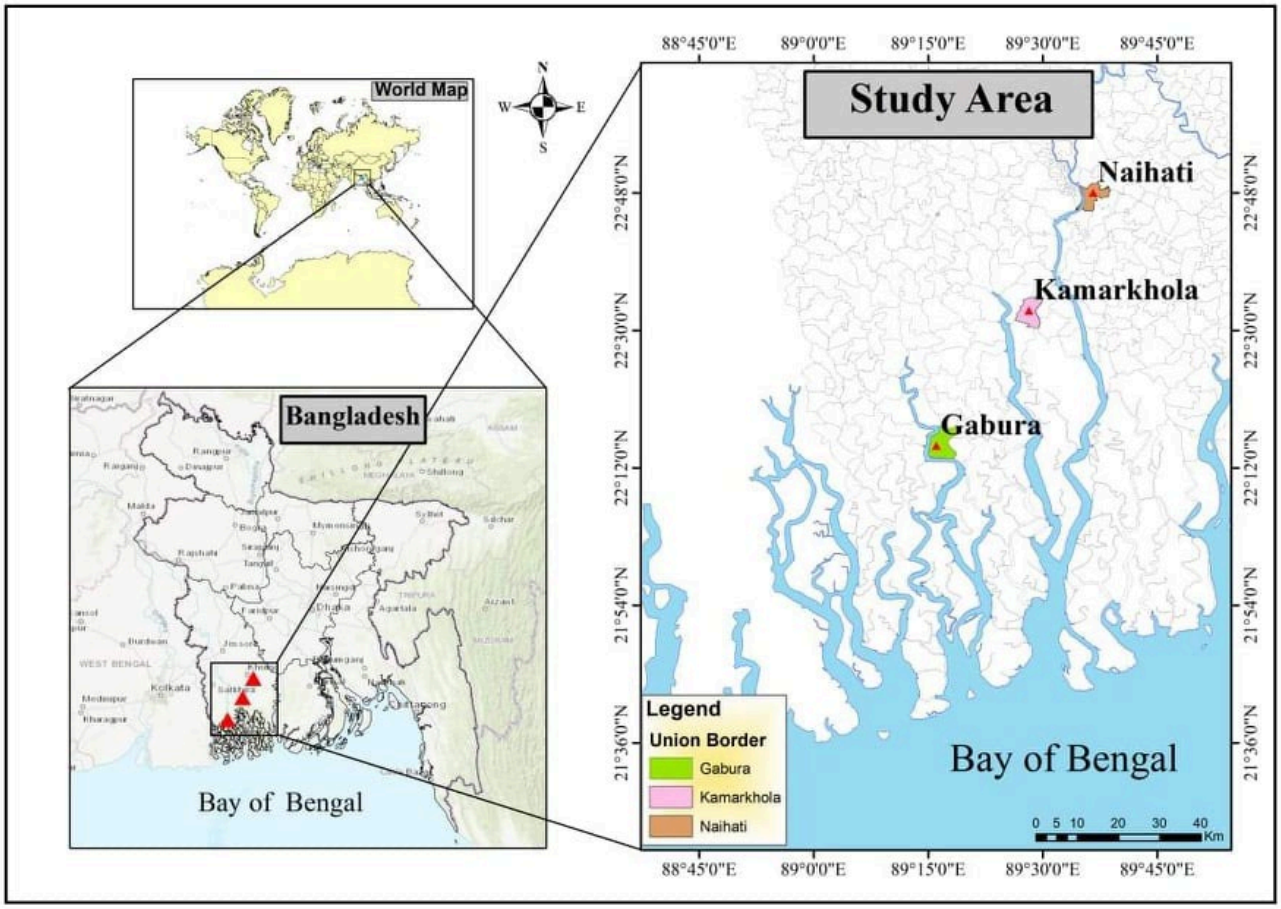
3.4. Methods

3.4.1. *Target population*

Participants were recruited from coastal communities of two districts in southwest Bangladesh, namely Satkhira and Khulna. SLR is a pressing issue in these areas due to their geographical setting, high incidence of poverty, and heavy reliance on agriculture (Rahman et al., 2018). Almost every year, immense loss of property is a common phenomenon in these localities due to the incidence of socio-natural hazards (e.g., salinity intrusion, coastal flooding), which jeopardize people's livelihoods (Pearce et al., 2018). Data were collected through surveys with individuals recruited via random sampling within selected high, moderate, and low vulnerable coastal communities (Figure 3.2).

Figure 3.2

Sampling Location in Southwest Bangladesh



3.4.2. *Sampling*

Gabura (60 km from the existing coastline), Kamarkhola (93 km), and Naihati (120 km) were three coastal communities with high, moderate, and low level of vulnerability respectively, based on a recent Bangladesh Bureau of Statistics report (BBS, 2019b) (Figure 3.2). The BBS determines environmental vulnerability via hazard-related statistics (e.g., flood, coastal erosion, salinity intrusion) and an economic vulnerability index (e.g., crops, livestock, poultries, fisheries, and homestead forestry). The classification was further supported by information on hazard-prone areas of Bangladesh from a geographic information system (GIS), which indicated the communities' (i.e., Gabura, Kamarkhola) geographical positions would place them at a high risk of salinity ingress, coastal flooding and agricultural damage associated with frequent cyclones (Shammi et al., 2019).

Table 3.1

Demographic Attributes of Selected Areas

Demographic variable	**Gabura union** (Highly vulnerable)	**Kamarkhola union** (Moderate vulnerable)	**Naihati union** (Low vulnerable)
Total population	38825	15407	78870
Gender	Male 50%, female 50%	Male 52%, female 48%	Male 50%, female 50%
Age	Child 34%, adult (18+ years) 64%, aging (70+ years) 2%	Child 35%, adult (18+ years) 62%, aging (70+ years) 3%	Child 32%, adult (18+ years) 64%, aging (70+ years) 4%
Religion	Muslim 94%, Hindu 4%, and others 2%	Muslim 42%, Hindu 55%, Buddhist 2%, and others 1%	Muslim 84%, Hindu 15%, and others 1%
Education (literacy rate)	36%; male 39%, female 33%	47%; male 54%, female 39%	55%; male 58%, female 51%
Occupation	Crab fattening, shrimp farming, farming, fishing, wage labor, and small trades	Farming, fishing, wage labor, small trades	Farming, fishing, service, wage labor
Source of income	Agriculture 65%, non-agricultural labourer 6%, commerce 15%, service 4%	Agriculture 66%, non-agricultural labourer 5%, commerce 13%, service 4%	Agriculture 25%, non-agricultural labourer 17%, commerce 21%, service 14%
Socio-economic conditions	75% below poverty line	30% below poverty line	29% below poverty line

Source: Bangladesh Bureau of Statistics (BBS, updated in February 2022) and Bangladesh National Information Window (Bangladesh Govt. updated in August 2022). Union is the smallest administration unit in Bangladesh.

Gabura is considered the most vulnerable community because of its proximity to the Bay of Bengal and ongoing effects of SLR (BBS, 2019b; Shammi et al., 2019). Floods, tidal surges, high level of salinity, land erosion, and periodic waterlogging are common in Gabura (Abedin et al., 2012). With

6,753 households and 33 km^2 in size, the main livelihood activities of the people are farming, fishing, petty trading, forest resource collection, and wage laboring (BBS, 2019b; NGF, 2019).

Salinity ingress, coastal flooding, and agricultural damage in Kamarkhola and Naihati are considered moderate and low, respectively, compared with Gabura in terms of poverty and socioeconomic status (BBS, 2019b; NGF, 2019). Like Gabura, the main livelihood activities in both locations are farming, fishing, and wage labor (BBS, 2019b; NGF, 2019). Table 3.1 presents the demographic attributes of the three communities.

3.4.3. *Data collection*

The sampling strategy employed in this study was designed to support the research objectives and ensure statistical validity. It was guided by demographic characteristics of the target population and involved recruitment of 10% of the population from each village under study, a decision supported by Pollack et al. (2016). The selected sample size of 100 per village, or a total of 400 participants across all three communities (Figure 3.3), exceeds 10% of the population in these areas, ensuring a robust degree of representation.

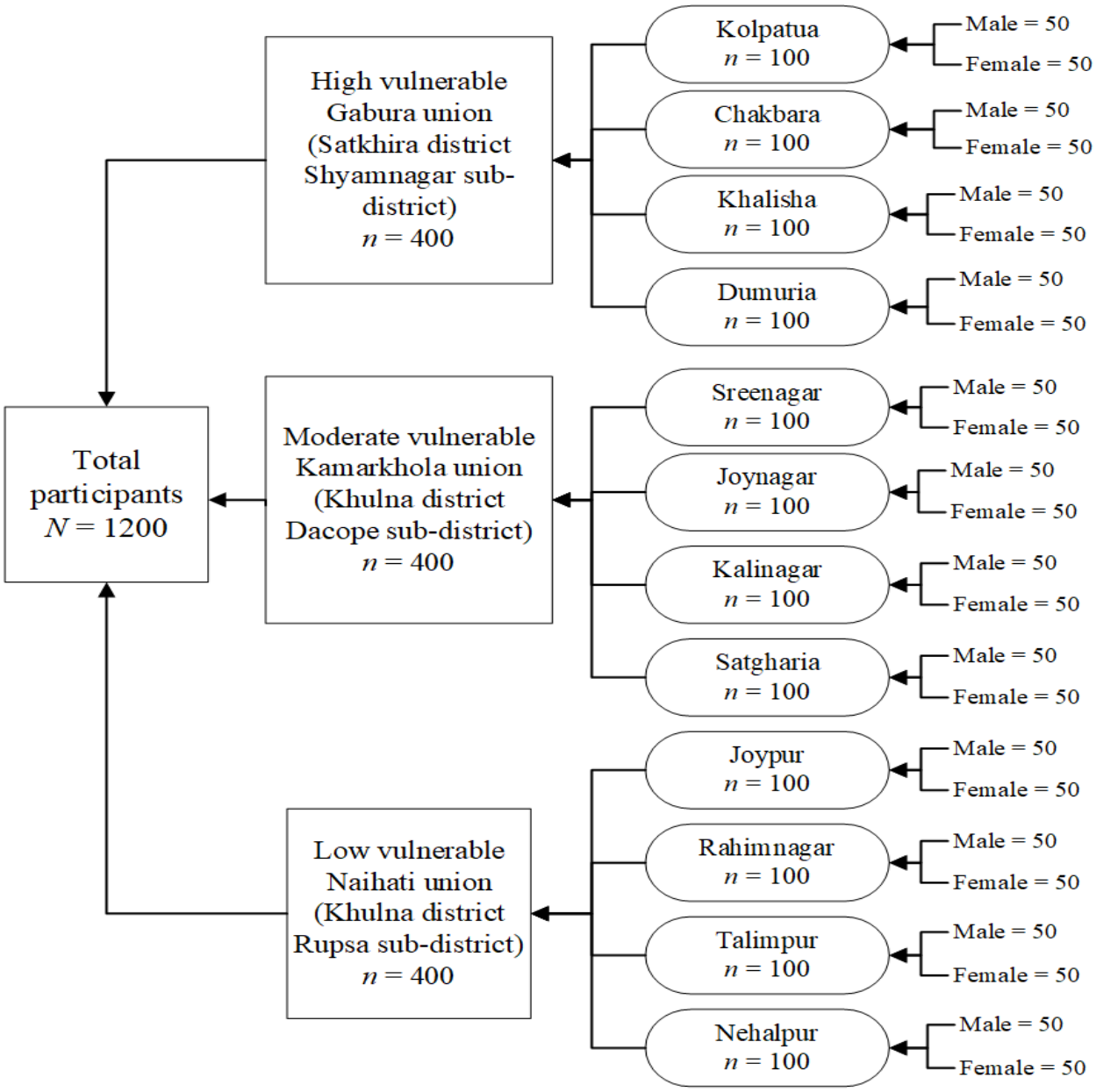
The sampling process started with a purposive approach, identifying specific villages for research focus. The selected communities for data collection were Gabura, Kamarkhola, and Naihati, with an aim to recruit an equal number of participants, split evenly by gender, from each (Figure 3.3). This gender-balanced approach ensured an adequate representation of both male and female perspectives in the research data. After purposive identification of these villages, a randomized selection procedure was employed within the pre-selected pool of potential respondents. An up-to-date voter list from each village, accessible for research purposes from Election Commission, was used to randomly select participants. From 1224 individuals invited to partake in the survey, 24 opted out, resulting in a final participant count of 1200.

Strict adherence to data protection principles was maintained, with all voter information kept confidential and securely stored during the data collection process. Upon completion of data collection, all personal information was destroyed to further protect participant privacy.

Data collection occurred during the pre-monsoon season, specifically from March 6, 2021, to April 5, 2021. Six field assistants were employed to facilitate efficient and effective data collection.

Figure 3.3

Sample Size of the Study



The data collection for this study was performed under the supervision of an expert with extensive familiarity with Bangladesh's coastal communities. This specialist's role was pivotal in facilitating

the process, providing valuable insights into local customs and practices. Ethical approval was sought and received from both Curtin University's Human Research Ethics Committee (HRE2020-0645) and Dhaka University Research Ethics Committee (Ref. No. 109/Biol. Scs.), ensuring the process adhered to globally recognized ethical standards.

Prior to the initiation of data collection, field assistants from the target communities were rigorously trained by the primary researcher. The training encompassed an overview of the study's objectives and methodology, data handling procedures, risk assessment, and ethical considerations. To ensure the effectiveness of the training, a small pilot survey (n = 6) was carried out. Once participants were randomly selected from the voter list, the assistants reached out to them via phone calls to schedule survey appointments and collect written informed consent.

