Environmental Stress and Health in Bangladesh: The Moderating Effects of Migration and Social Support

By

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To Baba,
full of wisdom, strength, and love for life

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INTRODUCTION AND LITERATURE REVIEW

Introduction

The link between environmental conditions and population processes has garnered significant interest from the scientific community over the years, and recent concerns about climate change have focused on coupled human-environment interactions. According to the Intergovernmental Panel on Climate Change (IPCC), the authoritative body on global climate change, one human consequence related to environmental conditions is through its impact on health outcomes (2014). The IPCC stresses that warming of the global climate system will exacerbate the health risks posed by the environment if substantial mitigation and adaptation measures are not implemented. Hence, protecting and promoting human health and well-being in the face of increasing environmental degradation is a fundamental challenge of our time.

There is a growing body of research that examines the relationship between environmental factors and population-related outcomes, most notably mortality and morbidity (see Patz et al. 2005; McMichael 2013), and estimates the global burden of disease attributable to environmental factors. For instance, Smith, Corvalán and Kjellström (1999) estimate that between one-fourth and one-third of ill health across the world may be linked to environmental conditions. Using World Health Organization (WHO) data for 192 countries, another study suggests that 24 percent of the global disease burden and 13 million premature deaths may be prevented by addressing the environmental risk factors associated with water, sanitation and hygiene, indoor air pollution, and outdoor air pollution (Prüss-Üstün, Bonjour, and Corvalán

2008). Moreover, developing nations, including Small Island Developing States (SIDS[1]) and atoll settlements, disproportionately shoulder a larger burden of death and disease from environmental deterioration and extreme events (Haines et al. 2006; Mendelsohn, Dinar, and Williams 2006).

Studies also examine a range of health outcomes in different country settings to estimate how environmental factors correlate with these outcomes. For instance, in the Matlab area of Bangladesh, arsenic exposure is linked to excess adult mortality (Sohel et al. 2009); higher than average temperature, rainfall, and river water levels in Dhaka are associated with increasing prevalence of typhoid fever (Dewan et al. 2013); and saline drinking water is associated with higher rates of hypertension among pregnant women in Dacope (Khan et al. 2011). Together these findings demonstrate a strong relationship between environmental factors and health. However, our understanding of the environment-health link is far from complete because we know little about how social factors influence it. In addition, although both the natural and social sciences have made important contributions to existing scholarship, much of our understanding is piecemeal and fragmented across disciplines.

This dissertation seeks to address these shortcomings. By drawing on studies spanning various disciplines and integrating household and environmental data, I investigate the health impacts of environmental attributes among children and adults in Bangladesh and focus on the adaptive (e.g. migration) and coping (e.g. social support) capacities that families may mobilize in the face of environmental adversity. Specifically, I assess whether and how these social resources moderate the relationship between environmental stress and health. Understanding the

[1] SIDS, a group of 52 low-lying coastal, developing nations, are considered highly vulnerable to the effects of climate change because of their small physical size, exposure to natural disasters and climate extremes, low adaptive capacity, and developing economy (Mimura et al. 2007).

effects of such resources is extremely important in Bangladesh, a nation where many live in environmentally and socioeconomically vulnerable settings.

Prior studies have shown that financial and social transfers related to migration have positive health effects. Children in migrant households report better health than their counterparts living in nonmigrant households (Kanaiaupuni and Donato 1999; Frank and Hummer 2002; Carletto, Covarrubias, and Maluccio 2011; Donato and Duncan 2011). However, other studies reveal that the impact of migration is not straightforward. For instance, Kanaiaupuni and Donato (1999) find that infant mortality is lower in migrant households but this effect appears only after migration has become prevalent in origin communities and after remittances received exceed the average amount. Likewise, Donato and Duncan (2011) report that although children in migrant households have better health than those in nonmigrant households, children in households with parents who were once migrants and returned fared worse than children in migrant and nonmigrant households. Research also shows that social support, which is bestowed by social relationships, moderates the negative impacts of external social and non-social influences on health (Lin, Ye, and Ensel 1999; Turner and Avison 2003; Kanaiaupuni et al. 2005). However, we do not know whether the protective role of migration and social support also extends to populations experiencing environmental stress.

