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Sonia Akter and Bishawjit Mallick

Department of Economics, Helmholtz Centre for Environmental Research – UFZ, Institute of Regional Science (IfR), Karlsruher Institute of Technology (KIT), 76131, Karlsruhe, Germany

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Sonia Akter[a*] and Bishawjit Mallick[b]

[a]Department of Economics, Helmholtz Centre for Environmental Research – UFZ, Permoserstraße 15/04318, Leipzig, Germany.

[b]Institute of Regional Science (IfR), Karlsruher Institute of Technology (KIT), 76131, Karlsruhe, Germany.

[*]Corresponding author's e-mail: sonia.akter@ufz.de, phone: +49-341-235-1846, fax: +49-341-235-1836.

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Abstract

This paper presents an empirical investigation of socio-economic resilience to natural disasters of a tropical cyclone-prone coastal community in Bangladesh. It applies the state-and-transition model, a widely used applied ecology model, to (1) assess the current state of socio-economic resilience to tropical cyclone, (2) identify its drivers and (3) examine its nexus with poverty and socio-economic vulnerability. The results of this study can be summarized into three key findings. First, tropical cyclones had significant negative medium-run impacts on coastal residents' lives and livelihoods, particularly in terms of income, employment and access to clean water and sanitation. Second, the loss of productive assets, human capital shock, credit constraint and proximity to the forest reserve were the key factors explaining resilience heterogeneity across households. Finally, although the poor were the most vulnerable and suffered from relatively higher economic, physical and structural damage, they exhibited relatively better ability to cope and recover from the shock compared to the non-poor. These findings imply that the increased risk of tropical cyclone is likely to reduce income and standards of living among the tropical coastal communities. However, the burden of these adverse impacts is unlikely to be disproportionally borne by the poorer segment of the society.

Key words

State-and-transition model, socio-economic vulnerability, socio-economic resilience, natural disasters, tropical cyclone, Bangladesh

Highlights:

- This paper develops a state-and-transition model for assessing socio-economic resilience to natural disasters.
- The model provides the opportunity to incorporate a broader spectrum of resilience dynamics.
- We present the first empirical study that tests the nexus between socio-economic vulnerability and resilience.
- Our results suggest that high vulnerability does not necessarily imply low resilience.

1. Introduction

Natural disaster risk management frameworks have witnessed a paradigm shift in recent years: evolving from a process of providing a one-off emergency response towards a proactive and holistic disaster risk management system. One of the defining characteristics of this new paradigm is its emphasis on building climate-resilient societies by enhancing the capacity of vulnerable people to cope with environmental hazards.

Vulnerability is the susceptibility of groups or individuals to harm from social or environmental change (IPCC, 2012). The term 'resilience' is originated in the discipline of ecology and refers to an ecosystem's ability to absorb and recover from the occurrence of a hazardous event. Elasticity, the ability to bounce back or rebound is also commonly used to describe resilient ecosystems (Folke, 2006). This concept gained prominence in the social science disciplines after the adoption of 'Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters' − a multilateral agreement on integrated disaster risk management signed by 168 countries at the World Conference for Disaster Reduction in Kobe, Japan, in 2005. The Hyogo Framework for Action compiles an internationally agreed set of targets and priorities to be implemented for disaster risk management and to be used for measuring individual country's progress in disaster risk reduction. It urges on building community resilience rather than reducing vulnerability solely.

Despite being frequently used in the contemporary policy discourse and its overriding dominance in the multilateral agreement on global and national disaster risk management frameworks, the empirical understanding of socio-economic resilience is limited (Gallopi´n, 2006; Cutter et al., 2008a). There has been a surge of empirical research on social vulnerability over the past decades (see for example Adger, 1999; Adger, 2006; Brouwer et al., 2007; Cutter and Finch, 2008c; Hahn et al., 2009). These studies devised frameworks and indices for measuring static and dynamic vulnerability, identified the sources of vulnerability and examined its nexus with poverty and adaptive capacity. The handful of empirical studies that addressed socio-economic resilience to natural disasters have confined themselves to the study of adaptive strategies (i.e. ex-anti measures) (Tadele and Manyena, 2009; Sharma et al., 2009) and effectiveness of coping capacities (i.e. ex-post measures) (Van den Berg, 2010; Alam and Collins, 2010; Paul and Routray, 2011). Some studies focused on the role of a specific strategy such as microfinance, out-migration and remittance in determining households' ability to rebound after a disaster (Parvin and Shaw, 2012; Mallick and Vogt, 2012; Mohapatra et al., 2012).

In the context of the increased risk of natural disasters all over the world and the new paradigm of disaster risk management that centers on building resilient societies, an enhanced and in-depth understanding of the dynamics of socio-economic resilience is becoming increasingly eminent (Cutter et al., 2008a). In particular, three questions deserve urgent attention: (1) What is the current state of socio-economic resilience to natural disasters? (2) What are the drivers of resilience or the lack of it? (3) How does resilience interact with poverty and socio-economic vulnerability? The first question is about short- to medium-run impacts of natural disasters on the lives and livelihoods of the communities that are at risk of recurrent natural hazards. This knowledge will help understand the magnitude to which climate change induced hazard risks are going to impact the lives of the communities that live on low-lying flood-plains and coastal deltas. The second question is about understanding how resilience varies across the socio-economic groups living within a community and what type of policy adjustment would eliminate the discrepancy (if any) by better preparing them to adjust to the changes invoked by a hazard.

The last question (i.e. the nexus between poverty, vulnerability and resilience) has recently gained significant ground in the disaster risk literature due to the ongoing intellectual debate about the degree of overlap between vulnerability and resilience. Some scholars consider vulnerability as the flip side of resilience (Galderisi et al., 2010; Cannon, 2008). Others argue that resilience and vulnerability are fundamentally different concepts (Gallopi´n, 2006; Cutter et al., 2008a; Sapountzaki, 2012). They are linked or mutually interacting but the specific nature of their interplay is not obvious (Gallopi´n, 2006; Cutter et al., 2008a). Gallopi´n (2006) refers to resilience as an internal property of the system leading to state shifts while vulnerability arises from external sources and leads to changes in the system. Sapountzaki (2012) defines resilience as a catalyst for vulnerability change, transfer and transformation.

This long standing debate clouds our understanding with regards to the way the relatively longer term impacts of natural disasters will be distributed across the poor and non-poor groups. The former case, where resilience is considered as the flip-side of vulnerability, implies that highly vulnerable communities (i.e. the poor and marginalized) are also less resilient. Therefore, the immediate (physical, economic and structural damage) as well as the longer term impacts (e.g. lower income, unemployment and lower standard of living) will be born disproportionately by the poorer segment of the society. The latter case implies that vulnerability and resilience follow distinct paths, and hence, high vulnerability does not necessarily lead to low resilience. More specifically, the poor and marginalized may bear the larger share of the immediate impacts of a natural disaster; but they might be resilient enough to avoid its longer term consequences.

Given this background, this paper presents a case study that empirically examines these three questions. It uses household survey data collected from a low-income coastal community in Bangladesh which was battered by a tropical cyclone in 2009 (Cyclone Aila). Applying an adapted version of the state-and-transition model, a widely used applied ecology model, we assessed socio-economic resilience in five temporal phases over a period of one year. The first and last phases are the pre- and post-disaster steady states. The intermediate phases (i.e. preparedness, resistance, coping & recovery) define the trajectory that leads the transition between the two steady states. The results indicate that the cyclone had negative impacts on the community, particularly in terms of income, employment and access to clean water and sanitation. Consistent with the findings of the social-vulnerability literature, our results also suggest that the poor were more vulnerable and they suffered significantly higher economic, physical and structural damage. However, high vulnerability did not necessarily lead to low resilience as the poor exhibited a greater ability to withstand the shock and a higher capacity to bounce back to the pre-cyclone steady state compared to the non-poor. This refutes the flip-side relationship hypothesis of vulnerability-resilience inter-relationship and implies that the relatively longer-term burden of environmental risks is unlikely to fall disproportionately on the poor.

The remainder of this article is organized as follows. Section 2 outlines the analytical framework used to assess socio-economic resilience. Section 3 describes the context of the case study followed by a description of the study area and the survey. Sections 4 to 9 present the empirical findings. Section 10 discusses the results and presents concluding remarks.