The survey was carried out at locations of the participants' choosing, such as their homes, workplaces, or communal spaces. The questionnaire, which was made available only in Bengali and in paper format, took approximately 40-45 minutes to complete. The survey process involved a research assistant who asked the questions and filled out the survey. To ensure data integrity, participants were reminded of the importance of providing honest and comprehensive responses. Furthermore, acquired data were thoroughly reviewed for inconsistencies or irregularities, thus ensuring reliability and validity of the study's findings.

3.4.4. Measures

3.4.4.1. Psychological Distress Scale (PDS)

The Kessler Psychological Distress Scale (PDS), known as K10, is a commonly used tool in epidemiological surveys for capturing psychological distress (Islam, 2019; Kessler et al., 2002; Khan et al., 2019). The K10 was adapted to the Bengali language through a comprehensive translation process (TMHC, 2012), ensuring both cultural and linguistic appropriateness (Ethnologue, 2018; Khan et al., 2019; Uddin et al., 2018). Its validity and reliability were proven in a previous study conducted in Dhaka, showing an acceptable internal consistency (alpha = .88) and test-retest

reliability (.82) (Khan et al., 2019). The scale uses a five-point Likert scale, using the response options ranging from 5 (all of the time) to 1 (none of the time). This scale contains fourteen questions, the first ten questions ask about how you have been feeling in the last four weeks, for example "In the last four weeks, about how often did you feel tired out for no good reason?" A total summed score was used in the analyses, with high scores indicating higher levels of distress.

3.4.4.2. Depression Anxiety Stress Scale (DASS-21)

The Bengali version of the DASS-21 was administered in this study, a scale well-validated within the Bangladeshi population (Alim et al., 2017; Sadiq et al., 2019; Sarkar et al., 2018). This scale consists of three subscales (Depression, Anxiety, and Stress), each containing seven items. Each of the three DASS-21 subscales contains seven items, the depression subscale measures devaluation of self, devaluation of life, anhedonia, lack of interest, dysphoria, and feelings of hopelessness (e.g., I couldn't seem to experience any positive feeling at all). The anxiety subscale assesses anxious affect, situational anxiety, and physical arousal (e.g., I was aware of dryness of my mouth), and the stress subscale extracts presence of a chronic non-specific arousal (e.g., I found it hard to wind down). The internal consistency of the subscales in this study was high, with alpha values of .99 for Depression, .96 for Anxiety, and .97 for Stress. Each item is rated on a four-point Likert scale, using the response options as indicating 0 (didn't apply at all) to 3 (apply most of the time). Subscale scores were used in the analyses, and higher scores indicate greater symptom severity.

3.4.4.3. Environmental Stressor Scale (ESS)

The ESS was specifically designed for this study, drawing items from previous studies (Hahn et al., 2009). This new scale includes twelve items that represent various environmental stressors related to sea-level rise, such as coastal flooding and salinity intrusion. Each item is rated on a scale of 0 (not at all) to 4 (all the time), and the total score provides an indication of the degree of environmental stress experienced by the participant. To ensure local contextual relevance, the ESS underwent a rigorous forward and backward translation process into Bengali. Furthermore, the scale's internal

consistency reliability was confirmed with Cronbach's alpha coefficients, all surpassing the universally accepted benchmark of 0.7, which substantiates the ESS's reliability and validity within this research framework.

3.4.4.4. Resource Loss Scale (RLS)

The Resource Loss Scale (RLS), a 35-item scale initially conceptualised by Hobfoll (1989) and further refined in subsequent epidemiological studies (Hobfoll et al., 2015; Sattler et al., 2018). This instrument, adapted to incorporate elements from the "Resources Questionnaire Scale" of Sattler et al. (2018) and the "Livelihood Security Model" of Mutahara et al. (2016), measures five domains of resource loss attributable to sea level rise induced environmental stressors: condition resources, basic object resources, object resources, energy resources, and personal characteristic resources. Given the cultural and contextual nuances of Bangladesh, the RLS was subjected to a rigorous pilot study to ascertain its appropriateness for the local context. This process included a thorough forward and backward translation to maintain linguistic precision. Utilising a five-point Likert scale (0 indicating no loss and 4 indicating extensive loss), cumulative scores provide an overall measure of resource loss, with higher scores denoting more pronounced loss. The RLS underwent a comprehensive validation process to ascertain its reliability and validity within this specific research paradigm. An exploratory factor analysis was conducted to confirm the construct validity of the scale. The internal consistency reliability of the RLS was established through Cronbach's alpha coefficients, all exceeding the widely accepted cut-off point of 0.7, thereby substantiating the scale's reliability and validity within the context of this research.

3.4.4.5. Demographic attributes

In addition, demographic information, specifically age, gender, religion, marital status, dependent family member (if any), occupation, annual household income, and education level were obtained. Age and number of dependent family member were asked in an open-ended format. All other demographic variables were asked by presenting participants with a set of options. These variables

were gender (male, female, other, and prefer not to say), religion (Islam, Hindu, Buddhist, Christian, and other), marital status (single - never married, married, widowed, divorced, separated, and other), education (primary, secondary, higher secondary, bachelor, masters, and other), occupation (fishing, farming, wage labour, petty trader, household worker, and other), household annual income (low income - below BDT 120k, lower-middle - BDT 121k to BDT 360k, middle - BDT 361k to BDT 600k, and upper-middle - over BDT 601k).

Income sources was also measured, by asking participants to indicate income from agricultural sources (i.e., field crops, shrimp firming/fish cultivation, fruits/ vegetables, poultry rearing, cattle rearing, and others), non-agricultural sources (viz., service, business, sewing works, cottage industries, labour wages, remittance from abroad), and other sources (e.g., mangrove forest). The subjective socioeconomic status was assessed within a community and country by using MacArthur SSS Scale (Giatti et al., 2012). In the community ladder, at the top of the ladder were people who had the highest standing and at the bottom who had the lowest standing in their community. Similarly, the country ladder as representing where people stand in Bangladesh, at the top of the ladder were the people who were the best off - those who had the most money, the most education, and the most respected jobs. At the bottom were the people who were the worst off - those who had the least money, least education, the least respected jobs, or no job (Bullock & Limbert, 2003; Curhan et al., 2014).

3.4.5. *Data analysis*

As the dataset had a hierarchical structure where individuals were nested within their villages, this study utilized a multilevel mixed-effects model with random intercepts for the analyses. In this two-tier model, individuals are considered at level 1 and their corresponding villages at level 2, thereby accommodating the structure of the data suitably. Three principal analyses were carried out. The first investigated whether the levels of psychological distress, depression, anxiety, and stress differed significantly across communities marked as low, moderate, or high vulnerability. In this exploration, demographic variations were controlled to provide insights into the psychological impacts of

environmental stressors across different vulnerability contexts. The second analysis probed the role of resource loss as a mediator (refer to Figure 3.1) in the relationship between environmental stressors and psychological health outcomes. The aim here was to understand the indirect effects environmental stressors can have on psychological health via the conduit of resource loss. In the third analysis, the focus was on determining whether age, gender, and income moderated (refer to Figure 3.1) the effects of environmental stressors on psychological health outcomes, thereby allowing for a nuanced understanding of how demographic characteristics interact with environmental stressors to influence psychological health.

While these analyses accounted for potential data clustering within villages, using cross-sectional mediation effects for this study comes with certain limitations. These include the inability of cross-sectional studies to establish causal relationships due to simultaneous data collection, making it unclear whether the independent variable is the cause of changes in the dependent variable, or if the mediator variable has had an influence over time. Moreover, the method runs the risk of reverse causality, where individuals already experiencing psychological distress might perceive their environment as more stressful or report greater resource loss. Also, multilevel models can present statistical challenges such as multicollinearity and convergence difficulties owing to the complexity of the hierarchical data structure. Therefore, the results would be interpreted with these limitations in mind. Despite these drawbacks, cross-sectional mediation effects offer valuable initial insights into the psychological health impacts of environmental stressors among individuals in these coastal communities and can pave the way for more comprehensive, longitudinal research.

3.5. Results

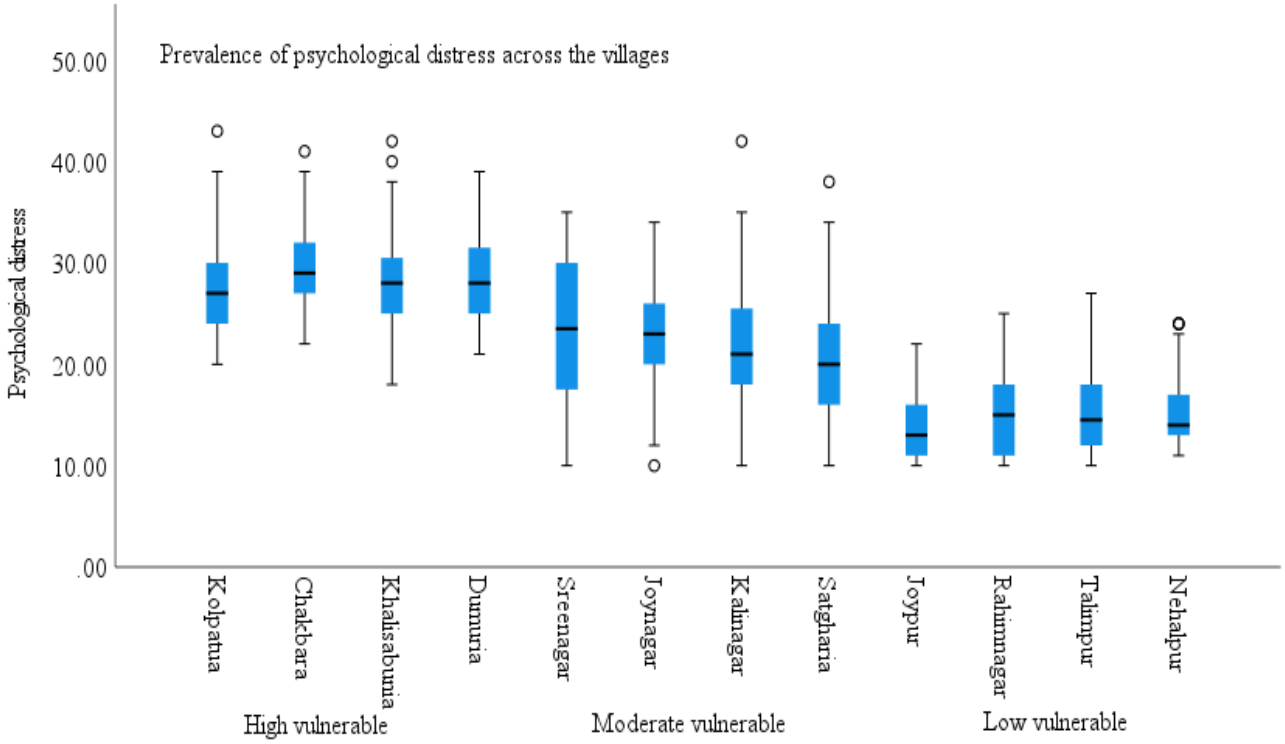
3.5.1. *Environmental vulnerability and psychological distress*

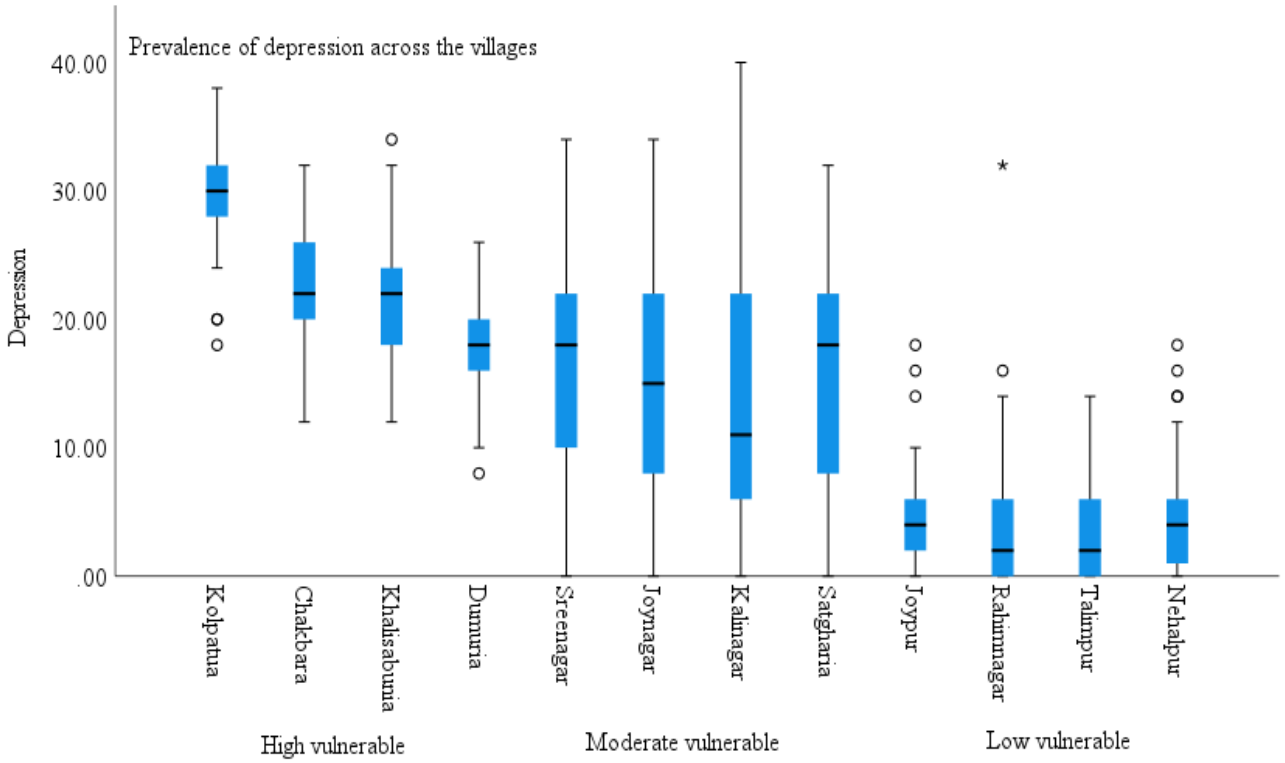
The first hypothesis of this study was that people living in more vulnerable coastal communities have a higher prevalence of psychological distress (PD), depression, anxiety, and stress. Figure 3.4 illustrates the difference in prevalence of psychological health, environmental stressor, and resource loss across the coastal communities of low, moderate, and high vulnerability. The prevalence of PD was the highest in a highly vulnerable coastal area of the Chakbara village (M = 29.730, SD = 4.015) and the lowest in a low vulnerable coastal area of the Joypur village (M = 13.800, SD = 3.012). Depression, anxiety, and stress symptoms followed similar patterns (Figure 3.4).