Thus, building on prior studies, I pose three broad sets of research questions in this dissertation:

1) How do environmental conditions affect child and adult health in Bangladesh? Specifically:

   a. Are environmental conditions characterized by rural/urban residence and proximity to coastal areas, in addition to individual and contextual characteristics, associated with child and adult health in Bangladesh, and if so, how?

   b. Are environmental conditions – perceived and actual – related to physical health in southwest Bangladesh, and if so, how?

2) To what extent does migration moderate the effect of environment on health?

   a. Does migration protect against the negative health impacts of the environment? Specifically, does household migration moderate the relationship between environmental stress and physical health outcomes?

   b. What attributes related to migration, such as the number of trips made by household members or receipt of remittances, are more salient to the environment-health relationship?

3) To what extent does social support moderate the effect of environment on health?

   a. Does social support protect against the negative health impacts of the environment? Specifically, does the provision of household support moderate the environment-health association?

   b. What types of social support – practical help, monetary support, or emotional support – are more salient for the environment-health relationship?

By answering these questions, my dissertation makes several unique contributions from the standpoints of research and policy. First, findings will add to an understanding of one of the most pressing global issues – health impacts of environmental conditions in developing country context. This is especially important because poor countries are more likely than their richer counterparts to experience the devastating impacts of deteriorating environmental conditions and natural disasters due to climate change (Mendelsohn, Dinar and Williams 2006; Harrington et al. 2016). By incorporating sociological perspectives and showing how social resources interact with environmental factors to influence physical health outcomes, I argue that knowledge of and response to global environmental change must integrate the social processes related to environmental conditions.

Second, my dissertation incorporates a variety of data sources and multidisciplinary perspectives, thereby advancing understanding about how environmental conditions are related to health. By combining different methodological approaches and using various types of data across different disciplines, I demonstrate how environmental and spatial data can be combined with household survey information in quantitative social science modeling of health outcomes.

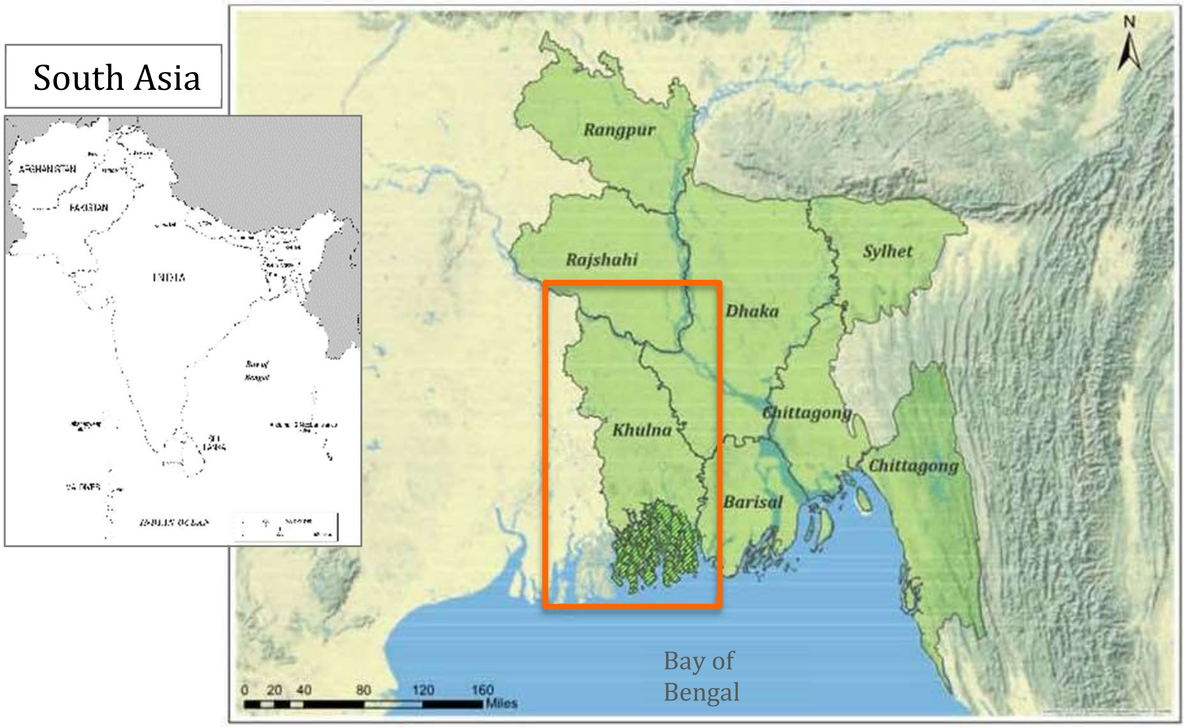
Finally, my dissertation findings add value because they have policy implications for solutions aimed at mitigating environmental risks. The most commonly recommended adaptation strategies focus on institutional changes such as strengthening health care infrastructure, improving surveillance systems and disaster preparedness, and shifting public attitudes (IPCC 2014). Although important, communities in remote settings have limited resources to improve emergency preparedness or strengthen health care systems. My dissertation suggests family and community-based resources are important and may complement institutional level strategies in protecting and promoting health of populations living in low resource settings.