2. Framework for Resilience Assessment

A widely accepted framework of resilience assessment currently does not exist (Mayunga, 2007; Cutter et al., 2008a). The existing frameworks vary depending on their underlying definition of resilience. The next subsection presents an overview of the available frameworks of resilience assessment followed by a discussion of the state-and-transition model in the succeeding sub-section.

2.1. Existing Frameworks

There are two approaches that are commonly applied to explain disaster resilience in human communities: (1) outcome; and (2) process. The outcome based approach defines resilience as the ability to withstand and recover from a hazard (Simon, 2007). The resilience assessment framework used by DFID (2011) entails four possible states. The best case is ‘bounce back better’ which implies that the household is better able to deal with future shocks and stresses than it was in the past. The second-best case is ‘bounce back’ to status quo or the pre-event condition. ‘Recover, but worse than before’ refers to a decreased capacity relative to pre-event status and ‘collapse’ refers to the worst-case scenario where the household exhibits a catastrophic reduction in their capacity to cope with future shocks.

The process based approach describes resilience as a mechanism of self-organization, the capacity to learn from experience, to process information and adapt accordingly (Resilience Alliance, 2005). This approach uses pre-disaster socio-economic conditions as measures of resilience. Mayunga (2007) recommended a framework that combines the pre-disaster states of five major forms of household/community capital: social (trust, norms, networks); economic (income, savings and investment); physical (housing, public facilities, business/industry); human (education, health, skills, knowledge/information); and natural (resources stocks, land and water, ecosystem). Cutter et al. (2008b) proposed the Pre-Event Resilience Measurement Model, which defined resilience as a function of three vulnerability dimensions (i.e. social, structural and environmental) and mitigation measure. The indicators of social vulnerability are race, age and economic status and the structural vulnerability indicators are factors such as construction materials of housing units; the number of commercial establishments; and the availability of lifelines such as the number of hospitals, schools, and electric power facilities. Potential variables for environmental vulnerability include storm surge inundation zones, 100-year flood zone delineations, and the amount of water-resistant surfaces. Mitigation in Cutter et al.'s (2008b) model refers to households' capabilities and assets as well as any conscious or deliberate actions taken by a community prior to, during, or after an event.

Forgette and Boening's (2010) '4 Rs' model accounts for the phases in between pre-event status and post-event outcome, and measures resilience by assessing household capacity in terms of risk recognition, resistance, redundancy and rapidity. Risk recognition is the degree to which households recognize the risk of a natural disaster. Resistance is the strength of a system to withstand disruptions from a natural disaster (i.e. extent of damage). Redundancy is the extent to which structural, environmental and socio-economic conditions permit substitutes or resources for the replacement of critical goods and services (e.g. food, water, medical supply, credit etc.) and rapidity is the degree to which individuals/groups within a community have access to internal and external agents that promote long-term recovery (e.g. time for accessing aid).

The DROP model proposed by Cutter et al. (2008a) defines resilience in terms of pre-event (or baseline) conditions as well as post-event processes. The model measures the impact of a hazardous event as the sum of pre-event or base-line conditions, event characteristics and coping capacities. The baseline conditions are static snapshots of household characteristics determined by the social, natural and built environment systems at time t=0. The post-event processes capture the dynamic notion of resilience by including mitigation and coping capacities such as cyclone shelters, early warning and emergency response plans.

2.2. The State-and-Transition Model

The frameworks discussed in the previous section form a spectrum. While the pre- and post-event based frameworks lie at the two ends of the spectrum, the DROP model (Cutter et al., 2008a) and Forgette and Boening's (2010) '4 Rs' model lie somewhere in the middle. There does not currently exist a single model that covers the full spectrum of all of the scientifically accepted aspects of disaster resilience. Hence, we use the state-and-transition model as it accommodates a broader spectrum of the resilience dynamics. The state-and-transition model, first developed by Westoby et al. (1989), is widely used in the applied ecology discipline. The model defines a state as a recognizable, resistant and resilient complex of a rangeland ecosystem. The borders of each possible state in space and time are called the threshold. Once the threshold is crossed due to environmental or human induced disturbances, the state loses its fundamental ecological characteristics beyond the point of self-repair. This initiates a process of transition to a new state with different ecological characteristics (Stringham et al., 2003).

We modify the applied ecology model to make it useful for understanding socio-economic resilience to natural disasters. We assume that households live close to a stable steady state at time t=0. Exogenous environmental shocks (e.g. cyclones or floods) may invoke a level of devastation that exceeds households' capacity to maintain the pre-cyclone steady state. If so, this triggers a transition as households cross the threshold and move from one steady state to another.

Briske et al. (2005) categorized ecological thresholds into two general groups: structural and functional. In applied ecology literature, the former refers to changes in community composition or spatial distribution of vegetation, while the later implies positive or negative changes in various ecological processes (e.g., soil and hydrologic properties, nutrient cycling and productivity). Translating these concepts into appropriate social science indicators poses a considerable challenge since ecological and socio-economic processes are not directly comparable. However, the concept of a structural threshold in a socio-economic context can be interpreted as changes in structural vulnerability (e.g. housing structure, access to water, sanitation and electricity). Likewise, a functional threshold can be viewed in terms of changes in fundamental socio-economic characteristics such as income, employment, inequality and so on.

In order to structure our analysis, we divide the state-and-transition process into five temporal phases by applying the logic commonly used in a disaster management cycle; pre-event steady state, preparedness, resistance, coping, recovery and post-event steady state (Figure 1). Table 1 summarizes the indicators used for each of these phases. Pre- and post-event steady states are defined as two states at time t=0 and t=1 respectively. The combined phases of preparedness, resistance and coping can be compared with the notion of a trajectory that navigates the transition between the two steady states. Pre- and post-event steady states are separated by functional and structural thresholds. A range of socio-economic and household characteristics can be used as indicators of functional and structural thresholds. These indicators may vary depending on the case study context and the community in questions. For the purposes of this study we used the following indicators: income, expenditure, employment, housing structure and access to clean water, sanitation and electricity.

INSERT FIGURE 1 HERE

INSERT TABLE 1 HERE

As shown in Figure 1, the different phases of this temporal process are likely to be inter-linked through poverty. Pre-event vulnerability indicators are expected to influence households' level of preparedness (or adaptive capacities) as more vulnerable people are expected to be less prepared (Brouwer et al., 2007). Further, both pre-event vulnerability status and the level of preparedness are likely to influence resistance, i.e. higher exposure combined with a lack of preparedness is likely to cause higher damage (Fothergill and Peek, 2004). Likewise, each of these three components (i.e. pre-event vulnerability, preparedness and resistance) is expected to be correlated with households' capacities to cope and recover. For example, empirical evidence shows that the beneficiary targeting process of post-disaster emergency relief distribution is often politically negotiated through the established elite networks of a village or community (Harvey and Lind, 2005). Therefore, people with low or no elite contacts may have difficulty accessing relief and recovery aid. Finally, the nature and magnitude of interactions between the indicators for all four phases are likely to determine the transition path. More specifically, all or some of the key indicators for these four phases act as forces that breach the thresholds and initiate the transition across steady-states.

3. Description of the Case Study

3.1. The Context

Tropical cyclones associated with strong winds, high waves and storm surges are the most destructive weather systems that impact on coastal areas (Kuleshov et al., 2012). Historical trend analysis suggests that the intensity and destructiveness of tropical cyclones markedly increased over the past 30 years (Emanuel, 2005; Elsner et al., 2008). This trend is projected to continue over the next 20 years exacerbating disaster risk for the poorest inhabitants of the countries along the Indian Ocean (Peduzzi et al., 2012).

Bangladesh, a low-lying deltaic country located on the northern Indian Ocean, is ranked as the most vulnerable country to tropical cyclone risk (Peduzzi et al., 2012). Approximately 75 percent of the total population of Bangladesh lives in rural areas, earning an average of US$1,300 per household per year (BBS, 2010). The southern part of the country borders the Bay of Bengal forming a 600 km long coastline. The coastal belt comprises 30 percent of Bangladesh’s geographical area and is home to a third of the country’s population. In addition to high population density, the overwhelming majority of the coastal residents are poor who live in weakly built houses (BBS, 2010).