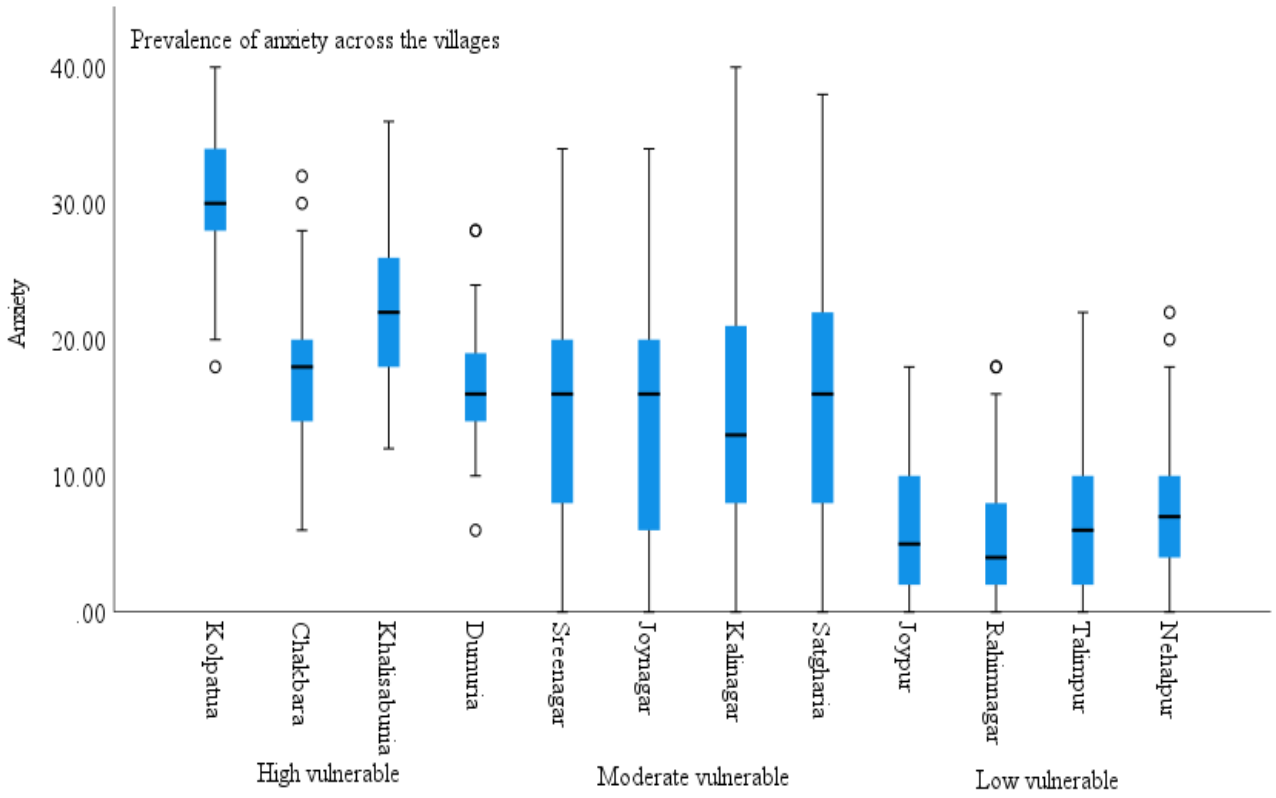
Table 3.2 summarizes the results from the multilevel mixed-effects model. Separately psychological distress, depression, anxiety, and stress were examined as the outcome variables using community vulnerability as the predictor variable.

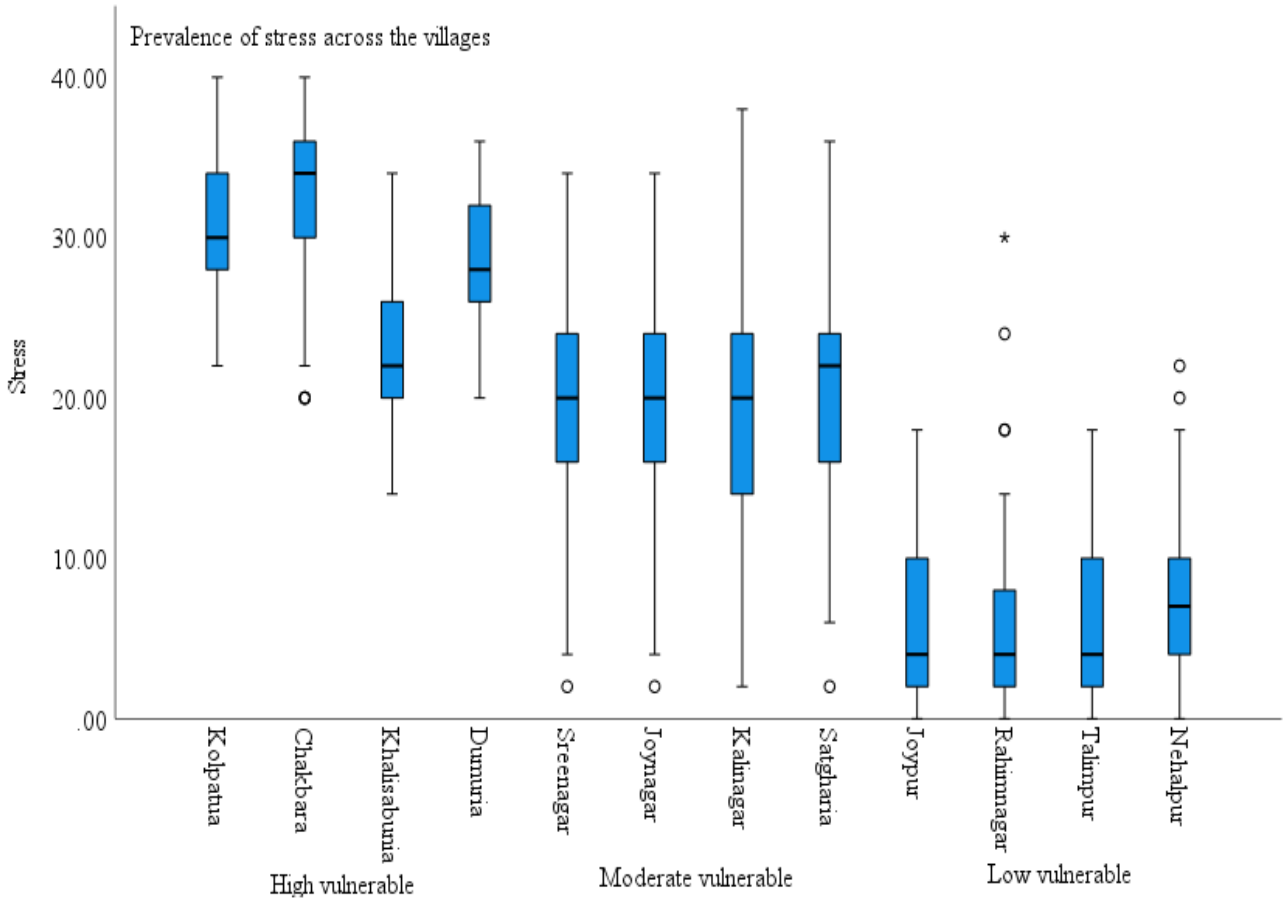
Figure 3.4

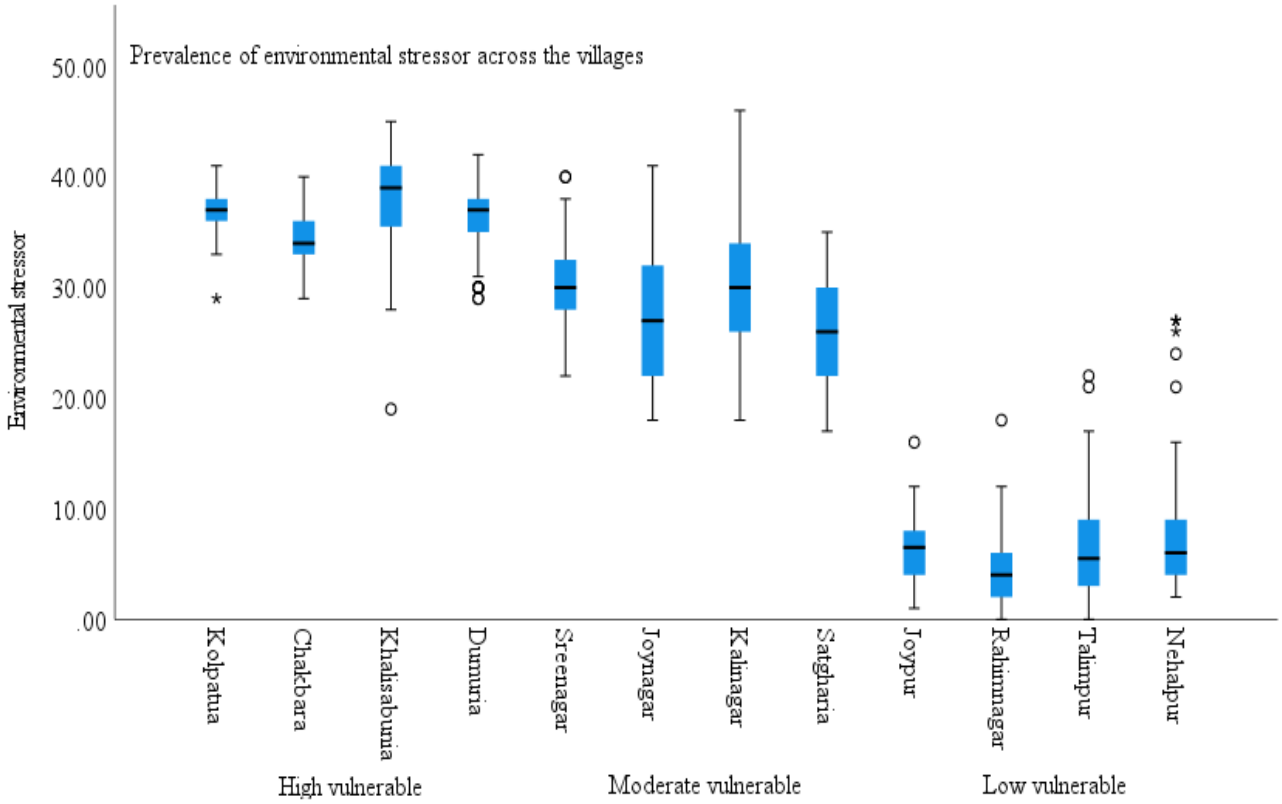
Psychological Distress, Depression, Anxiety, Stress, Environmental Stressor, and Resource Loss across Coastal Community-Level Geographical Vulnerability in Bangladesh (n = 1200)






Prevalence of anxiety across the villages
Anxiety
40.00
30.00
20.00
10.00
.00
Kolpatua
Chakbara
Khalisabunia
Dumuria
Sreenagar
Joynagar
Kalinagar
Satgharia
Joypur
Rahimnagar
Talimpur
Nehalpur
High vulnerable
Moderate vulnerable
Low vulnerable


Prevalence of stress across the villages
Stress
40.00
30.00
20.00
10.00
.00
Kolpatua
Chakbara
Khalisabunia
Dumuria
Sreenagar
Joynagar
Kalinagar
Satgharia
Joypur
Rahimnagar
Talimpur
Nehalpur
High vulnerable
Moderate vulnerable
Low vulnerable


Prevalence of environmental stressor across the villages
Environmental stressor
50.00
40.00
30.00
20.00
10.00
.00
Kolpatua
Chakbara
Khalisabunia
Dumuria
Sreenagar
Joynagar
Kalinagar
Satghania
Joypur
Rahimnagar
Talimpur
Nehalpur
High vulnerable
Moderate vulnerable
Low vulnerable