The dissertation is divided into six chapters. This first chapter describes the research context and discusses the relevance of studying environment-health relationship in Bangladesh. I examine and evaluate current scholarship, drawing on studies in sociology and demography as well as in the environmental and geological sciences. At the end of this section, I present my overarching research hypotheses. In Chapter 2, I describe the data sources, variables under study, and the analytic strategies used to answer my research questions. Chapters 3-5 present empirical findings; I begin each with a description of the analytic strategy that outlines the chapter's modeling approach and conclude with a summary of key points. In Chapter 3, I describe results from the 2007 Bangladesh Demographic and Health Survey (BDHS). Chapters 4 and 5 shift focus to southwest Bangladesh, a region that faces gradual environmental degradation as well as extreme cyclones and flooding, and relies on a unique data set collected in this region. Chapter 6 presents study conclusions, limitations of the findings, and policy implications.

Research Context

Bangladesh is a developing nation located in South Asia. Figure 1.1 presents a map of Bangladesh and shows how it is bordered by India to its north, east and west, Myanmar to its southeast, and the Bay of Bengal to its south. Bangladesh is a young nation, having gained independence from Pakistan in 1971. The vast majority of Bangladeshis are Muslim (90%); Hindus (9%), Buddhists (<1%), and Christians (<1%) are religious minorities (U.S. Department of State 2016). Bangladesh's population is currently estimated at more than 163 million, and ranks as the eighth most populous country in the world (World Bank n.d.). According to the 2011 Population and Housing Census, the national literacy rate stands at 56 percent (Bangladesh Bureau of Statistics 2015).

Figure 1.1 Map of South Asia, Bangladesh, and Khulna Division



Politics in the country remain highly volatile with frequent mass demonstrations, known as *hartals,* crippling the economy and the everyday lives of residents. The nation is considered very poor; its Gross Domestic Product (GDP) per capita is just $1,212 (in current US$), but its national economy has exhibited an average growth of 6 percent annually over the last decade (World Bank n.d.).[2] The economy is largely agrarian, but in the last 10-15 years, growth in its service sector and garment industry has been dramatic. The ready-made garment sector[3] alone is now a $19 billion industry and employs more than four million people (International Finance Corporation 2014).

[2]By comparison, India's GDP per capita is $1,593 and its annual GDP growth rate has averaged approximately 7 percent in 2010-15 (The World Bank n.d.).
[3]The garment industry in Bangladesh has recently come under international scrutiny for dangerous working conditions after a building with several garment factories collapsed and killed more than 1,100 people in 2013 (Manik and Najar 2015).