Bangladesh's coast witnessed 14 serious cyclones in the last 25 years and, of these, three (Bhola in 1970, Gorky in 1991 and Sidr in 2007) were catastrophic (Khan, 2008). Cyclone Bhola and Cyclone Gorky are amongst the two deadliest tropical cyclones on record.

Given the country's high vulnerability to tropical cyclone risks and the high economic and social damage inflicted by the previous cyclones, national and international efforts have been intensified over the past decades to minimize the impacts of these weather events on coastal communities. The Government of Bangladesh, together with national and international agencies, implemented the Comprehensive Disaster Management Plan (CDMP) in 2003. The CDMP aims to achieve disaster resilience by shifting its focus from ex-post relief and recovery to disaster risk minimization through capacity building, partnership development and community empowerment (Haque et al., 2012). Some of these strategies, e.g. improving the early-warning system, building shelters, cyclone preparedness training and reforesting coastal areas, drastically reduced cyclone fatalities (Peduzzi et al., 2012). Between 1991 and 2007, cyclone related death toll decreased 100-fold (from 140,000 in 1991 to 3,400 in 2007) (Paul, 2009).

Despite this overwhelming success in curbing human fatalities, property and livelihood damage risk is on the rise since 1970 as a result of high level of poverty and increasing population pressure (Peduzzi et al., 2012). Further, the amount of financial, physical and human resources devoted towards disaster management in Bangladesh are inadequate, poorly managed and often mistargeted (Haque et al., 2012; Mahmud and Prowse, 2012).

For instance, the central government-led post-disaster response and recovery programs are characterised by a strong presence of corruption and a lack of intra-agency partnership and coordination (Haque et al., 2012; Mahmud and Prowse, 2012). The combinations of these factors, (i.e. high degree of vulnerability, inadequate resource and poor governance) tend to impede post-disaster recovery and rehabilitation, in some cases contributing to increased sufferings and social damage.

3.2. The Study Area

The data used for this study was collected from a coastal community located on the southwest coast of Bangladesh (Shyamnagar, a sub-district of Satkhira district) (Figure 2). The area is situated within a unique geo-ecological setting which borders the Sundarbans, the largest mangrove forest reserve zone in the world, and the Bay of Bengal. The area has been listed as UNESCO's World Heritage Site since 1999.The district is around 2,000 km^2 in size and is home to three million people. Non-mechanized agricultural farming and aquaculture are the main livelihoods here. Villagers living closest to the mangrove (bordering the coast) are the poorest and depend on mangrove resources for livelihood and income generation activities, such as timber harvesting, honey and wax production, eco-tourism, extraction of poles and posts for fuel wood (Hussaine and Badola, 2010). The Department of Forestry manages the reserve by allocating access permits in certain parts of the reserve and prohibiting access to specific areas at specific times of a year. However, weak enforcement of these restrictions allow illegal logging and widespread overexploitation of fisheries and non-timber forest resources.

On May 25 2009, the region was struck by a Category I tropical cyclone (Cyclone Aila) that generated 120 km/h wind speed and a storm surge three meters above the normal astronomical tide. Eleven out of the 19 coastal districts were severely affected. The cyclone claimed 190 lives, injured 7,000 people, killed 100,000 livestock and caused US$170 million worth of economic damage (UNDP, 2010). Nearly 350,000 acres of crop were destroyed, 500,000 houses were destructed, 8,000 kilometres of road were fully or partially damaged and around 1,400 km of coastal embankments were washed away (UNDP, 2010). Following Cyclone Aila, the central government distributed relief assistance including food, cash, drinking water, emergency medicine and other non-food materials to the affected communities. Ninety percent of the assistance was distributed under the Government's existing safety-net networks such as Vulnerable Group Feeding, Vulnerable Group Development and Gratuitous Relief. Some of these assistances continued until 2010. The central Government also rolled out a 40-day 'Cash for Work' program in the affected districts to generate post-cyclone employment. Although no official appeal was made for international assistance, the international community extended their generous support by supplying relief and rehabilitation aid to the affected communities.

INSERT FIGURE 2 HERE

One year after the devastation caused by Cyclone Aila, a household survey was administered in one of the worst affected coastal sub-districts (Shyamnagar). Around 300 structured interviews were conducted in 12 villages (Figure 1). A random sampling procedure was followed where every 15th household along the village road was approached for an interview. A draft questionnaire was prepared after two focus group discussion sessions and interviews with local experts (government and non-government workers, village leaders and school teachers). The questionnaire was finalized after two subsequent rounds of pre-tests in the study area. The final questionnaire consisted of around 30 questions which were divided between one general section and three specific sections. The general section contained questions about demographic characteristics while the remaining sections contained questions about household income, consumption, wealth and standard of living before and after Cyclone Aila. Respondents were also asked about physical and economic damages incurred due to the cyclone, the ex-ante and ex-post measures employed to cope with it, and the nature and extent of the support received from government and non-government organizations (NGOs). Sampled households' locations were recorded using GPS. This allowed the measuring of distances from the shoreline, mangrove reserve and the road-river networks.

4. Pre-event Socio-economic Vulnerability

This section presents the pre-event vulnerability assessment of the sampled households. The pre-event vulnerability is assessed by combining Mayunga (2007)'s capital based model, Cutter et al.'s (2008a) DROP model and Cutter et al.'s (2008b) Pre-Event

Resiliency Measurement model. Table 2 presents a description of the variables used to measure the indicators in each of these categories.

INSERT TABLE 2 HERE

Eighty-nine percent of the sample was Muslim while the remaining 11 percent were from the minority Hindu religion. Over one-third (40%) of the respondents were unable to read and write. The average per capita income equaled US$15 per month, slightly higher than the national average rural per capita income of US$14 (BBS, 2005). The average size of cultivable land owned by households was five hectares while 50 percent of households owned less than three hectares of agricultural land. As expected, a significant positive relation was observed between monthly household income and farm size ($r=0.15$, $p<0.001$) implying that households earning a larger monthly income, on average, also owned a larger parcel of arable land. Day laborers earned significantly lower incomes (US$48) than self-employed and salaried individuals (US$100) ($Z=2.6$, $p<0.01$). They also owned significantly smaller parcels of agricultural land (3 hectares) compared to the remainder of the sample (7 hectares) ($Z=2.1$, $p<0.05$).

Forty-one percent of sampled households were recorded as living below the poverty line before the cyclone. The poverty line measure was calculated by applying the Cost of Basic Need (CBN) income threshold (US$105 per capita per year) recommended by the Bangladesh Bureau of Statistics (BBS, 2005). The CBN income comprises the values of both food and non-food items needed to satisfy minimum subsistence. Households living below the poverty line were significantly more likely to be illiterate, to be from a minority religious community, to have a significantly larger household size, and a relatively smaller parcel of farmland. A significantly larger proportion of households living below the poverty line were day laborers and were significantly less likely to have access to electricity or own a television or private vehicle. Over one-third (38%) of respondents had no contact with the social elites (e.g. government officials, NGO workers, villages leaders, school teachers or religious leaders). The rest of the sample had at least one contact. No significant difference in elite contacts was observed across households' income and assets. Some differences were observed across religion and occupation; with Muslims significantly more likely to be acquainted with the religious leaders and self-employed households more likely to be acquainted with government officials.

Over two-thirds (68%) of the houses were built with mud, bamboo or golpata. These houses are locally known as 'kacha' houses. The remaining houses were built with concrete and wood. These houses are called 'pucca' houses by local people. Households who lived in pucca houses earned significantly higher monthly incomes and owned significantly larger parcels of farmland (income: $Z=-4.5$, $p<0.001$; land: $Z=-1.9$, $p<0.10$).

On average, each household lived within 45 minutes walking distance of a cyclone shelter, seven kilometers from the village market, seven kilometers from the main (pucca) road and 600 kilometers from the main river. A significant negative correlation was observed between distance to the cyclone shelter and monthly household income (r=-

0.15, $p<0.05$); implying that relatively richer households lived closer to the shelters. On average, the sampled households lived within five kilometers of the mangrove forest; a quarter lived less than two kilometers from the forest and 50 percent lived within five kilometers. Relatively poorer households lived closer to the mangrove forest. Households who lived within two kilometers of the forest earned less (US$62 per month) than those who lived further away (US$86 per month) (Z=-8, $p<0.001$).