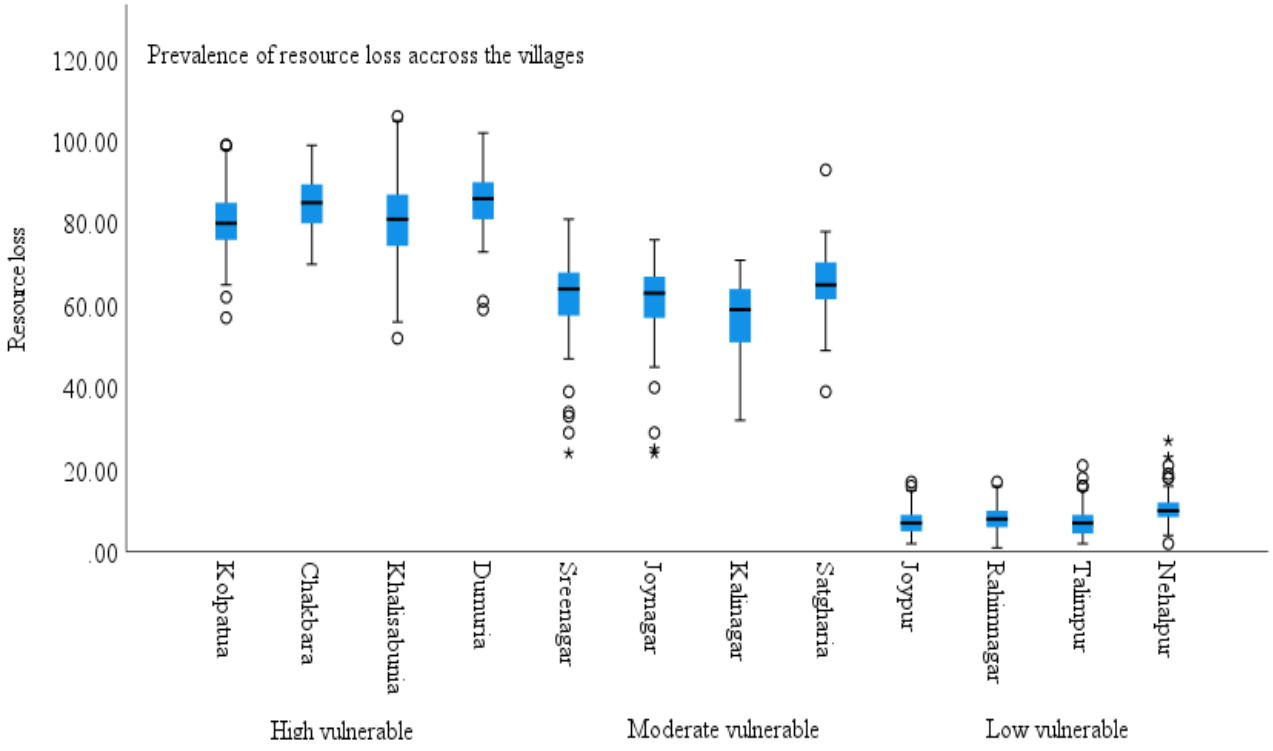

Prevalence of resource loss accross the villages
Resource loss
120.00
100.00
80.00
60.00
40.00
20.00
.00
Kolpatua
Chakbara
Khalisabunia
Dumuria
Sreenagar
Joynagar
Kalinagar
Satghania
Joypur
Rahimnagar
Talimpur
Nehalpur
High vulnerable
Moderate vulnerable
Low vulnerable

Table 3.2

Prevalence of Psychological Distress, Depression, Anxiety, and Stress among Coastal Communities

Variable		**Psychological distress**	**Depression**	**Anxiety**	**Stress**
Vulnerability (Ref: Low)					
	Moderate	7.223**	11.311**	8.993**	12.191**
		(.969)	(2.019)	(2.653)	(1.647)
	High	12.739**	18.296**	14.773**	21.106**
		(.946)	(2.002)	(2.639)	(1.628)
Age		.087**	.068**	.079**	.099**
		(.011)	(.013)	(.014)	(.013)
Gender (Ref: Male)					
	Female	2.155**	4.031**	3.868**	2.830**
		(.549)	(.666)	(.701)	(.644)
Household income (Ref: Low income)					
	Lower-middle	-1.321**	-1.969**	-1.586**	-1.837**
		(.391)	(.474)	(.499)	(.458)
	Middle	-1.884**	-2.559**	-1.631*	-2.901**
		(.562)	(.682)	(.719)	(.660)
	Upper-middle	-2.359**	-3.197**	-1.756	-3.063**
		(.808)	(.982)	(1.034)	(.949)
Constant		23.811**	15.150**	16.923**	18.440**
		(1.129)	(1.523)	(1.730)	(1.410)
Observations		1,200	1,200	1,200	1,200
Number of groups		12	12	12	12

Robust standard errors in parentheses; $^{**}p < .010$, $^{*}p < .050$

Psychological distress among respondents living in moderately and highly vulnerable coastal communities was significantly higher (moderate vulnerability: $b = 7.223$, $p < .010$; high vulnerability: $b = 12.739$, $p < .010$) than those living in low vulnerability communities. A similar pattern was evident for depression, anxiety, and stress. These findings suggest that coastal community members of highly vulnerable areas are more psychologically distressed than people living in moderately or low vulnerable coastal communities.

The impact of demographic variables on psychological health outcomes is evident in the analysis. Age was identified as a significant predictor across all psychological health measures. In coastal communities, older individuals reported the increased levels of psychological distress, depression, anxiety, and stress. In terms of gender, women experienced higher levels of psychological distress, depression, anxiety, and stress compared to men. Also noteworthy is the impact of religion on psychological health outcomes. Compared to Muslim participants, Christian participants reported higher levels of psychological distress, while Buddhist participants reported lower stress levels. It's crucial to clarify that these findings do not imply a causal relationship between religious beliefs and the impact of SLR. Instead, they underscore the diverse psychological health profiles across different demographic groups.

The study also revealed the differences in psychological health outcomes based on marital status, educational level, and income. Divorced respondents experienced higher levels of psychological distress, anxiety, and stress compared to unmarried participants. Regarding education, those with some formal education reported lower levels of distress, anxiety, and depression in comparison to respondents without education. A similar pattern was observed for household income, where individuals in higher income brackets reported lower levels of psychological distress, depression, anxiety, and stress. These results suggest that socioeconomic factors may serve as protective elements for psychological health amidst environmental stressors. Further research is warranted to explore these relationships.

3.5.2. *Environmental stress and psychological distress mediated by resource loss*

Environmental stressor and resource loss reported by the participants differed systematically and, in a manner, like psychological health measures across communities (Figure 3.4). The second hypothesis was examined that resource loss mediates the relationship between environmental stressors and psychological distress, as postulated in this model (Figure 3.1). The "ml_mediation" command of STATA (17 version) was used to estimate the mediating role of resource loss in a multi-

level analysis, taking individuals as level 1 and villages as level 2 and including random intercept for villages as before. The indirect, direct, and total effects were calculated while bootstrapping the results with 500 replications. The indirect effect in this model corresponds to the hypothesized mediation relation (Figure 3.1). The direct effect corresponds to the effect of environmental stressors on psychological health which is independent of the effects of resource loss. The total effect refers to the sum of the direct and indirect effects.

Table 3.3

Summary of the Mediation Analysis

Outcome variable	**Indirect effect**		**Direct effect**		**Total effect**	
	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Psychological distress	.350	.001	.032	.258	.382	.001
Depression	.587	.001	-.062	.117	.525	.001
Anxiety	.387	.001	.043	.286	.430	.001
Stress	.626	.001	-.004	.907	.622	.001

Results are summarized in Table 3.3. The indirect effect of environmental stressors on psychological health through resource loss was significant for all psychological health measures. The direct effect was non-significant in all analyses, whereas the total effect of environmental stressors was significant in all cases. In sum, as depicted in Figure 3.1, environmental stressors affect all four measures of psychological health via its effect on resource loss.

3.5.3. *Environmental stress and psychological distress moderated by age, gender, and income*

Next, the third hypothesis was examined that the detrimental psychological health impact of environmental stress was more pronounced among residents of the coastal communities who were older, women, and have lower household incomes. A moderation analysis was conducted through a linear mixed model, entering age, gender, and household annual income as moderating the effect of environmental stressors. Table 3.4 summarizes the results.

Table 3.4

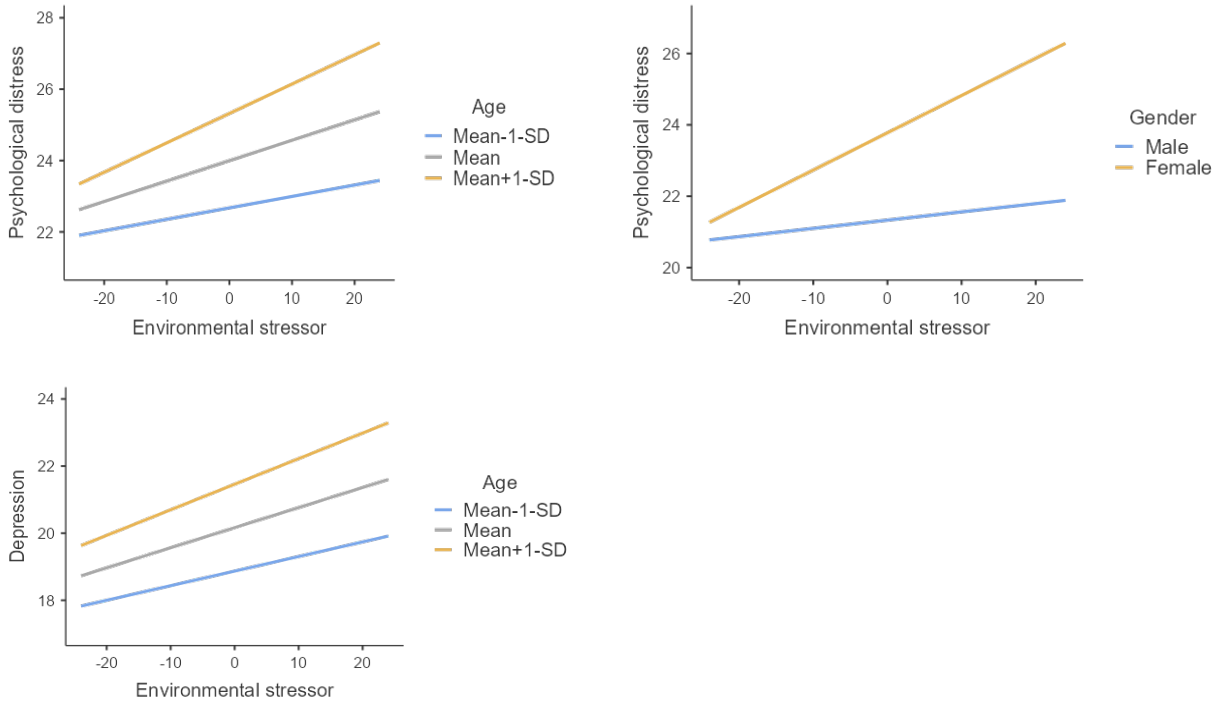
Summary of the Moderation Analysis

Moderator	Psychological distress			Depression			Anxiety			Stress		
	b (SE)	95% CI	*p*	*b (SE)*	95% CI	*p*	*b (SE)*	95% CI	*p*	*b (SE)*	95% CI	*p*
Age	.002 (.001)	.001 - .004	.001	.002 (.001)	.001 - .004	.037	.001 (.001)	-.001 - .003	.192	.002 (.001)	-.001 - .003	.054
Gender	.077 (.019)	.040 - .114	.001	.014 (.023)	-.032 - .060	.549	.042 (.024)	-.005 - .090	.080	-.031 (.022)	-.074 - .012	.161
Income	-.006 (.013)	-.033 - .020	.641	.008 (.017)	-.025 - .040	.641	.017 (.017)	-.017 - .050	.339	.003 (.016)	-.028 - .034	.840

Age was a significant moderator of the environmental stressor on psychological distress (b = .002, p = .001) and depression (b = .002, p = .037). These findings suggest that older residents were affected more by the environmental stressor, especially in terms of psychological distress and depression (Figure 3.5). Gender moderated the effect of environmental stressors on psychological distress (b = .077, p = .001) in that the effect of environmental stressors was particularly pronounced among women (Figure 3.5). Household income did not moderate the effect of environmental stressors on psychological health.

Figure 3.5

Simple Slope Analyses for the Significant Moderating Relationship



3.6. Discussion

This study presents a unique investigation of the association between sea-level rise and psychological distress among coastal communities of Bangladesh, focusing on the effect of SLR-induced environmental stressors on psychological distress and its mediating and moderating factors. The prevalence of psychological distress, depression, anxiety, and stress was substantially higher in more environmentally vulnerable coastal communities than among moderate and low-risk communities.

The effect of environmental stressors on psychological health was mediated by resource loss for all four psychological health measures examined, supporting the mediation model in Figure 3.1. This finding suggests that environmental stressors such as salinity and flooding worsen resource loss, which exacerbates distress, possibly by reducing the economic security and health status of communities (Cunsolo & Ellis, 2018; Yanda et al., 2018). Prior research indicates that resource loss (e.g., the loss of property) affected psychological distress and anxiety among populations in hazard-prone coastal areas (Freedy et al., 1994; Gibson et al., 2019; Rudolphi et al., 2020). The current findings provide direct evidence of resource loss as an underlying factor in psychological distress, providing further evidence to support the Conservation of Resources Theory (Hobfoll, 2012).

The analysis revealed limited effects of moderation factors: the moderation effect of age was evident for psychological distress and depression, and gender moderated psychological distress so that environmental stressor affected women more severely than men. This finding supports the suggestion made in the literature that older adults may be more vulnerable to environmental change due to issues related to reduced mobility, limited access to resources like compromised agriculture, dependence on caregivers and health support, reduced availability of freshwater, and limited capacity for evacuation (Berry et al., 2018; DeVito et al., 2018), which may limit their capacity to cope with environmental stressors. Likewise, the current finding augments literature suggesting that women may be more vulnerable to psychological distress in settings at risk of climate hazards. Cultural and societal barriers that restrict women's skills development, including restrictions on education access and property

ownership, may limit their ability to implement adaptation strategies for environmental stressors (Shahjalal, 2021). SLR-induced stressors have potential to perpetuate gender inequalities and create security, health, and livelihood risks for women and girls with significant psychological health implications (Rahman, 2013b; Shahjalal, 2021). Contrary to the prediction, household income did not moderate the detrimental effect of environmental stressors.