International migration also plays an important role in the nation's economy through the outflow of substantial labor migrants and the inflow of remittances (Afsar, Yunus and Islam 2002; Siddiqui 2003). Since the late 1970s, Bangladesh has sent many labor migrants worldwide. According to the Bangladesh Bureau of Manpower, Employment and Training (BMET) (2017), more than 757,000 Bangladeshis left for foreign employment in 2016 alone. In the same year, Bangladesh received approximately 13.6 billion (US$) in remittances, making it one of the largest recipients of remittances in the world (BMET 2017). To compare, when BMET was first established in 1976, approximately 6000 Bangladeshis left the country as foreign workers. Until recently, the overwhelming majority of labor migrants have been men because cultural practices and national policy restricted women's labor migration. Although the Bangladeshi government imposed a ban on the migration of semi-skilled and unskilled women in 1981, this restriction was eased in 2003, when women over 35 years of age were permitted to leave (Siddiqui 2005; Oishi 2005).

In addition to authorized labor outmigration, reports suggest there is substantial unauthorized cross-border movement to India (Anand 2016; Naik 2016; Wu 2017). Although no estimates exist about the extent of unauthorized movement, this type of migration is likely because of strong family ties that extend across the Bengal region of South Asia. Rural-to-urban migration is also very common; Afsar (2003) suggests it accounts for two-thirds of total migration. Moving to urban areas, when rural livelihoods are threatened, has long been a survival strategy in Bangladesh (Ellis 2000; Siddiqui 2003; Black et al. 2011). Many rural-urban male migrants work in informal urban sector jobs such as wage laborers, rickshaw pullers, and street vendors; migrant women usually work in the garment industry (Saadi 2003). Marriage migration, which involves women moving to their husband's place of residence after marriage, is also a form of internal migration in the country (Rahman, Akter, and Rahman 2010). Hence, migration – international and internal – is woven into the economic and cultural fabric of the Bangladeshi society.

Environmentally, Bangladesh is one of the most compromised nations in the world, and has experienced a host of gradual and rapid onset environmental events in recent decades (Yu et al. 2010; Penning-Rowsell, Sultana, and Thompson 2013; Black et al. 2013; Sussex Center for Migration Research and Refugee and Migratory Movements Research Unit 2013a-c). The vast majority of the country is located in the floodplains of the Ganges, Brahmaputra and Meghna delta, the largest delta in the world. As a result, the population is frequently exposed to environmental threats that interfere with daily life in significant ways. One recent report estimates more than one-quarter of the 163 million residents of Bangladesh have been affected by cyclones in their lifetime and about three-quarters live in flood-prone areas (Cash et al. 2013). Flooding from heavy rains during this year's monsoon alone has claimed almost 150 lives and affected over 8.5 million people across the country (George 2017).

In addition, each year soil erosion damages homes and farmlands of more than one million people (Siddiqui 2003). Access to safe drinking water is also a big challenge, especially in rural areas (Benneyworth et al. 2016). Salinization of water sources and agrarian land – related to increasing saltwater intrusion from the ocean and expansion of brine shrimp aquaculture in the southwest – has created water insecurity, decreased agricultural production, and triggered a range of health problems in rural, low-lying communities (Vineais, Chan, and Khan 2011; Khan et al. 2014). In addition, arsenic in groundwater is a widespread problem and poses serious health risks across the country (Abedin, Habiba, and Shaw 2014). Hence, unfavorable environmental conditions coupled with socio-economic and demographic challenges create an overwhelmingly compromised nation for its residents.