5. Cyclone Preparedness

Only 11 percent of the sampled households attended cyclone preparedness training before Cyclone Aila. Over three-quarters of those who attended the cyclone preparedness training were from above poverty line with the rest from below (Chi square=5, $p<0.05$). Almost two-thirds (65%) of respondents did not receive early warning of Cyclone Aila. Two thirds of those who received early warning were also from above poverty line and the rest below (Chi square=6, $p<0.05$). Television ownership had a significant positive correlation with the likelihood of receiving early warning (r=0.27, $p<0.001$) while owning a mobile phone had no significant correlation with early warning reception (0.07, $p=0.85$).

A quarter of the sampled households (26%) did not evacuate during Cyclone Aila; either staying at home or sheltering in neighbors' houses. Around a quarter (22%) of those who went to cyclone shelters were not allowed entry due to a lack of adequate space. Distances to the nearest cyclone shelter (measured in terms of travel time) and the major river had a significant correlation with evacuation decisions (travel time to the cyclone shelter: Z=-6.50, $p<0.001$; distance from the main river Z=2.6, $p<0.001$). Households living closer to the main river were significantly more likely to evacuate. A significantly (Chi square=7, $p<0.01$) higher proportion of those who attended the preparedness training went to a cyclone shelter (94%) as opposed to those who did not (71%). A significantly larger proportion of those who evacuated owned a private vehicle (Chi square=3, $p<0.10$).

6. Cyclone Resistance

On average, each household suffered US$355 of economic damage; equivalent to 37 percent of the sample's average yearly household income. Households who lived below the poverty line incurred significantly higher relative economic damage (damage as a proportion of income) (Table 3).

INSERT TABLE 3 HERE

Half of the sampled respondents' houses were completely destroyed. Sixteen percent of the sampled households (n=45) experienced physical damage with five deaths across four households and 59 injuries across 41 households. Although no statistically significant relationship was observed between the number of children and elderly people, and the number of deaths and injuries experienced by households, women were more likely to be injured in households that had a higher number of infants and elderly people (r=-0.12,

$p<0.05$). This is because women are generally responsible for ensuring the safety of children and elderly people. Their mobility during emergency is also significantly impaired by traditional long clothing (*saree*) and long hair.

Physical, economic and structural damages were significantly positively correlated. Households who did not experience any physical damage (no injuries or fatalities) incurred an average of US$320 economic damages, significantly ($Z=-4.5$, $p<0.001$) lower than the average economic damages incurred by households who also experienced physical damages (US$533). The significant relationship between economic and physical damage persisted even when median damage and distributions of damage across the two groups were considered. Likewise, households with no physical damage reported significantly lower structural damage (65%) compared to those households who experienced some form of physical damage (75%) ($Z=-1.75$, $p<0.10$). A significant positive correlation was observed between economic and structural damage ($r=-0.21$, $p<0.001$). This suggests that households who experienced higher economic damage, on average, also experienced higher damage to their houses.

Physical, economic and structural damages were significantly positively correlated with structural and environmental vulnerabilities. On average, the kacha houses suffered significantly higher damage than the pucca houses (Table 4). Further, households who lived in kacha houses were significantly more likely to experience fatality or physical injury as well as higher economic damage (Table 4). Proximity to the shoreline had statistically significant negative association with economic and structural damages.

Households who lived further away from the coast suffered from significantly lower absolute (r=-0.15, $p<0.001$) as well as relative economic damage (r=-0.13, $p<0.001$). The percentage of damage to houses was also higher for households who lived closer to the coast (r=-0.14, $p<0.001$). While the correlation coefficient between physical damage and distance to the coast was negative, implying that households who lived closer to the coast experienced higher cases of fatalities and injuries, it was not statistically significant at the ten percent level (r=-0.05, $p<0.30$).

INSERT TABLE 4 HERE

Distance from the cyclone shelter (in terms of travel time) and cyclone preparedness training had no significant correlation with physical or economic damage. However, a statistically significant negative relationship was observed between the failure to access a cyclone shelter and the likelihood of physical injury (r=-0.16, $p<0.05$); implying that those households who wanted to access shelters but were unable to, were more likely to experience death or injury.

7. Coping and Recovery

A number of interesting facts were observed while examining households' capacities to access post-disaster emergency relief and rehabilitation aid. First, as expected, statistically significant positive relationships were observed between elite contacts and ability to access emergency relief. Households who had a connection with the socio-political or religious network of the region (i.e. higher number of elite contacts), could access food and medical supplies faster (food: r=-0.24, $p<0.001$; medicine: r=-0.28, $p<0.001$). Second, poor and minority communities had relatively faster access to certain types of emergency relief than the rest; households living below the poverty line could access emergency food relief quicker than those who lived above the poverty line (r=-0.18, $p<0.001$). Being from a minority religious community increased the likelihood of receiving all types of emergency relief, particularly food (all relief: r=0.14, $p<0.05$; food: r=0.18, $p<0.001$). Third, the distance from the main village road had a significant negative association with the rapidity of access to relief (r=-0.24, $p<0.001$). Households who lived further away from the main (pucca) village road experienced delays in accessing emergency assistance. This is because areas that do not have a pucca road lacked accessibility due to wind and storm damages.

Interestingly, economic damage had no statistically significant correlation with rapidity of access to emergency relief, although physical and structural damages had a significant positive association with it. Households whose houses were severely damaged, on average, could access all forms of emergency relief faster than the rest (r=-0.14, $p<0.05$). Likewise, households who had suffered death or injury were able to receive medical assistance/supplies significantly faster than those who did not suffer physical damages (r=-0.16, $p<0.001$). A similar trend was observed in the case of rehabilitation aid (provision of construction material for houses). Households who accessed rehabilitation aid, on average, suffered from a significantly higher proportion of house damage (86%) than those who could not access it (73%) (Z=-3.5, $p<0.001$). Those households who had contacts with government officials were more likely to receive house construction materials in the areas where aid was distributed by the central government (r=-0.18, $p<0.001$).

Only ten percent of those who suffered from economic, structural or physical damage borrowed money from microcredit organizations. All of these households who borrowed money were acquainted with local NGO workers and 50 percent of them borrowed money even before the cyclone. The average loan size was US$875 with a minimum of US$35 and a maximum of US$4,000. No statistically significant difference was observed between the likelihood of borrowing money and the extent of physical, economic or structural damage incurred by households. Pre-cyclone income or assets also had no statistically significant correlation with the likelihood of borrowing or the size of the loan. This low penetration of post-cyclone microcredit is likely to be the outcome of the liquidity constraint experienced by the microfinance institutions in the wake of a large-scale covariate shock. The widespread loan default triggers intense competition for the limited credit, thereby creating opportunities nepotism.

8. Pre- and Post-cyclone Steady States

Table 5 compares the key characteristics of the pre- and post-cyclone steady states in the study area during 2009 and 2010 with regards to a number of indicators representing functional and structural thresholds. It also presents 2010 statistics for the broader administrative region within which the study area is located (Khulna Division). The cyclone appeared to have caused significant breaches in the functional and structural thresholds. The proportion of households living below the poverty line increased from 41 to 64 percent in 2010. This number is much higher than the average CBN poverty rate of the west-coastal division in 2010 (32%) (BBS, 2011). Eleven percent of the households who were poor before (n=12) moved out of poverty after the cyclone while 46 percent of the non-poor (n=75) fell below the poverty threshold. Both average household income and income per person declined significantly after the cyclone. Fifteen percent of the sampled households reported a higher monthly income while over 40 percent of the households experienced a decline in income between 5 to 40 percent, and a quarter reported incomes over 40 percent lower. A quintile of the sample earned the same income before and after the cyclone. Households who were below the poverty line before the cyclone experienced significantly lower income shocks (-5%) than those who were above the poverty line (-28%) (Z=6, $p<0.0001$).

INSERT TABLE 5 HERE

Unemployment increased from 11 to 60 percent following the cyclone. No significant correlation was observed between post-cyclone employment and pre-cyclone poverty status. As expected, those who became unemployed experienced a significantly higher income shock (-30%) than those who were employed (-15%) (Z=3, $p<0.001$). Improvement was observed in terms of structural conditions, with over 20 percent of the kacha houses being rebuilt with relatively stronger materials (i.e. wood) after the cyclone. Structural and economic resilience did not go hand in hand. Households who exhibited higher structural resilience, on average, suffered from significantly higher income shocks (-28%) than those whose structural conditions remained unchanged (-16%) (Z=-2.3, $p<0.05$). No significant correlation was observed between structural resilience and a change of employment status.