The findings contribute to a growing evidence base on the psychological impacts of climate change, addressing recent calls for empirical data to inform governmental policies (Berry et al., 2018; Evans, 2019; Hwong et al., 2022). By revealing specific pathways by which sea-level rise affects levels of distress in Bangladesh, this study illuminates the relationships between environmental stressor, resource loss, and psychological health. The Sendai Framework for Hazard Risk Reduction 2015-2030 sought to enhance community health resilience via the introduction of a framework for action across the hazard risk management (DRM) continuum (prevention, preparedness, response, and recovery) (Kayano et al., 2019). It is now evident that climate change will compress the DRM continuum in settings at risk of frequent and simultaneous hazards. Without an immediate and drastic reduction in the use of fossil fuels, temperature rise will continue to exacerbate hazards in coastal areas, with significant implications for psychological health. As such, in line with priorities outlined by the World Health Organization's Thematic Platform on Health Emergency and Hazard Risk Management (Kayano et al., 2019), and the Asia Pacific Hazard Mental Health Network (Newnham, Dzidic, et al., 2020), government policy and funding to address psychological health risks in coastal areas of the Asia-Pacific most vulnerable to sea-level rise will be vital. Cost-efficient models of care, including task shifting and peer-support models (Deimling Johns et al., 2018), will enable a rapid up-scale of psychological health resources in high-risk settings. Evidence-based, culturally safe, and sustainable psychological health services are needed, and accessibility for women and older adults must be ensured. This study, thus, contributes evidence-based insights for policymakers to make long-term plans for local and national psychological health services to ensure sustainable and targeted programs for communities affected by SLR and related hazards.

1.6.1. *Implications*

The findings of this research elucidate a clear association between SLR and psychological distress among coastal communities in Bangladesh. Primarily, it reveals that environmental stressors, such as heightened salinity and flooding, play a role in escalating resource loss and intensifying psychological distress, thereby potentially threatening community health and economic stability. These findings provide further evidence in support of the COR theory, while also highlighting pronounced impact of environmental stressors on elderly individuals and women, in particular.

The implications of this study extend beyond academia and bear significant relevance for policy formulation and climate change mitigation efforts. It underscores the necessity for risk management strategies that incorporate community health resilience, including measures to address psychological health risks. Informed policymaking is crucial, emphasizing cost-efficient care models with a specific focus on accessibility for vulnerable groups, such as women and older adults. This work highlights the importance of continuous, rigorous investigation to produce robust empirical evidence to guide such strategies. Additionally, the need for broader exploration is evident, particularly around the unexpectedly insignificant moderating effect of household income, as well as the applicability of these findings in different geographical contexts.

1.6.2. *Limitations*

This study includes certain limitations. The absence of a significant moderating effect of household income prompts further exploration of the intricate relationship between economic stability and psychological health within this context. The findings, based on coastal communities in Bangladesh, might not directly translate to other geographical or cultural settings, thereby necessitating similar research in diverse demographic and geographical contexts. The cross-sectional design of the study limits the establishment of causality, thus suggesting the need for longitudinal designs in future research for a more comprehensive understanding of causal relationships. These limitations not only

provide a roadmap for future research but also highlight the necessity for an interdisciplinary approach to climate change research.

3.7. Conclusion

This study provides novel evidence for an association between sea-level rise and psychological distress among coastal communities in Bangladesh. The effect of environmental stress was disproportionately experienced by vulnerable residents in these communities: sea-level rise-induced environmental stressors were associated with resource loss, which in turn heightened psychological distress, depression, anxiety, and stress. These findings highlight a significant need for the integration of psychosocial support in hazard risk reduction policy and call for accessible clinical interventions for communities affected by sea-level rise amidst the growing threat of climate change.

CHAPTER FOUR: FOLLOW-UP STUDY

Sea-level rise and psychological distress evidence from coastal communities in Bangladesh: A longitudinal investigation

4.1. Introduction

The aim of this study is to longitudinally examine the association between sea-level rise (SLR) and psychological health and determine whether changes in resource loss mediate the relationship between environmental stressors of SLR and change in psychological distress, depression, and anxiety over time.

Prior research has identified psychological health risks and suffering tend to intensify on the coastal populations and established an association between SLR and psychological distress. For example, in a cross-sectional survey among 1200 participants from coastal communities of Bangladesh, Kabir et al. (under review) reported in Chapter Three found that SLR-induced environmental stressors were associated with multiple indicators of psychological health, specifically distress, depression, anxiety, and stress. Kabir et al. (under review) found that participants' sense of resource loss mediates the effects of SLR-related environmental stressors on psychological health. Among the residents of East Malaita in the Solomon Islands, Asugeni et al. (2015) focused on psychological health issues related to SLR. Fifty-seven participants in their study completed an open-ended questionnaire and the responses were analyzed quantitatively and through thematic analysis. Their quantitative findings indicated that nearly all participants 98% (56 out of 57) reported that SLR negatively affected their psychological health expressed as fear and worry.

However, much of the existing literature is based on data drawn from cross-sectional observations and hence may be affected by confounding factors. For example, in Kabir et al. (2022) one confounding factor is socioeconomic status that in the community most vulnerable to SLR, 75% of the residents were below the poverty line compared to the community less vulnerable to SLR, where only 28.5% of the community residents were below the poverty line. Consequently, in Kabir et al. (under review) the higher level of psychological distress, depression, anxiety, and stress observed in

high relative to low-vulnerability communities might have reflected differences in socio-economic status, rather than the vulnerability to SLR.

One way to disentangle the impact of SLR from differences in socio-economic status and other confounding factors is to observe the impacts of SLR longitudinally. Currently, there is no study reported in the literature that has examined the psychological impact of SLR longitudinally. As such, the current study conducted a longitudinal observation of Kabir et al. (under review). The initial observation (Time 1) reported by Kabir and colleagues was collected between March to April 2021, before the monsoon season in the region. In this region, about 80% of all precipitation falls during the monsoon season (June to October) and is subject to devastating cyclones and floods (Abdullah et al., 2022). For example, riverbank erosion results in the loss of thousands of hectares of agricultural land (Mojid, 2020) and affects the population (Rahman et al., 2021). Moreover, floods contribute to the further salinization of coastal lands, causing not only loss of harvests but also of productive agricultural land (Thomas et al., 2013). Out of 2.85 million hectares of coastal and offshore areas in the region, about 1.2 million hectares of arable land are already affected by varying degrees of soil salinity (Habiba et al., 2014). Therefore, every year salinity intrusion and flooding cause immense loss of properties, and the impact varies significantly between seasons i.e., from pre-monsoon and post-monsoon (Hayes & Poland, 2018; Uddin et al., 2020). Consequently, the severity of existing psychological health risks and suffering is anticipated to intensify in the coastal populations in post-monsoon. As such, the current follow-up observations took place in the post-monsoon season (October to November 2021), eight months after the first survey reported by Kabir et al. (2022).

One factor that helps coastal communities to adapt to climatic hazards is resilience. Resilience refers capacity to successfully deal with challenging or difficult conditions in life (APA, 2014). It entails having the psychological, emotional, and behavioural flexibility to adjust to both internal and external influences (APA, 2014). Some research has already examined the resilience of coastal communities to climate change in different settings (Hoque et al., 2019; Hossain et al., 2013; Kais & Islam, 2021;

Kokorsch & Benediktsson, 2018; Uddin et al., 2020). For example, in a mixed methodology approach among the fishing communities of the North-western Region of Iceland, Kokorsch and Benediktsson (2018) examined resilience of coastal communities and reflected on the possible shortcomings of the resilience. They found that resilience was considered both cause and effect: stressor and stress; and the communities have had to adjust to a radical climate change, with the loss of resource entitlements. In another study, among the coastal communities of Bangladesh, Uddin et al. (2020) focused on community recovery and attributes of resilience to cyclones, storm surges, and other environmental hazard shocks. They collected empirical data from January 2014-2015, using a household questionnaire and various participatory rural appraisal tools (i.e., a survey among 300 household heads, 8 focus group discussions, 20 key informant interviews, and 5 in-depth case studies). They found that community resilience significantly depends on their economic base, occupations, and their respective contexts of vulnerability. Kais and Islam (2021) conducted a cross-sectional study using ethnography and in-depth interviews among coastal communities of the three coastal districts (Bagerhat, Khulna, and Satkhira) in Bangladesh to examine the nature, effects, and efficacy of resilience strategies related to vulnerability. They administered 45 interviews and two ethnographic visits to each of the sites and found a clearly visible resilience gradient in the coastal communities related to climatic hazards in Bangladesh. In another study, Hossain et al. (2013) conducted interviews among 250 coastal fishing community household heads from November 2009 to April 2010 in Noakhali of Bangladesh to identify assets (e.g., human, physical, financial, natural, and social) for analyzing resilience. They found that natural assets as the most significant in fisher resilience. Thereafter, resilience of the coastal communities was measured to depict the impact of SLR-induced environmental stressors on psychological health.

There are two aims of this study. The first aim is to examine whether environmental stressors and psychological distress are higher after the monsoon season, relative to the pre-monsoon season and whether this pattern is particularly pronounced in communities most vulnerable to SLR. This pattern is expected because SLR-produced environmental stressors (e.g., salinity, flooding) may be

heightened during post-monsoon season (Hayes & Poland, 2018; Uddin et al., 2020). The second aim is to determine whether residents' increased sense of resource loss after the monsoon season underlies psychological distress associated with environmental stressors that is hypothesized to increase. In a cross-sectional analysis, Kabir et al. (under review) examined the model, where the association between environmental stressors and psychological distress is mediated by resource loss. This study's focus on resource loss was based on the Conservation of Resource theory, where psychological distress is seen as one reaction to the threat of or actual resource loss following individuals' investment into it (Hobfoll, 2012; Zadow et al., 2017). From this perspective, resources are defined as objects, states, and conditions that individuals strive to obtain, retain, and protect (Hobfoll, 2012). COR theory posits that the loss of these types of resources will elevate distress (Hobfoll, 2012). Climate change can create these situations (Hobfoll, 2012; Zadow et al., 2017). In Kabir et al. (under review), the findings supported the model, consistent with the prior literature linking environmental stressors (i.e., salinity, flooding, agricultural damage) with loss of resources (Ahmed et al., 2019; Rabbani et al., 2013) as well as the literature linking resource loss with psychological distress (Hobfoll, 2012; Zadow et al., 2017), anxiety, and depression (Rudolphi et al., 2020). The current analysis examines these associations longitudinally. A stronger sense of resource loss is expected after the monsoon season as salinity intrusion and flooding cause immense loss of agriculture (Hayes & Poland, 2018; Uddin et al., 2020). Consequently, the severity of existing psychological health risks and suffering especially in communities vulnerable to SLR may exacerbate in post-monsoon.

In sum, the current study examines the following hypotheses.

(1) Psychological health is in a poorer state after the monsoon season (Time 2) than the pre-monsoon seasons (Time 1), and this pattern is more pronounced in communities vulnerable to SLR.
(2) The level of environmental stressors is higher in Time 2 compared to Time 1, and this pattern is more pronounced in communities vulnerable to SLR.
(3) An increased sense of resource loss is evident at Time 2 compared to Time 1, and this pattern is more pronounced in communities vulnerable to SLR.

(4) Worsening of psychological health from Time 1 to Time 2 is associated with increase in environmental stressors. This association is mediated by an increase in resource loss.

In addition to these hypotheses, it was also examined and explored the effects of participants' COVID-19 anxiety, salient at the time of data collection, as well as their resilience.

4.2. Methods

4.2.1. *Data collection*

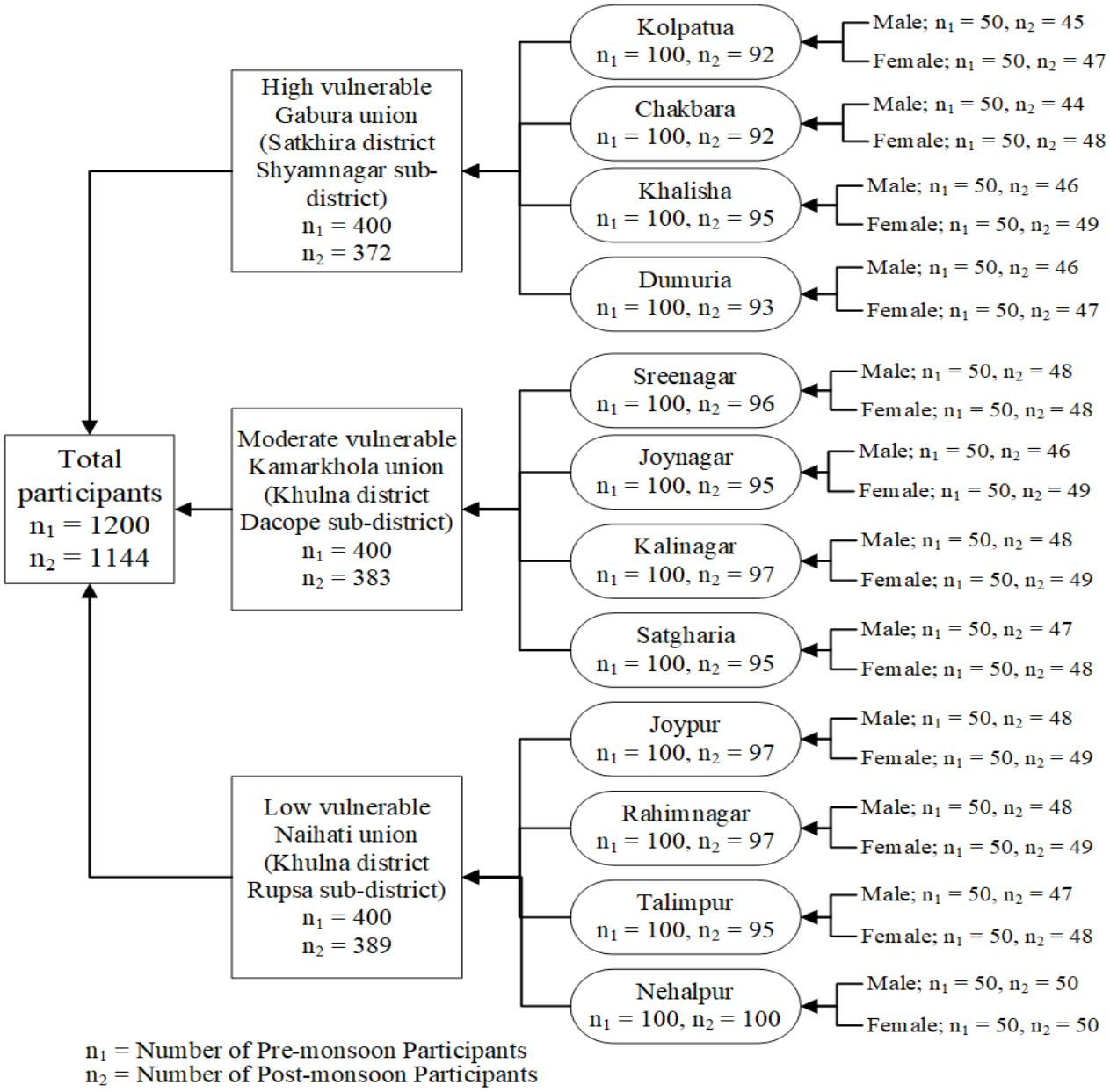
A total of 1200 participants participated in the Time 1 data collection (collected during the pre-monsoon season March to April 2021) and were recontacted for this round of data collection, during the post-monsoon season (October to November 2021) with the help of six field assistants. As described by Kabir et al. (under review) and in Chapter Three, these participants were recruited from communities classified as having high, moderate, and low levels of vulnerability based on the Bangladesh Bureau of Statistics report (BBS, 2019a). Consistent with the Time 1 data collection, the researcher administered the questionnaires in a common gathering place, the participant's home or workplace, depending on the participant's preference. Ethics approval was obtained from Curtin University's Human Research Ethics Committee (HRE2020-0645) and Dhaka University Research Ethics Committee (Ref. No. 109/Biol. Sci.). The questionnaire was available in Bengali, and participants provided written responses, taking up to 45 minutes to complete the measures.