Yet despite numerous challenges, Bangladesh has made noteworthy improvements in the health status of its population and surpassed neighboring India and Pakistan on some key national indicators (Abed 2013). For example, life expectancy at birth has increased from 53 to 72 years between 1980 and 2015, compared to 53 to 68 years in India and 57 to 66 years in Pakistan during the same period (World bank n.d.). The total fertility rate (TFR) currently stands at 2.1, which is about one-third of its rate in 1980; by comparison, India's and Pakistan's current TFRs are slightly higher at 2.4 and 3.5, respectively (World Bank n.d.). In addition, dramatic reductions in infant mortality (from 100 to 31 per 1000 live births) and child mortality (from 144 to 38 per 1000 live births) between 1990 and 2015 have put Bangladesh on track to achieve some of the key United Nations Millennium Development Goals (United Nations Children's Fund 2015). These health gains in child survival were achieved through the social, political, and economic empowerment of women and system-wide improvements related health promotion and services (United Nations Development Programme 2014). Such "exceptional health achievement despite economic poverty" has been touted as "the Bangladesh Paradox" (Chawdhury et al. 2013:1734).

However, many health challenges remain. For example, Bangladesh lags behind most nations in quality of life indicators for children who survive their first year of life. The nation has one of the highest worldwide rates of chronic undernutrition, or stunting, which is a standard measure of child growth and physical health status (Faruque et al. 2008). Stunting reflects inadequate nutrition over a long period of time and is often worsened by childhood illnesses and chronic conditions. Childhood undernutrition has serious repercussions as it increases the risks of chronic conditions, such as weakened immune functions, high blood pressure, and impaired cognitive ability in adult life (Victora et al. 2008). Generally speaking, childhood malnutrition is a matter of great concern because Bangladesh comprises a fairly young population; about 37 percent of the population are 18 years old or younger and about 10 percent are children under five years of age (United Nations Children's Fund 2012).

Malnutrition is also prevalent among adults in Bangladesh. Malnutrition, which refers to both under- and over- nutrition, is a serious public health issue in many developing and middle-income countries (Food and Agriculture Organization 2006; Shrimpton and Rokx 2012; Haddad, Cameron, and Barnett 2015). Although historically undernutrition has been a difficult and insurmountable public health issue, Bangladesh is now in the midst of nutrition transition as its population is facing higher risks of being overweight or obese as undernutrition rates only gradually decline (Khan and Talukder 2013).

The Double Burden of Malnutrition

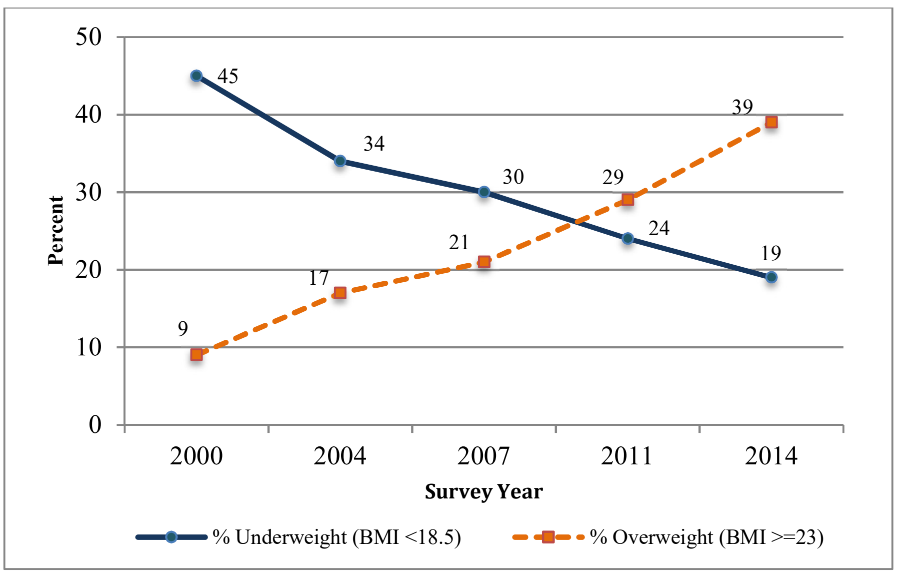
Bangladesh along with a number of other developing and middle-income countries are experiencing the double burden of malnutrition (DBM), which the World Health Organization defines as "the coexistence of undernutrition along with overweight, obesity or diet-related noncommunicable diseases within individuals, households and populations, and across the life course" (2017:2). This "new paradigm" in nutritional health was first brought to attention at the 1992 International Conference on Nutrition organized by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) (Shrimpton and Rokx 2012:1). Since then, the severity and the extent of the problem have compounded into a serious global health threat.