Households' access to sanitation, clean water and electricity significantly declined after the cyclone. The loss of clean water access was more substantial than the loss of access to sanitation and electricity. A significantly higher proportion of the households who were above the poverty line before the cyclone (23%) lost their access to clean water compared to those who were below the poverty threshold (9%). Post cyclone income growth and access to water was significantly negatively correlated implying households who experienced a positive income growth were significantly more likely to have lost access to clean water (Z=3.30, $p<0.001$). The loss of access to water and sanitation was significantly positively correlated, implying that households who lost access to clean water was also more likely to lose access to sanitation (r=0.12, $p<0.05$). These households lived significantly closer to the coast than those who restored their access to water and sanitation in the post-cyclone steady-state (water: Z=-4, $p<0.001$; sanitation: Z=-3.7, $p<0.001$). Households who lost access to sanitation experienced significantly higher structural damage (Z=-3.5, $p<0.001$). The loss of access to drinking water was not correlated with structural damage. However, households who were acquainted with the local NGO workers were significantly more likely to restore their access to clean water after the cyclone.

9. Identifying the Drivers of Change

This section presents the results of three regression models. Table 6 presents the results of a difference-in-difference model of income growth that controls for time-varying as well as fixed household level heterogeneity. We define $\ln Y_{it}$ as the natural logarithm of income per capita for household i in pre-event steady state. $\Delta \ln Y_{it+1,t}$ is the growth rate of income per capita in the household i between post and pre-event steady states. With regards to time-varying variables (i.e. physical and economic damage), we observe a statistically significant negative impact of male family members being affected (injured or died) by the cyclone on income growth. Households who experienced an injury and/or fatality of a male member, on average and other things remaining the same, experienced 26 percent decline in post-cyclone income. Absolute economic damage had no significant impact on income growth. Hence, we used economic damage per hectare of land as an indicator of relative damage. Households who experienced higher relative economic damage, on average and other things remaining the same, experienced significantly higher income growth in the post-cyclone steady state.

INSERT TABLE 6 HERE

Among the fixed variables, household head's occupation, number of elderly family members (aged 60+) and distance from the mangrove forest significantly influenced post-cyclone income growth. Self-employed households and salaried individuals experienced a significantly lower growth in income compared to day laborers. Households with higher dependents (members aged 60+) were more likely to experience a negative income growth. A distance-decay relationship existed between income growth and proximity to the mangrove forests. With each kilometer increase in distance from the mangrove forest, average sampled household income declined by 14 percent. The slope of the decay function was positive implying the weakening of the distance-income nexus with each additional kilometer increase in distance. This pattern is due to the availability of informal and ad-hoc income generation options to the forest fringe dwellers which arises as the local authorities relaxes the stringent restrictions to access the reserve after the cyclone (Zohora, 2011). Religion, access to microcredit, education, elite contacts and social safety nets had no statistically significant influence on post-cyclone income growth.

Model 1 in Table 7 identifies the determinants of unemployment using a binary logit regression model. The dependent variable in Model 1 was coded zero if the head of the household was employed before and after the cyclone and one if they were employed before the cyclone but became unemployed afterwards. Households who experienced an injury and/or fatality were more likely to become unemployed in the post-cyclone steady state. Day laborers were more likely to be employed relative to self-employed and salaried individuals. This finding is consistent with the previous regression results (Table 6) which showed day laborers experienced significantly positive income growth compared to individuals from other occupations. This is because day laborers are more flexible across different employment options than self-employed and salaried individuals. For example, an agricultural day laborer can work as a construction worker or in a shrimp firm while self-employed and salaried individuals are tied to a specific type of employment. The loss of livestock and damage to crops influenced the likelihood of employment significantly negatively. Access to post-cyclone microcredit and higher marginal propensity to save before the cyclone significantly and positively influenced the likelihood of being employed.

INSERT TABLE 7 HERE

As was observed in case of income growth, a distance-decay relationship persisted between employment and mangrove forests. However, the direction of the relationship was the opposite. Households living closer to the mangrove forest periphery had significantly fewer employment opportunities than those who lived further inland. This apparent inconsistency can be explained by two opposing factors. The severely damaged road-river networks caused significant delays in the launch of the low paid (US$1.5 per day) post-cyclone employment generation programs run by the local government and NGOs in the villages close to the mangroves (Oxfam, 2012). As a result, households who lived closer to the mangrove did not have any formal employment, yet they managed to earn income through extraction of forest resources as the access restrictions to the forest were relaxed following the cyclone.

Model 2 in Table 7 examines the drivers of higher structural resilience. The model uses a dummy dependent variable that is assigned a value of 1 if households had a kacha house before the cyclone and a pucca house after, and 0 if they lived in a kacha house before and after the cyclone. The decision to build a pucca house was dictated, to a large extent, by households' willingness to protect their family, livestock and property (house) against future hazards. Elite contacts had a significant positive relationship with higher structural resilience implying that households who had stronger connection with the local elites had higher access to relief and rehabilitation aid that enabled them to rebuild better. Finally, a statistically significant positive relationship was identified between distance from the mangrove and higher structural resilience implying those who were the least environmentally vulnerable were also significantly more likely to be structurally resilient.

10. Discussions and Conclusions

The main objective of this paper was to empirically assess socio-economic resilience to natural disaster and enhance our understanding of the nexus among poverty, vulnerability and resilience. To this end, we applied a state-and-transition model of disaster risk that assesses resilience in five temporal phases. Empirical testing of the proposed state-and-transition model was carried out using the data collected from a low-income coastal community in Bangladesh which was struck by a devastating tropical cyclone in 2009. Through this empirical application, we tested the inter-linkages between the temporal phases of the state-and-transition model and identified the key factors that initiate the transition between the two steady states.

The results of our study show that pre-event socio-economic, structural and environmental characteristics were closely inter-linked. Relatively poorer households owning smaller parcels of arable land and earning lower per-capita incomes lived in poorly built houses. Wealthier households lived further away from the shoreline and closer to the cyclone shelters. As hypothesized, pre-event vulnerabilities had a significant negative influence on disaster preparedness and resistance. Relatively poorer households were significantly and systematically less prepared, and suffered significantly higher economic, structural and physical damage. As expected, different aspects of disaster resistance (i.e. economic, structural and physical damage) were closely interlinked. Households incurring higher economic damage were also significantly more likely to experience higher structural and physical damage. Contrary to expectation, no significant inter-relation was observed between hazard preparedness and hazard resistance. Cyclone preparedness trainings, reception of an early warning and evacuation decisions had no significant influence on the likelihood of physical, economic or structural damage.

Contrary to conventional beliefs, pre-event vulnerability and (a lack of) hazard resistance were positively inter-linked with disaster coping and recovery capacities. Households below the poverty line as well as households from the minority religious community had quicker access to post-disaster relief and rehabilitation aid. Households who experienced higher structural and physical damage were able to access food and medical assistance faster than the others. Elite contact significantly influenced the relief and aid distribution process, as households who were connected to the socio-political or religious network had significantly faster access to relief. Contacts with the local NGO workers helped restore clean water supply and allowed access to post-cyclone credit under circumstances when the credit market was confronted by acute liquidity shortage. However, we did not find any evidence to suggest that poor and/or minority communities had lower or no contacts with social elites. This suggests that, although households' coping capacities were distorted by elite influence, the distortion did not cause any systematic bias against the poor.

The pre- and post-cyclone steady states were compared with respect to six structural (housing structure, access to water, sanitation and electricity) and functional (income and unemployment) thresholds. A majority of the sampled households' earned significantly lower per-capita income and a significant proportion of the sample became unemployed in the post-cyclone steady state. Household access to water, sanitation and electricity also declined significantly following the cyclone. However, a significant proportion of the households who lived in a kacha house in the pre-cyclone steady state had a pucca house in the post-cyclone steady state. Structural and functional dimensions of socio-economic resilience did not go hand-in-hand. Households who managed to safeguard the functional thresholds (i.e. experienced positive income growth) were more likely to experience a breach in the structural thresholds (i.e. weaker house structure and low access to clean water).