An attrition rate of 4.7% between survey rounds was found, thus, a total of 1144 participants completed both surveys (Figure 4.1). The data were recorded first in paper-pencil (using questionnaires) and then inputted electronic (using IBM SPSS version 28) format. The selected participants were followed up via phone and address from Time 1 and the attrition reasons retrieved by getting information from their families or neighbours. While the attrition rate was generally very low, it was somewhat higher in the highly vulnerable communities (7%, male 9% & female 4%) compared to moderate (4%, male 5% & female 3%) and low (3%, male 3% & female 2%) vulnerable communities. The reason for attrition was migration to nearby areas (highly vulnerable = 13,

moderate = 11, low = 0), migrated for livelihood purposes (high = 12, moderate = 3, low = 9), death (high = 2, moderate = 2, low = 0), and hospitalized (high = 1, moderate = 1, low = 2).

Figure 4.1

Sample Size of the Study



4.2.2. *Measures*

Using the same measures reported in Chapter Three (Kabir et al., 2022), this study assessed respondents' psychological distress, depression, anxiety, stress, environmental stressors, resource loss, and demographic information. This Chapter also reports on the measures of resilience and COVID-19 anxiety that were included in both data collection points, although these data were not

reported in Chapter Three as this was outside the scope of the manuscript (Chapter Three intended for publication). Resilience was included to examine its possible role as a protective factor in the current population and anxiety regarding COVID-19 was included because data collection was conducted during the global pandemic, which was likely to play a role in psychological distress.

Resilience was measured by the Protective Factors for Resilience Scale (PFRS), developed by Harms et al. (2017) to comprehensively measure the factors that promote greater resilience. It is a self-report instrument and consists of 20 items, 10 items for personal resources (e.g., "I believe in myself") and 5 items each for peers (e.g., "I feel that I belong with my friends") and family and social resources (e.g., "my family are a source of strength for me"). Responses for each item were indicated on a seven-point Likert scale, ranging from strongly disagree (1) to strongly agree (7). The Bengali version of PFRS was previously translated, validated, and used in relation to the resilience of Bangladesh coastal communities to climate change (Hoque et al., 2019; Hossain et al., 2013; Kais & Islam, 2021). A summed score was used, and higher scores indicate higher levels of protective factors of resilience.

Anxiety towards COVID-19 was measured with the Coronavirus Anxiety Scale (CAS), which was developed by Lee (2020) as a psychological health screener of dysfunctional anxiety related to the COVID-19 crisis (Ahmed et al., 2022; Lee, 2020). Ahmed et al. (2020) translated and validated the Bengali CAS and found good internal consistency reliabilities, test-retest reliability, and construct validity in Bangladesh (Ahmed et al., 2022). This scale consists of five items (e.g., "I had trouble falling or staying asleep because I was thinking about the coronavirus"). Responses are indicated on a five-point Likert rating scale ranging from 0 (not at all) to 4 (nearly every day over the last 2 weeks). Elevated scores on a specific item or a high total scale score (≥ 9) may indicate problematic symptoms for the person who might warrant further assessment and/or treatment (Ahmed et al., 2022; Lee, 2020).

4.3. Data analysis

The analysis consists of two responses from each participant (measured before and after the monsoon season) from 12 different villages (refer to Figure 4.1), utilized a linear mixed-effects model. This model was chosen because of the need of accounting for clustering within the participants and villages and control variations among participants' demographic characteristics. The model allowed for an examination of Hypotheses 1-3, specifically determining if significant differences existed in participants' responses pre- and post-monsoon seasons, with a particular focus on communities most susceptible to SLR. This involved analyzing measures of psychological health (H1), environmental stress (H2), and resource loss (H3).

Each outcome variable, such as psychological distress, was evaluated in a model that considered two responses for each participant and their respective community's vulnerability level. The model included an interaction between the data collection phase (Time 1 and Time 2) and community vulnerability. To account for the clustering effects, a random intercept for the village was incorporated, along with a random slope for the data collection phase. The model also entered the participants' demographic attributes. These were respondents' age, gender (with the male set as the reference), religion (with 'Muslim' set as the reference), marital status (with 'unmarried' set as the reference), education ('no education' set as the reference), occupation ('farming' as the reference), annual household income ('low income' as the reference), number of dependent family members, socioeconomic status on the community ladder. In addition, the analysis also included COVID-19 anxiety and resilience in the model. The analysis conducted for the mediation model (Hypothesis 4) is detailed in section 4.4.2. A central tenet in mediation analyses, temporal precedence, was maintained by measuring hypothesized causal factors, such as environmental stressors, before assessing outcome variables like resource loss and psychological health. To counter potential bias in mediation testing, various strategies were employed. These included implementing rigorous measurement reliability, controlling personality traits that might affect responses, and using diverse

data sources to limit common method bias. Additionally, the adoption of bootstrapping as a statistical technique ensured robust confidence intervals for indirect effects in mediation analysis.

4.4. Results

4.4.1. *Environmental vulnerability and psychological health*

Table 4.1 exhibits descriptive statistics. Psychological distress, depression, anxiety, and stress were all significantly higher in Time 2 compared to Time 1. Moreover, a statistically significant interaction was evident between phase x vulnerability for psychological distress, depression, and anxiety. For example, in comparison to low-vulnerability communities, participants in high-vulnerability communities reported a significantly higher increase in psychological distress in Time 2 (b = 4.635, SE = .441, p < .001). Similarly, in comparison to low-vulnerability communities, those in moderate-vulnerability communities reported a significantly higher increase of psychological distress in Time 2 (b = 2.597, SE =.437, p < .001). Figure 4.2 Panel A shows these results. The same pattern was evident for depression and anxiety, though for anxiety moderate and low vulnerability communities did not differ in their increased level of anxiety (b = 3.185, SE =1.633, p = .083) (Table 4.2). Phase x vulnerability interaction was not evident for stress. In sum, these findings partially support Hypothesis 1.

Hypotheses 2 and 3 were examined in a similar fashion. Environmental stressors were increased in the post-monsoon survey, and these increases were more pronounced among respondents living in moderate and highly vulnerable coastal communities, 4.478 points (b = 4.478, SE =.798, p < .001) and 5.757 points (b = 5.757, SE =.329, p < .001) respectively, compared to those living in low vulnerability communities (Figure 4.2 Panel E). As such, Hypothesis 2 was supported. Regarding resource loss, a higher level was reported in Time 2, and this increase was significantly more pronounced in moderate and highly vulnerable communities (increased by 16.693 points, SE = 1.330, p < .001; and by 19.054 points, SE = 1.334, p < .001) compared to the low vulnerable communities (Figure 4.2 Panel F). These results support Hypothesis 3.

Table 4.1

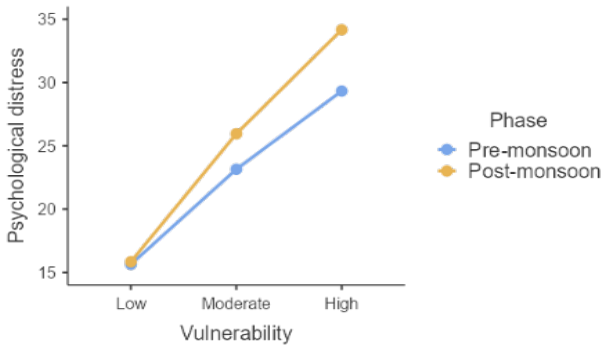
Summary Statistics of Psychological Health Measures, Environmental Stressors, Resource Loss, Anxiety Rooted in COVID-19, and Resilience in Pre- and Post-monsoon Seasons across the Communities

Variable	**Vulnerability**					
	Low		**Moderate**		**High**	
	Pre-monsoon (T1)	Post-monsoon (T2)	Pre-monsoon (T1)	Post-monsoon (T2)	Pre-monsoon (T1)	Post-monsoon (T2)
Psychological distress	14.820 (3.700)	15.399 (4.303)	22.223 (6.029)	25.115 (4.571)	28.438 (4.367)	33.634 (3.856)
Depression	3.895 (3.916)	5.100 (3.750)	15.165 (8.879)	19.488 (6.569)	22.955 (5.769)	28.683 (3.761)
Anxiety	6.265 (4.690)	6.231 (4.225)	14.830 (8.514)	17.645 (6.075)	21.670 (7.372)	26.124 (4.072)
Stress	6.420 (4.634)	7.496 (4.628)	19.430 (6.807)	22.360 (5.692)	28.555 (5.503)	31.086 (3.621)
Environmental stressors	6.340 (4.334)	8.373 (3.788)	28.403 (5.365)	34.896 (3.782)	36.533 (3.161)	44.375 (1.696)
Resource loss	8.388 (3.698)	18.576 (5.251)	61.518 (9.029)	88.193 (3.782)	82.975 (8.592)	111.925 (6.567)
COVID-19 Anxiety	2.805 (2.866)	4.488 (2.254)	1.718 (1.681)	2.366 (1.422)	1.090 (1.162)	1.707 (1.139)
Resilience	96.945 (15.822)	94.686 (10.751)	105.520 (15.423)	85.034 (8.883)	97.070 (10.639)	73.258 (7.882)
Observations	389	389	383	383	372	372

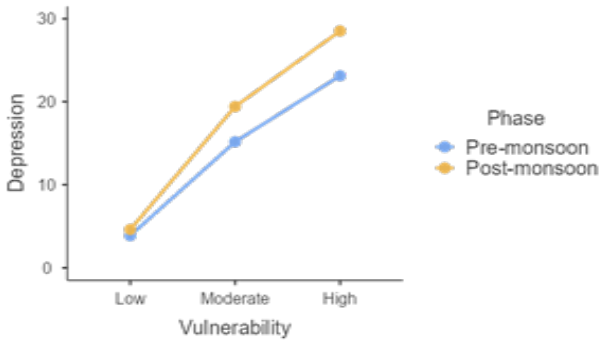
Standard deviation in parentheses

Figure 4.2

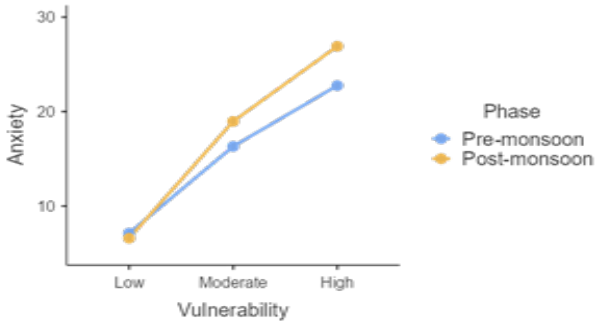
Difference Between Pre- and Post-Monsoon Levels of Psychological Health, Environmental Stressors, Resource Loss, COVID-19 Anxiety, and Resilience across Communities by Level of Vulnerability



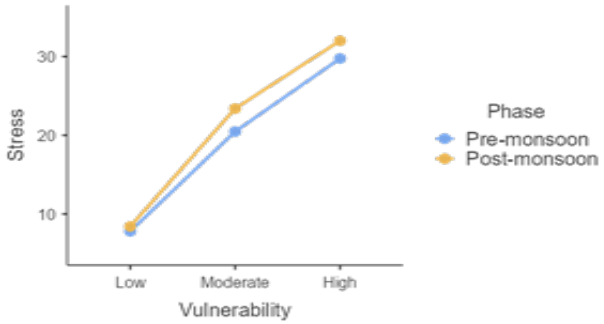
A. Psychological distress



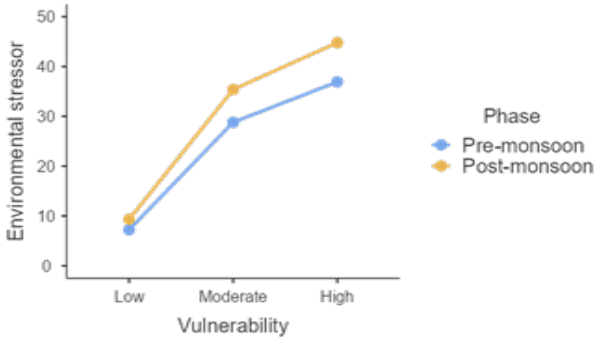
B. Depression



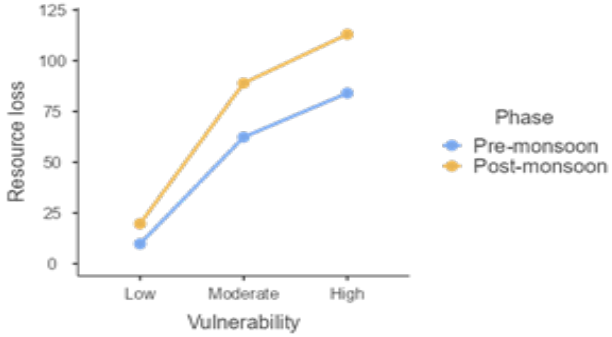
C. Anxiety



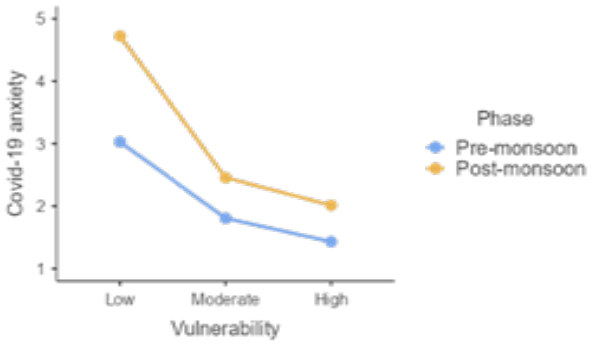
D. Stress



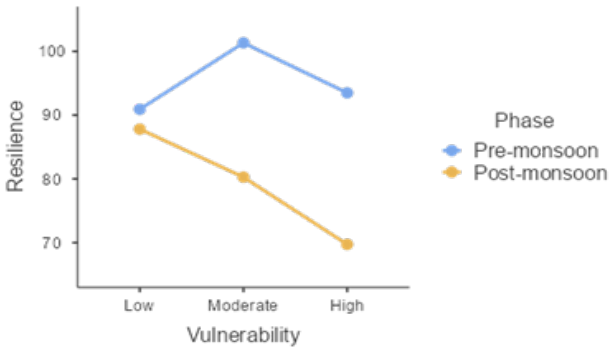
E. Environmental stressor



F. Resource loss



G. Covid-19 anxiety



H. Resilience

The same analyses were conducted on COVID-19 anxiety and resilience. COVID-19 anxiety generally was higher in Time 2. Interestingly, a larger increase in COVID-19 anxiety was found among respondents living in low and moderate vulnerable coastal communities than those living in highly vulnerable communities (Figure 4.2 Panel G). Hence, the pattern for COVID-19 anxiety diverged findings for other measures of psychological health: distress, depression, anxiety, and stress (refer to Figure 4.2). Resilience generally decreased in Time 2, and this pattern was pronounced among respondents living in moderate (b = -17.928, SE = 2.943, $p < .001$) and highly (b = -20.641, SE = 2.947, $p < .001$) vulnerable coastal communities than those living in low vulnerable communities.

Table 4.2

Psychological Distress, Depression, Anxiety, and Stress across the Communities at Pre and Post-monsoon Seasons

Variable	Psychological distress	Depression	Anxiety	Stress	Environmental stressors	Resource loss	COVID-19 anxiety	Resilience
Phase (Post- and Pre-monsoon)	2.616**	3.458**	2.093*	1.930**	5.517**	21.814**	.976**	-15.970**
	(.185)	(.640)	(.670)	(.458)	(.329)	(.549)	(.074)	(1.208)
Vulnerability (Ref: Low)								
Moderate	8.807**	13.055**	10.774**	13.821**	23.815**	60.876**	-1.746**	1.436
	(.961)	(1.498)	(1.868)	(1.196)	(1.163)	(1.721)	(.494)	(3.513)
High	16.005**	21.583**	17.969**	22.769**	32.567**	83.752**	-2.155**	-7.751*
	(.954)	(1.492)	(1.863)	(1.189)	(1.158)	(1.712)	(.491)	(3.500)
Phase ⁎ Vulnerability (Ref: Low)								
Moderate	2.597**	3.508*	3.185	2.320	4.478**	16.693**	-1.045**	-17.928**
	(.437)	(1.560)	(1.633)	(1.113)	(.798)	(1.330)	(.179)	(2.943)
High	4.635**	4.662*	4.690*	1.650	5.757**	19.054**	-1.111**	-20.641**
	(.441)	(1.562)	(1.635)	(1.115)	(.800)	(1.334)	(180)	(2.947)
COVID-19 anxiety	.192**	.250**	.257**	.234**	-.050	.162*	---	.526**
	(.049)	(.057)	(.057)	(.055)	(.0422)	(.076)		(.124)
Intercept	24.012**	15.788**	16.448**	20.301**	27.080**	62.955**	2.577**	87.254**
	(.754)	(.965)	(1.071)	(.871)	(.728)	(1.212)	(.342)	(2.169)
Observations	2,288	2,288	2,288	2,288	2,288	2,288	2,288	2,288
Number of groups	12	12	12	12	12	12	12	12

Robust standard errors in parentheses; $^{**}p < .010$, $^{*}p < .050$.

4.4.2. *Resource loss, environmental stressor, and psychological health*

The fourth hypothesis in this study was that the worsening of psychological health from Time 1 to Time 2 would be associated with increase in environmental stressors, and this association is mediated by an increase in resource loss. To examine these possibilities, the difference scores between Time 1 and Time 2 responses for environmental stressors, psychological distress, and resource loss were computed. Using these difference scores as an outcome variable, a multilevel mediation analysis was conducted, to estimate the indirect, direct, and total effects.

The total effect in this model refers to the degree to which the increase in the environmental stressors predicted a worsening of psychological health. The indirect effect refers to the degree to which the change in resource loss mediated the effect of environmental stressors' increase on the worsening of psychological distress. The direct effect corresponds to the effect of environmental stressors increase on the worsening of psychological health that is independent of the change in resource loss. The model included a random intercept for the village and a random slope for the data collection phase as per previous analyses (demographic variables, i.e., age, gender, religion, marital status, education, occupation, household income, dependent members, socioeconomic ladder). These effects were computed in "ml_mediation" command of STATA (17 version) by bootstrapping the results with 500 replications (Roodman et al., 2019). All the demographic factors above mentioned, and COVID-19 anxiety were used as covariates for the analysis.

Table 4.3

Summary of the Mediation Analysis

Outcome variable	**Total effect**		**Indirect effect**		**Direct effect**	
	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Psychological distress	.085	.014	.060	.001	.025	.464
Depression	.194	.001	.096	.001	.098	.038
Anxiety	.090	.041	.051	.001	.039	.380
Stress	.084	.046	.071	.001	.013	.756

Results are summarized in Table 4.3. The total effects of environmental stressors were significant for psychological distress (b = .085, p = .014), depression (b = .194, p = .001), anxiety (b = .090, p = .041), and stress (b = .084, p = .046) respectively. These findings support the first part of Hypothesis 4 that the increase in psychological distress from Time 1 to Time 2 is associated with increase in environmental stressors. Supporting the second part of Hypothesis 4, the indirect effect was significant for all outcome variables. These findings suggest that increased sense of resource loss underlies the relationship between the increase in environmental stressors and worsening of psychological health.

4.5. Discussion

This study provides a unique longitudinal examination of the association between sea-level rise and psychological health among coastal communities in Bangladesh. The results indicated that psychological distress, depression, and anxiety were significantly higher after the monsoon season than the pre-monsoon seasons, and this pattern was more pronounced in communities more vulnerable to SLR. The same pattern of results was found for environmental stressors and resource loss.

The current findings revealed that an increase in environmental stress is related to the worsening of psychological health and this association was mediated by the increase in resource loss. The current study drew on the Conservation of Resources theory, which suggests that resource loss exacerbates levels of psychological distress (Hobfoll, 1989, 2012), depression, anxiety, and stress (Acosta et al., 2016; Gibson et al., 2019; Islam et al., 2020). The current findings are the first to support the validity of this theory in a longitudinal framework and in the context of coastal communities vulnerable to SLR. The current findings suggest that the severity of existing psychological health risks and suffering tends to intensify in coastal populations in the post-monsoon period.

In addition to these findings, this study found that resilience was generally lower after the monsoon season, and this was particularly noticeable among respondents from moderately and severely

susceptible coastal villages. Environmental stressors induced by SLR, such as saline ingress, coastal flooding, and agricultural damage, may have the capacity to reduce resilience, with the potential for this effect to be more prominent in the high-vulnerability coastal population. Prior studies also found that resilience is negatively correlated with resource loss (Kokorsch & Benediktsson, 2018) and environmental stressors in different settings (Uddin et al., 2020).

Interestingly, a large increase in COVID-19 anxiety was found among respondents living in low and moderately vulnerable coastal communities than among those living in highly vulnerable communities. While prior studies found that people in poverty, living in precarious circumstances (e.g., in areas vulnerable to rising sea levels or prone to droughts), and lack of social support are at-risk groups for COVID-19 anxiety-related pathology (Saeed et al., 2022; Shalaby et al., 2022; Taylor, 2020), the current research evidenced that low and moderately vulnerable communities experienced higher COVID-19 anxiety compared to highly vulnerable coastal communities. It may be that SLR-produced environmental stressors (e.g., cyclones, flooding) can be more salient rather than the COVID-19 pandemic in highly vulnerable coastal communities compared to low and moderately vulnerable coastal communities. Therefore, COVID-19 anxiety was higher in less vulnerable communities which are more distant from the coast and more densely populated compared to moderate and highly vulnerable coastal communities.

The current findings address recent calls for empirical data to guide governmental policies and add to the body of knowledge on the psychological effects of climate change (Berry et al., 2018; Evans, 2019; Hwong et al., 2022). This study sheds light on the long-term relationships between environmental stresses, resource depletion, and psychological health by identifying the precise processes by which sea-level rise affects psychological distress in Bangladesh. The Sendai Framework for Hazard Risk Reduction 2015-2030 introduced a framework for action across the hazard risk management (DRM) continuum (prevention, readiness, response, and recovery) to improve community health resilience (Kayano et al., 2019). It is now obvious that climate change

will compress the DRM continuum in environments at risk for multiple hazards occurring at once. Unless there is an immediate and significant reduction in the use of fossil fuels, the dangers in coastal areas will continue to increase, with serious implications for psychological health. In accordance with the priorities set forth by the Asia Pacific Hazard Mental Health Network (Newnham, Dzidic, et al., 2020) and the Thematic Platform on Health Emergency and Hazard Risk Management of the World Health Organization (Kayano et al., 2019), government policy and funding to address psychological health risks in coastal areas of the Asia-Pacific most vulnerable to sea-level rise will be crucial. Two efficient treatment models - task shifting and peer support will facilitate the rapid growth of psychological health services in high-risk settings (Deimling Johns et al., 2018). Treatments for psychological health must be evidence-based, culturally safe, and sustainable, with special attention to accessibility for women and older adults. Policymakers may use the information from this study to help them develop long-term plans for local, state, and federal psychological health services to provide sustainable and targeted programs for communities affected by SLR and other hazards.

4.5.1. *Implications*

The outcomes of this study have significant implications at both theoretical and policy levels. Firstly, the results deepen our understanding of the relationship between climate change, particularly sea-level rise, and the psychological health of coastal communities in Bangladesh. It introduces evidence of how climatic phenomena such as the monsoon season can exacerbate psychological distress, depression, and anxiety in these populations, particularly in communities highly vulnerable to sea-level rise. Furthermore, this study establishes a first-time validation of the Conservation of Resources theory in a longitudinal framework in the context of such communities. The patterns discovered not only further the theoretical underpinnings of environmental stress and resource loss as mediating factors but also shed light on their profound impact on psychological health.

Secondly, the observation that resilience reduces significantly after the monsoon season in moderately and severely susceptible coastal villages adds a new layer of understanding to the adverse effects of

environmental stressors triggered by sea-level rise. The fact that resilience was negatively correlated with resource loss and environmental stressors provides a guide for future research to delve deeper into building resilience in these communities. The insight that COVID-19 anxiety was more prevalent in less vulnerable communities further emphasizes the need for targeted psychological health interventions, considering the diverse sources of anxiety in different communities.

Lastly, and perhaps most critically, these findings hold substantial policy implications. By elucidating the complex interplay of environmental stresses, resource depletion, and psychological health in the context of climate change, this study provides robust, evidence-based insights for policymaking. As climate change compresses the hazard risk management continuum, urgent and informed actions become essential. The findings underpin the urgency to address psychological health risks in coastal areas, particularly in the Asia-Pacific region, and the necessity to reduce reliance on fossil fuels. The insights into efficient treatment models offer practical directions for developing long-term, sustainable mental health services. The focus on evidence-based, culturally safe treatments with accessibility for women and older adults underscores the need for nuanced, inclusive approaches in policymaking. In essence, this study furnishes valuable guidance for local, state, and federal policymakers to provide sustainable and targeted programs for communities affected by sea-level rise and climate change.

4.5.2. *Limitations*

While this study significantly furthers our understanding of the psychological impacts of climate change on vulnerable coastal communities, it includes some limitations. Although the two-wave longitudinal design provides some temporal insights, it may not fully outline the causal links between environmental stress, resource loss, and psychological health. A broader temporal framework could bring deeper understanding in future research. Additionally, the impact of recent tropical cyclones, Amphan and Yaas, on participants' perceptions could potentially skew reported levels of

psychological distress and resource loss. The timing of these significant events relative to this study may have led to heightened environmental stress and impacted perceptions of resilience.

In the second set of limitations, the potential biases introduced by the exclusive use of self-report measures need to be acknowledged. The use of additional objective measures could enhance the reliability and balance of the findings in future research. The exploration of resilience oscillations, although insightful, did not fully unravel the underlying mechanisms, suggesting that future research could delve deeper into this area. Further, the research did not consider potential variability in the impact of monsoon season across different regions, thereby missing potentially critical insights into regional mental health outcome disparities.