The factors that caused the breaching of thresholds and forced households to move to a different steady state were identified by testing a set of deterministic hypotheses. The results present strong evidence in support of natural disaster induced capital shock in low income economies. Households whose members suffered from death or physical injury earned significantly less income and were significantly more likely to be unemployed in the post-cyclone steady state. Households who lost productive asset (i.e. livestock) were also significantly more likely to be unemployed in the post-cyclone steady state. As the process based frameworks suggest, we find considerable evidence in favor of learning from experience; a significant proportion of the sampled households, particularly those who suffered from a loss of productive or human capital, were more likely to take preventive measures (i.e. build a stronger house) against such losses in future.

The results of our study do not provide evidence in support of the flip-side relationship hypothesis (i.e. vulnerability is the flip side of resilience). In our specific empirical application, high vulnerability did not necessarily mean low resilience. Households who lived below the poverty line during the pre-cyclone steady state experienced significantly lower income shocks in the post-cyclone steady state. Day laborers who tend to belong to the poorer segments of the society were significantly more likely to experience positive income growth and find employment in the post-cyclone steady state. Those households who lived closest to the mangroves were the poorest and suffered relatively higher economic damage, yet they were more income-resilient since the mangrove reserves offered higher income generation opportunities than the inland localities. Although the poor and minorities suffered from significantly higher physical and structural damage, they had faster access to emergency relief and rehabilitation aid and were more likely to restore their clean water supply. These findings point towards Sapountzaki's (2012) thesis regarding vulnerability-resilience interaction: Resilience is a process of vulnerability re-arrangement and a function of unequally distributed opportunities across communities.

Three key policy implications can be drawn for the area from the case study. First, the existing cyclone preparedness programs (i.e. cyclone preparedness training, early warning system and evacuation plan) seem to be systematically excluding the poorer segments of the society. The adequacy and effectiveness of the preparedness programs can be enhanced by: reaching out to poorer households; increasing the capacity and facilities of the cyclone shelters; and making transportation available to encourage evacuation, especially for families with elderly people and young children, and for those who live further away from the cyclone shelters. Second, the post-disaster relief and recovery aid disbursement program appears to be quite well targeted. However, the inadequacy of the aid supply relative to its overwhelming demand seems to exacerbate competition, thereby creating opportunity for social elites to influence the system. A potential way to curb such influence could be to increase the volume of aid and enhance monitoring of distributions. Finally, the government operated social safety net programs do not appear to be acting as a shield against environmental shocks. The existing social safety nets need to be cast wider to prevent people from becoming unemployed and falling below the poverty line. Although post-cyclone credit schemes appear to have prevented some people from becoming unemployed, the access to, and availability of, such credit programs does not seem to be widespread. Increased access and availability of soft credits (with low interest rates) should be targeted towards self-employed individuals to help them restore their livelihoods.

References

Adger, N.W., 1999. Social vulnerability to climate change and extremes in coastal Vietnam. World Development 27(2), 249–269.

Adger, N.W., 2006. Vulnerability. Global Environmental Change 16, 268–281.

Alam, E., Collins, A.E., 2010. Cyclone disaster vulnerability and response experiences in coastal Bangladesh. Disasters 34(4), 931–954.

BBS (Bangladesh Bureau of Statistics), 2005. Household income and expenditure survey 2005. Ministry of Planning, Dhaka, Bangladesh.

BBS (Bangladesh Bureau of Statistics), 2010. Preliminary report on Household Income & Expenditure Survey 2010. Ministry of Planning, Dhaka, Bangladesh.

BBS (Bangladesh Bureau of Statistics), 2011. Report of the Household Income & Expenditure Survey 2010. Ministry of Planning, Dhaka, Bangladesh.

Briske, D.D., Fuhlendorf, S.D., Smeins, F.E., 2005. State-and-transition models, thresholds, and rangeland health: A synthesis of ecological concepts and perspectives. Rangeland Ecology & Management 58(1), 1–10.

Brouwer, R., Akter, S., Brander, L., Haque, E., 2007. Socio-economic vulnerability and adaptation to environmental risk: A case study of climate change and flooding in Bangladesh. Risk Analysis 27(2), 313–326.

Cannon, T., 2008. Reducing people's vulnerability to natural hazards communities and resilience. Research Paper No. 2008/34. UN-WIDER, Helsinki.

Cutter, S.L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., Webb, J., 2008a. A place-based model for understanding community resilience to natural disasters. Global Environmental Change 18(4), 598–606.

Cutter, S.L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., Webb, J., 2008b. Community and regional resilience: perspectives from hazards, disasters, and emergency management. Community and Regional Resilience Initiative (CARRI) Research Report 1. Tennessee. url: http://www.resilientus.org/library/FINAL_CUTTER_9-25-08_1223482309.pdf (Accessed on May 14, 2012).

Cutter, S.L., Finch, C., 2008c. Temporal and spatial changes in social vulnerability to natural hazards. Proceedings of the National Academy of Sciences 105(7), 2301–2306.

DFID (Department for International Development), 2011. Defining disaster resilience: a DFID approach paper. Department for International Development, London, UK. url: http://www.dfid.gov.uk/Documents/publications1/Defining-Disaster-Resilience-DFID-Approach-Paper.pdf (Accessed on January 12, 2012).

Elsner, J.B., Kossin, J.P., Jagger, T.H., 2008. The increasing intensity of the strongest tropical cyclones. Nature 455(7209), 92–95.

Emanuel, K., 2005. Increasing destructiveness of tropical cyclones over the past 30 years. Nature 436(7051), 686–688.

Folke, C., 2006. Resilience: The emergence of a perspective for social-ecological systems analyses. Global environmental change 16(3), 253–267.

Forgette, R., Boening, M.V., 2010. Assessing Community Socio-Economic Resilience to Natural Disasters. SERP Research Report. url: http://www.olemiss.edu/depts/economics/serri/serpfactsheet.pdf (Accessed on March 25, 2012).

Fothergill, A., Peek, L.A. (2004). Poverty and disasters in the United States: A review of recent sociological findings. Natural Hazards 32(1), 89–110.

Galderisi, A., Ceudech, A., Ferrara, F.F., Profice, A.S., 2010. Integration of different vulnerabilities vs. natural and na-tech hazards. ENSURE Project, Deliverable 2.2.

Gallopi´n, G.C., 2006. Linkages between vulnerability, resilience, and adaptive capacity. Global Environmental Change 16, 293–303.

Hahn, M.B., Riederer, A.M., Foster, S.O., 2009. The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. Global Environmental Change 19(1), 74–88.

Harvey, P., Lind, J., 2005. Dependency and humanitarian relief. A critical analysis. Humanitarian Policy Group Research Report 19. London.

Haque, C.E., Khan, M.R., Uddin, M.S., Chowdhury, S.R., 2012. Disaster Management and Public Policies in Bangladesh: Institutional Partnerships in Cyclone Hazards Mitigation and Response. In C. E. Haque and D. Atkin (Eds) Disaster Risk and Vulnerability: Mitigation through Mobilizing Communities and Partnerships. McGill University Press, Montreal.

Hussaine, S.A., Badola, R., 2010. Valuing mangrove benefits: contribution of mangrove forests to local livelihoods in Bhitarkanika Conservation Area, East Coast of India. Wetlands and Ecology Management 18, 321–331.

IPCC, 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, New York.

Khan, M.S.A., 2008. Disaster preparedness for sustainable development in Bangladesh. Disaster Prevention and Management 17(5), 662–671.

Kuleshov, Y., Jones, D., Spillman, C.M., 2012. Climate extremes in the Pacific: improving seasonal prediction of tropical cyclones and extreme ocean temperatures to improve resilience, in: EGU General Assembly Conference Abstracts, Vienna, Austria, 22–27 April 2012.

Mahmud, T., Prowse, M., 2012. Corruption in cyclone preparedness and relief efforts in coastal Bangladesh: Lessons for climate adaptation? Global Environmental Change 22 (4), 933–943.

Mallick, B., Vogt, J., 2012. Cyclone, coastal society and migration: empirical evidence from Bangladesh. International Development Planning Review 34(3), 217–240.

Mayunga, J.S., 2007. Understanding and applying the concept of community disaster resilience: a capital-based approach. Draft working paper prepared for the summer academy, Megacities as Hotspots of Risk: Social Vulnerability and Resilience Building, Munich, Germany, 22–28 July 2007.