Recognizing another limitation in this study, the focus was predominantly on the psychological effects of sea-level rise, overlooking vital aspects like urban heat stress in the wider climate change context. Despite being defined by the study's scope, this constraint is acknowledged for its potential to influence a comprehensive understanding of climate change's impact on psychological health. Therefore, future research should contemplate incorporating these elements to present a well-rounded perspective, encapsulating all critical aspects of climate change.

Lastly, the focus on four specific coastal communities in Bangladesh potentially limits the generalizability of the findings. Future research could benefit from inclusion of a wider range of communities across diverse geographical and cultural contexts. Moreover, the study did not incorporate potential confounding variables, such as personal or familial psychological health history or prior experiences with severe weather events. Considering these could yield more accurate and comprehensive results in future research. Despite these limitations, the current study lays a valuable foundation for ongoing research in this critical area.

4.6. Conclusion

This longitudinal study provides clear evidence that increasing environmental stressors related to climate change have corresponding effects on psychological health (psychological distress, depression, and anxiety) and that this association is mediated by changes in resource loss. Psychological distress, depression, and anxiety were significantly higher after the monsoon season than the pre-monsoon seasons, and this pattern was more pronounced in communities most vulnerable to sea-level rise. The findings contribute to evidence-based insights for policymakers to make long-term plans for local and national psychological health services to ensure sustainable and targeted programs and call for accessible clinical interventions for communities affected by sea-level rise in relation to the growing threat of climate change.

CHAPTER FIVE: GENERAL DISCUSSION

5.1. Introduction

The overarching aim of this research was to explore how and to what extent sea-level rise (SLR) is associated with psychological distress among vulnerable coastal communities in the Asia-Pacific. This chapter briefly summarizes the key findings and discusses them in relation to the overall aim of this research and then presents theoretical and applied implications for future mechanisms to address the effects of SLR on psychological health.

5.2. Key findings

Across three studies in this thesis, the relationship between SLR-induced environmental stressors and psychological health was observed through different methodologies. First, the systematic review synthesized evidence of the relationship between SLR and psychological health in the Asia-Pacific region previously reported in the literature. This review (Chapter Two) identified thirteen studies across multiple disciplines. Ten studies (77%) indicated that exposure to SLR-induced environmental changes (e.g., salinity, flood) was associated with psychological distress, depression, anxiety, and stress. Another finding from the review was that 70% of the identified studies indicated a negative effect of SLR on people's livelihoods, especially among more vulnerable coastal communities. In this review, it was also noted that many researchers in the field recommend more empirical work in this space, as diverse communities must increasingly contend with myriad challenges associated with climate change (Berry et al., 2018; Brennan et al., 2022; Evans, 2019).

Chapters Three and Four reported a large-scale cross-sectional survey and its follow-up study conducted across 1200 participants in coastal communities of Bangladesh. The pre-monsoon data reported in Chapter Three found a direct effect of SLR on psychological health, a mediating role of resource loss, and moderating role of income, gender, and age. In other words, this study revealed that residents living in highly vulnerable areas were more distressed, depressed, anxious, and stressed, and that the effect of SLR-induced environmental stressors on psychological health was mediated by resource loss, and older people and women were especially vulnerable.

Chapter Four reported the follow-up study that longitudinally examined the association between SLR and psychological health. The findings indicated worsened psychological health in the post-monsoon than the pre-monsoon season and that this pattern was more pronounced in environmentally vulnerable communities. Worsened environmental stress and resource loss predicted the worsening of psychological health. The additional focus of this chapter was to evaluate the role of resilience and COVID-19 anxiety. Resilience was lower after the monsoon season and was particularly noticeable among respondents from moderately and severely vulnerable coastal communities. A large increase in COVID-19 anxiety was found among respondents living in low and moderately vulnerable coastal communities than among those living in highly vulnerable coastal communities.

5.3. Conceptual and applied insights from this research

Findings from this research contribute new insights that aid the development of a more comprehensive understanding of the relationship between SLR and psychological health. The first insight is that this research illuminates a clear link between SLR resulting from climate change and psychological health difficulties among coastal communities in the Asia-Pacific region. Prior research has suggested the relationship between SLR and psychological health; and found that salinity intrusion has a cascading effect on the livelihoods and health status of coastal populations (Cunsolo & Ellis, 2018; Ellis & Albrecht, 2017; Naeen, 2018; Yanda et al., 2018). Nevertheless, this research is the first in the literature that longitudinally examines the effect of SLR on psychological health in coastal communities of developing countries in a large scale. In particular, the current findings show that the negative effect of environmental stressors was disproportionately experienced among the most vulnerable residents. The risk of SLR-induced environmental stressors on psychological health is moderated depending on people's age, gender, and socioeconomic status. Older people and women in coastal communities reported higher levels of psychological distress, depression, anxiety, and stress. For elderly participants, this finding may be due to issues related to reduced mobility, limited access to resources like compromised agriculture, dependence on caregivers and health support, gradual decline in freshwater, and limited capacity for evacuation (Berry et al., 2018; DeVito et al.,

2018). For women, the finding may be due to cultural and societal barriers that restrict women's skills development, including restrictions on education access and property ownership, which may limit their ability to implement adaptation strategies for environmental stressors (Rahman, 2013a; Shahjalal, 2021). Although respondents with higher income reported a lower level of psychological distress, depression, anxiety, and stress, household income did not significantly moderate the detrimental effect of environmental stressors.

The second insight that the current findings afford is the central role of resource loss in the relationship between SLR and psychological health. To probe the role of resource loss, this research used the Conservation of Resources (COR) theory, which suggests that resource loss exacerbates the levels of psychological distress (Hobfoll, 1989, 2012), depression, anxiety, and stress (Acosta et al., 2016; Gibson et al., 2020; Islam & Wahab, 2020). These findings add to previous research that resource loss (e.g., property damage) affected psychological distress and anxiety among populations in hazard-prone coastal areas (Freedy et al., 1994; Gibson et al., 2019; Rudolphi et al., 2020). The current findings also contribute direct evidence of resource loss as an underlying factor, underscoring the COR theory (Hobfoll, 2012) and the validity of the COR theory in advancing the understanding of how SLR affects psychological health.

The third insight is that the longitudinal study revealed that environmental stressors and resource loss were significantly higher after the monsoon season than the pre-monsoon seasons and more pronounced in communities more vulnerable to SLR. Consequently, psychological distress, depression, and anxiety are significantly higher in post-monsoon and as expected more pronounced in communities more vulnerable to SLR. Prior research also found that salinity intrusion and prolong coastal flood affected people's livelihoods and negatively impacted their psychological health expressed as depression, anxiety, stress, fear, and worry (Asugeni et al., 2015; Newnham et al., 2022; Searle & Gow, 2010; Speldewinde et al., 2009).

The fourth insight provided by the current research is that resilience was generally lower among community members after the monsoon season, and this was particularly noticeable among respondents from moderately and severely susceptible coastal villages. Prior studies also found that resilience is negatively correlated with resource loss (Kokorsch & Benediktsson, 2018) and environmental stressors in different settings (Uddin et al., 2020). Environmental stressors induced by SLR, such as saline ingress, coastal flooding, and agricultural damage, may have the capacity to reduce resilience, with the potential for this effect to be more prominent in the highly vulnerable coastal population.

Findings from this research also contribute evidence-based insights for policymakers to make long-term plans for local and national psychological health services to ensure sustainable and targeted programs for those affected by SLR and related environmental stressors. By revealing precise processes by which sea-level rise affects levels of distress in the Asia-Pacific, this research illuminates the relationships between environmental stressors, resource depletion, and psychological health. For instance, accessibility for women, older persons, and those with lower socioeconomic status must be guaranteed, as well as the requirement for psychological health treatments that are evidence-based, culturally safe, and sustainable. Sustainable and targeted programs for populations affected by SLR and associated calamities. As such, in line with priorities outlined by Sendai Framework for Hazard Risk Reduction 2015-2030 sought to enhance community health like economic and health resilience of individuals and communities (Kayano et al., 2019), this research clarified psychological health risks in the coastal areas of Asia-Pacific. Governments will be required to rapidly expand the availability of psychological health resources in high-risk settings. Cost-effective care approaches, such as task shifting and peer-support models (Johns et al., 2018), provide optimal models to ensure scalability and improve service access.

The International Federation of Red Cross and Red Crescent Societies (IFRC, 2023) provides psychosocial support in the study area, such as strengthening health facilities, community-based health programs, developing climate-resilient livelihoods, managing water resources sustainably, scaling up efforts to reduce hazard risk due to climate change, improving early warning systems, and increasing public awareness of hazard. Yet, there is still more to be done for effective psychological intervention by using available resources. A psychological health program successfully implemented in Sri Lanka, supported by WHO, in the wake of the 2004 Indian Ocean Tsunami provides insights into the delivery of effective interventions in low-resource settings (Minas et al., 2017). The 2004 Indian Ocean Tsunami wreaked havoc on South Asian coastal villages, especially in Sri Lanka, where 30,000 people died and 6,000 were never found (Lace, 2009). One aspect of their recovery and reconstruction effort involved offering medical officers a 12-month certificate program in psychosocial aid and community-based psychological health services which was helpful for the Sri Lankan Tsunami affected coastal community (Griggs, 2017).

Hence, in low- and middle-income countries where psychological health services are unable to manage the high level of psychosocial requirements, psychological interventions that are brief, acceptable, effective, and can be provided by non-specialists are especially needed (Jordans & Tol, 2013). For instance, Problem Management Plus (PM+) developed by the World Health Organization, a five-session intervention, is designed for people who live in difficult environments and experience psychological distress (Dawson et al., 2015). Individual PM+ has been effective in reducing distress in Kenya and Pakistan, and group PM+ has been effective for Pakistani women affected by conflict (Bryant et al., 2017; Dawson et al., 2016; M. Khan et al., 2019). PM+ has also been effective to improve psychological health in Nepal among adults in earthquake-affected communities (Sangraula et al., 2020). This is especially beneficial for coastal communities in Asia-Pacific region, where a lack of human resources are available to give adequate psychological health care (IPCC, 2022).

5.4. Way forward

The field of climate change and psychological health is growing rapidly. Based on the findings deduced from this work, further research is urgently recommended.

The effects of SLR on children's and adolescents' psychological health is a further area for empirical investigation. Young people have grown up observing the effects of SLR-induced climate change as well as the comparatively inert response from governments and non-governmental organizations (Roy et al., 2022; Van Ginkel et al., 2020). They are on the front lines of climate change (Laux, 2021). The rates of depression and anxiety are significantly worse for children affected by hazards than for adults, with long-term implications (Newnham et al., 2022). Despite growing calls for climate change action, such as through the global youth climate strike movement (Laux, 2021), this topic has not been explored in the literature.

Psychosocial adaptation and interventions to a changing environment due to sea-level rise may be another crucial research area. Adaptation and implementation of interventions must consider specific settings and environmental challenges to be most successful (Charlson et al., 2022). Designing evidence-based adaptation strategies are urgently needed in this area, and there are significant research gaps (Charlson et al., 2022).

Another recommendation is to investigate the risks, impacts, and response interventions related to SLR-vulnerable contexts and marginalized groups in middle- and high-income countries. It is commonly acknowledged that vulnerable groups and people in low-, middle-, and high-income nations are suffering disproportionately from the effects of climate change (Gibson et al., 2020; Hayes et al., 2018; Watts et al., 2019). Therefore, a climate justice strategy that acknowledges that climate change can have differing economic, social, public health, and other adverse impacts on underprivileged populations, is required, with measures anchored in health equity and active hope, acknowledging the structural and intersectional character of pre-existing disparities in psychological health (Hayes et al., 2019; Ingle & Mikulewicz, 2020).

It is encouraging that there is an increase in interest in this topic and that there are more calls for action and funding to understand how climate change affects psychological health. For example, in a briefing on Canadian policy for the Lancet Countdown on climate change, prominent Canadian health professionals have identified seven priority areas for public health sectors (Howard et al., 2018). One of these seven priorities was to increase financing for research into the effects of climate change on psychological health and potential for psychosocial adaptation (Howard et al., 2018). Another well-known example of increased awareness for action is the World Health Organization Thematic Platform Research Network's (Kayano et al., 2019; Newnham et al., 2022; Oktari et al., 2022) identification of five key priority areas for Health EDRM (health emergency and hazard risk management) that support calls for psychological health-specific hazard risk management evidence from the World Association for Hazard and Emergency Medicine (Kayano et al., 2019). Government policy and funding to address psychological health hazards in coastal areas of the Asia-Pacific region most vulnerable to SLR will be vital because it is projected that climate change would intensify environmental threats.

5.5. Conclusion

This Doctoral thesis provides the first large-scale longitudinal investigations of sea-level rise induced environmental stressors on psychological health in coastal communities in the Asia-Pacific region. This research, comprising a systematic review of the literature and a large-scale longitudinal survey, found evidence that SLR-induced environmental stressors (e.g., salinity, erosion, and flooding) were associated with resource loss which in turn impacted psychological health outcomes such as distress, depression, anxiety, and stress. Residents of the coastal communities highly susceptible to SLR, especially women and older adults, were especially vulnerable, and resource loss mediated the effects of SLR on psychological health, supporting the usefulness of the COR theory. This research urges a need for the integration of psychosocial support in hazard risk reduction policy and calls for accessible clinical interventions for communities affected by SLR amidst the growing threat of climate change. Therefore, this work contributes evidence-based insights for policymakers to make long-term plans for local and national psychological health services to ensure sustainable and targeted programs for communities affected by SLR and related climatic events. Future research is needed to explore the risks, impacts, and response interventions related to sea-level rise and psychological health that have policy implications and clinical applications that support climate change mitigation and adaptation in different cultural settings across the globe.

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