Mohapatra, S., Joseph, G., Ratha, D., 2012. Remittances and natural disasters: ex-post response and contribution to ex-ante preparedness. Environment, Development and Sustainability 14(3), 1–23.

Oxfam, 2012. Country report on Full details of what Oxfam is doing in Bangladesh. url: http://www.oxfam.org.uk/~/media/Files/OGB/What%20we%20do/Countries%20we%20work%20in/Bangladesh/bangladesh_FINAL.ashx (Accessed on July 31, 2012).

Parvin, G.A., Shaw, R., 2012. Microfinance institutions and a coastal community's disaster risk reduction, response, and recovery process: a case study of Hatiya, Bangladesh. Disasters 37(1), 165–184.

Paul, B.K., 2009. Why relatively fewer people died? The case of Bangladesh's Cyclone Sidr. Natural Hazards 50(2), 289–304.

Paul, S.K., Routray, J.K., 2011. Household response to cyclone and induced surge in coastal Bangladesh: coping strategies and explanatory variables. Natural Hazards 57(2), 477–499.

Peduzzi, P., Chatenoux, B., Dao, H., De Bono, A., Herold, C., Kossin, J., Mouton, F., Nordbeck, O., 2012. Global trends in tropical cyclone risk. Nature Climate Change 2(4), 289–294.

Resilience Alliance, 2005. Key concepts. url: http://www.resalliance.org/564.php (Accessed on December 3, 2011).

Sapountzaki, K., 2012. Vulnerability management by means of resilience. Natural Hazards 60(3), 1267–1285.

Sharma, U., Patwardhan, A., Parthasarathy, D. (2009). Assessing adaptive capacity to tropical cyclones in the East coast of India: a pilot study of public response to cyclone warning information. Climatic change 94(1), 189–209.

Simon, D., 2007. Cities and global environmental change: exploring the links. The Geographical Journal 173(1), 75–79.

Stringham, T.K., Krueger, W.C., Shaver, P.L., 2003. State and transition modeling: An ecological process approach, Journal of Range Management 56, 106–113.

Tadele, F., Manyena, S.B., 2009. Building disaster resilience through capacity building in Ethiopia. Disaster Prevention and Management 18(3), 317–326.

UNDP, 2010. Cyclone Aila: UN Joint Multi-Sector Assessment & Response Framework. Dhaka, Bangladesh.

Van den Berg, M., 2010. Household income strategies and natural disasters: Dynamic livelihoods in rural Nicaragua. Ecological Economics 69(3), 592–602.

Westoby, M., Walker, B., Noy-Meir, I., 1989. Opportunistic management for rangelands not at equilibrium. Journal of Range Management 42(4), 266–274.

Zohora, F.T., 2011. Non-timber forest products and livelihoods in the Sunderbans, in: Fox, J. et al. (Eds.), Rural Livelihoods and Protected Landscapes: Co-management in the Wetlands and Forests of Bangladesh. Nishorgo Network, Dhaka, pp. 99–117.

Figure 1 Location of the study area

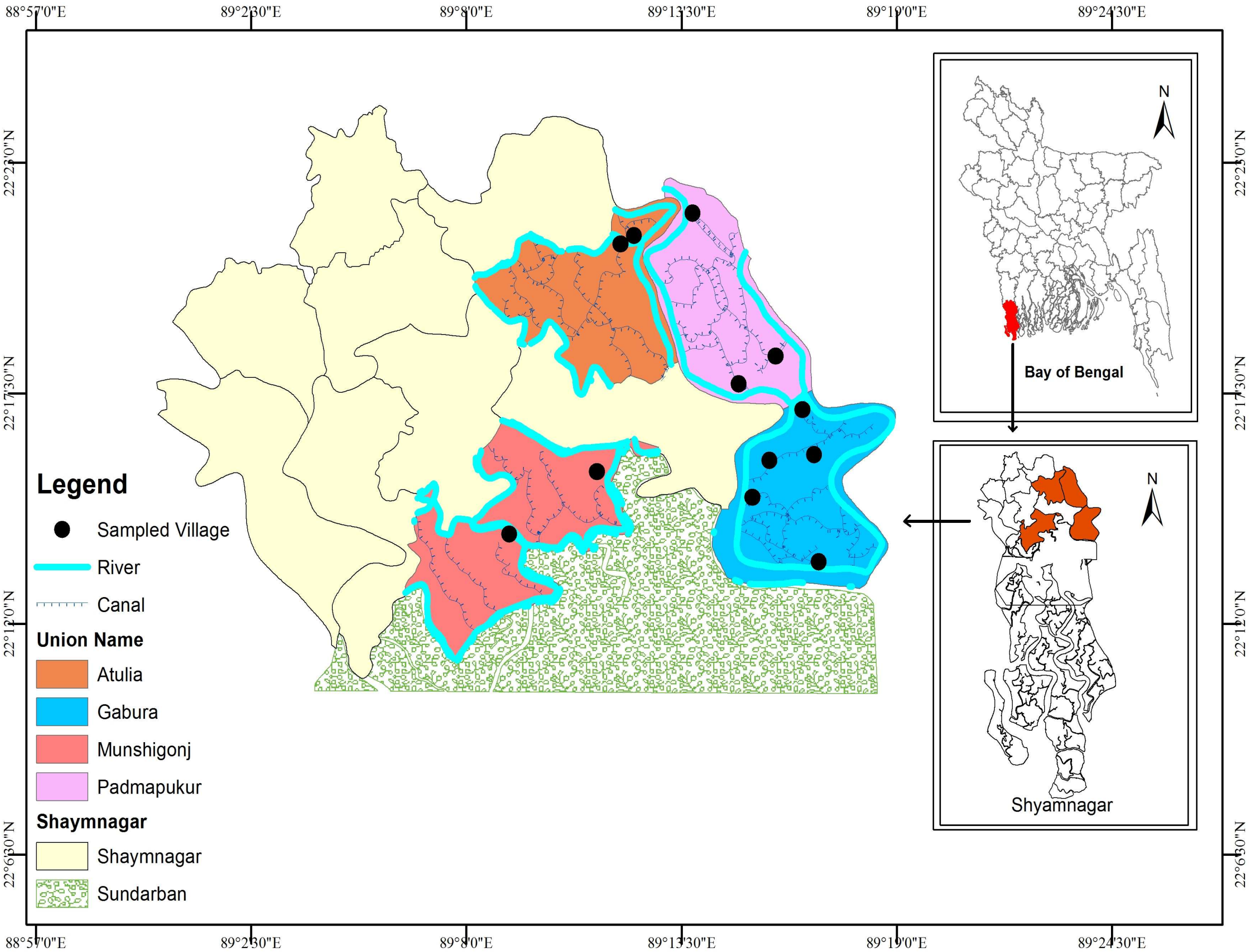

Figure 2 Analytical framework

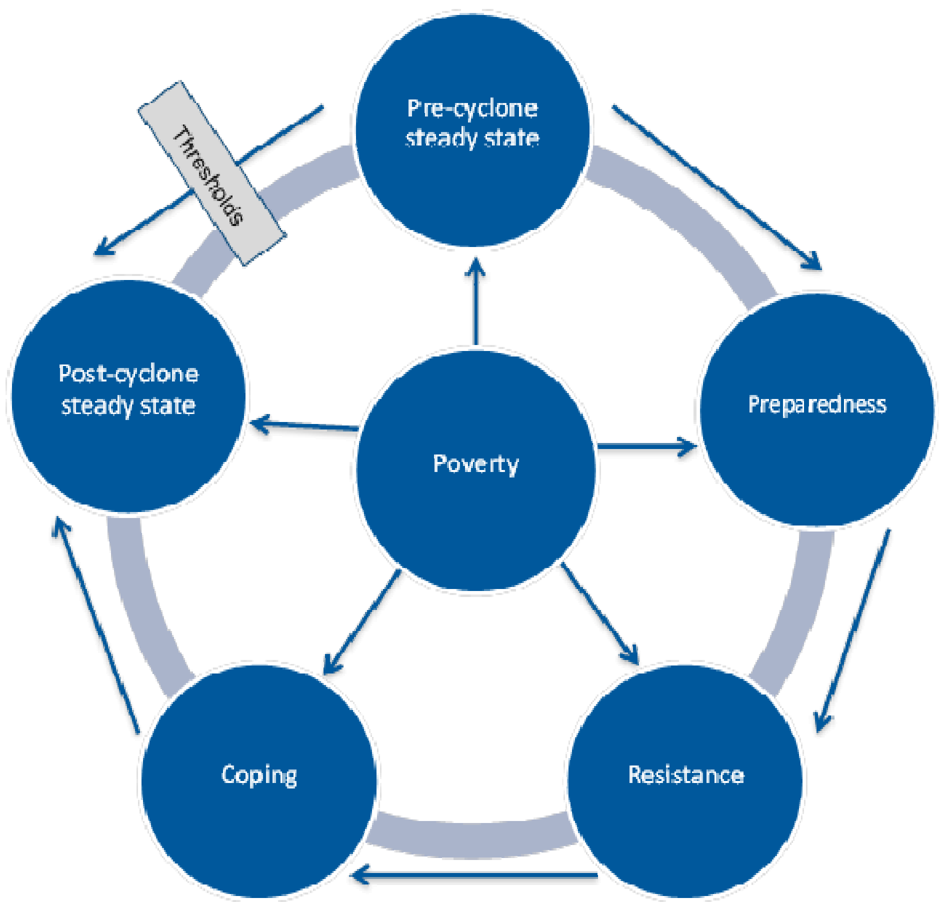

Table 1 Temporal phases and associated indicators

Temporal phases	**Models**	**Indicators**
Post-cyclone steady state	• Capital Base Model (Mayunga 2007) • DROP model (Cutter et al. 2008a) • Pre-Event Resiliency Model (Cutter et al. 2008b)	Socio-economic vulnerability: sex, religion, income, land ownership, natural resource dependent livelihood, literacy, social capital, ownership of TV and private vehicle
		Structural vulnerability: Construction materials of houses, proximity to the road-river network and cyclone shelter
		Environmental vulnerability: Distance from shore-line/forest
Preparedness, Resistance, Coping and Recovery	• 4 Rs model (Forgette and Boening 2010) • DROP model (Cutte et al. 2008a)	Hazard recognition: preparedness and awareness training, early warning, evacuation
		Hazard resistance: economic, structural and physical damage
		Hazard redundancy and rapidity: time to access emergency relief and rehabilitation aid
Post-cyclone steady state	• Outcome approach of DFID (2011)	Changes in income, employment and housing structure

Table 2 Indicators of pre-event vulnerability

Indicators			
Religion (Muslim) (%)		89	
Literacy rate (%)	Illiterate	40	
	Primary school	31	
	High school	26	
	University	3	
Households depend on natural resource dependent income source (%)			34
Elite contact (%)	No contact		38
	One contact		15
	Two contacts		27
	More than three contacts		20
Average household income before the cyclone (US$/month) (st. dev.)		81 (86)	
Median household income (US$/month)		53	
Average per capita income (US$/month) (st. dev.)		15 (20)	
Average land holding (hectare) (st. dev.)		6 (11)	

Median land holding (hectare)	3
Gini coefficient	0.34
Household had electricity (%)	17
Household owned a television (%)	16
Household owned a mobile phone (%)	40
Average distance from shoreline (km)	5
Average distance form a nearby waterbody (river or canal) (km)	0.2

Table 3 Socio-economic vulnerability and incidence of economic damage

	Average absolute economic damage (in US$)	Average relative economic damage (damage/income)	Median relative economic damage (damage/income)
Households below poverty line	443 (238)	10 (6)	8
Households above the poverty line	423 (256)	6 (5)	4
Z-statistics (2-Tailed Sig.)	0.59 (*p*=0.55)	5.71 (*p*<0.001)	10.80[a] (*p*<0.001)

Note:

[a]Chi square value for independent sample median test.

Table 4 Structural vulnerability and incidence of economic and physical damage

Construction material of wall	% of house damage	Median economic damage (in US$)	Number of people affected (injured or died)
Mud, bamboo and golpata wall	76 (32)	400	0.28 (0.74)
Concrete and wood	47 (42)	133	0.13 (0.48)
Z-statistics (2-Tailed Sig.)	6 (p<0.001)	-5.66 (p<0.001)	1.74 (p<0.10)

Note:

[a]Mann-Whitney Z value for independent sample median test.

Table 5 Socio-economic conditions of the study area before and after Cyclone Aila

Socio-economic conditions of the case study area	Before Cyclone Aila (2009)	After Cyclone Aila (2010) [Z-statistics (2-Tailed Sig)]	Regional Statistics (2010)
Households below poverty line (%)	41	63 [4.4 (p<0.001)]	31
Unemployment (%)	11	60 [12 (p<0.001)]	20
Monthly household income (US$)	81	54 [6.0 (p<0.001)]	122
Per capita income (US$)	15	10 [7.3 (p<0.001)]	20
Per capita expenditure (US$)	12	9 [5.3 (p<0.001)]	19
Kacha houses (%)	68	51 [7.1 (p<0.001)]	44
Access to latrine (%)	86	72 [5.1 (p<0.001)]	80
Access to clean water (%)	83	66 [7.3 (p<0.001)]	93
Access to electricity (%)	19	17	46

[1.7 (p<0.10)]

Table 6 Ordinary least square regression result for drivers of income growth (Dependent variable: $\Delta \ln Y_{it+1,t}$)

Explanatory Variables	Coefficients (SE)
Household members injured or died	
Men	-0.26**
	(0.09)
Women	0.08
	(0.11)
Value of relative property damage	
Damage per hectare of land (in thousand Tk)	0.002***
	(0.001)
Religion (Muslim=1, Otherwise=0)	-0.15
	(0.10)
Day laborer (=1, otherwise=0)[a]	0.25***
	(0.09)
Self-employed (=1, otherwise=0)[a]	-0.12*
	(0.07)
Literacy (Some literacy=1, Illiterate=0)	-0.08
	(0.06)
Number of family members aged over 60	-0.10**
	(0.04)

Connection to socio-political network	-0.01
	(0.02)
Social-safety net (Receives help from the government=1, otherwise=0)	0.11
	(0.12)
Borrowed money after the cyclone (Yes=1, otherwise=0)	-0.06
	(0.10)
Distance from the mangrove forest (in km)	-0.14***
	(0.04)
Square of distance from the mangrove forest (in km)	0.01***
	(0.003)
Constant	-0.022
	(0.13)
N	279
Adjusted R-squared	0.23

Note:

[a]Base line category is salaried individuals.

Table 7 Drivers of change in unemployment and housing structure

	Model 1: Δ in employment status[a]	Model 2: Δ in construction material of the house[b]
Explanatory Variables	Coefficients (SE)	Coefficients (SE)
Household members injured or died	0.89** (0.36)	0.74*** (0.26)
Death of livestock (Yes=1, otherwise=0)	1.4*** (0.38)	1.30*** (0.40)
Crop damage (Yes=1, otherwise=0)	0.97** (0.40)	-
Percentage of house damage	-	0.02*** (0.006)
Religion (Muslim=1, Otherwise=0)	-0.08 (0.60)	0.31 (0.84)
Day laborer (=1, otherwise=0)[c]	-1.00* (0.60)	-0.06 (0.60)
Self-employed (=1, otherwise=0)[c]	0.52 (0.50)	-0.12 (0.48)
Literacy (Some literacy=1, Illiterate=0)	0.51 (0.40)	-0.45 (0.36)
Connection to socio-political	0.03	0.50***

network	(0.15)	(0.16)
Social-safety net (Receives help from the government=1, otherwise=0)	-0.34 (0.71)	-0.11 (0.76)
Borrowed money after the cyclone (Yes=1, otherwise=0)	-1.42** (0.71)	0.05 (0.58)
Marginal propensity to save before the cyclone	-0.44* (0.27)	0.23 (1.30)
Distance from the mangrove forest (in km)	-0.11* (0.05)	0.10* (0.06)
N	202	196
Percentage correctly predicted	68	83
Nagelkerke R-squared	0.30	0.28
-2 Log likelihood	226	215
Chi Square	51, df=12	52, df=12

Notes:

[a]1=employed before, unemployed after, 0=employed both before and after.

[b]1=kacha house before, pucca house after, 0=kacha house both before and after.

[c]Base line category is salaried individuals.