For instance, in Bangladesh undernutrition rates are generally high among rural residents, the urban poor, and the elderly (Pryer and Rogers 2006; Ferdous et al. 2009; Milton et al. 2010) whereas obesity in urban populations is rising among adults and children (Rahman, Islam, and Alam 2014; Biswas et al 2017). DBM in developing countries is a direct consequence of the nutrition transition. Related to demographic and epidemiological transitions, the nutrition transition stems from changes in diet and physical activity, together they shift into DBM with high prevalence of undernutrition and growing rates of being overweight and obese (Popkin and Gordon-Larsen 2004). One global study estimates that more than 2 billion people are overweight or obese, which represents a 27.5 percent increase from 1980 to 2013 (Ng et al. 2014). Catalysts of the nutrition transition include rising food production, globalized food markets with proliferation of processed food containing high levels of fat and sugar, and increasing sedentary lifestyles without much physical exercise (Popkin, Adair, and Ng 2012; Shetty 2013).

Commissioned by Food and Agriculture Organization (FAO), early comprehensive case studies of China, Egypt, India, Mexico, the Philippines, and South Africa reveal three typologies of the double burden of malnutrition (2006). The first represents countries with high prevalence of undernutrition among children and adults and emerging overnutrition concentrated in urban areas; India and Philippines fell in this category. The second grouping includes South Africa, a nation experiencing high levels of stunting coupled with rising levels of child and adult overweight/obesity and increasing incidence of noncommunicable diseases. The third typology includes China, Egypt and Mexico, which exhibit high levels of child stunting and overweight, low levels of acute conditions such as underweight and wasting, and among adults, high and rising rates of overweight and obesity. Since this study, Black et al. (2013) document DBM in an expanding list of countries across Asia and Africa.

In South Asia, Balarajan and Villamor (2009) document DBM in Bangladesh, India, and Nepal. Using the Demographic and Health Surveys for multiple years for these countries, the authors found that the prevalence of obesity increased in these countries between the mid-1990s to mid-2000s. The percent of overweight or obese increased from 2.7 to 8.9 in Bangladesh, 10.6 to 14.8 in India, and 1.6 to 10.9 in Nepal. In the same period, percent underweight decreased from 51.5 to 34.2 in Bangladesh, 36.2 to 33 percent in India, and 27.8 to 24.1 in Nepal. Although Bangladesh saw a significant decline in the prevalence of being underweight, declines for Nepal and India were more modest.

Figure 1.2 Trend of Underweight and Overweight/Obese Among Ever-married Women aged 15- 49, 2000-2014



Source: Bangladesh Demographic and Health Survey, 1999/200, 2004, 2007, 2011, and 2014

Figure 1.2 shows the shares of women who are underweight and overweight estimated from Bangladesh Demographic and Health Surveys for years 1999/2000, 2004, 2007, 2011, and 2014. From the solid line that represents the percent of ever-married women of reproductive age (15-49) who are underweight, i.e. when Body Mass Index (BMI)[4] < 18.5, we see that the

[4] Body Mass Index is a commonly used indicator of adult nutritional health. It is calculated by dividing a person's weight (kg) by the square of their height (m^2). I describe this index in detail in Chapter II.

prevalence of being underweight has significantly declined between 2000 and 2014, dropping from 45 to 19 percent. From the dotted line that represents the share of overweight and obese women, i.e. BMI >=23, we see that in 2000 less than 10 percent of women were in this category; by 2015, the share had increased by fourfold to 39 percent. The year 2011 appears to be a turning point where the percent overweight exceeded the percent underweight. This is a dramatic shift in nutritional status and it has important public health consequences.

The Case of Khulna Region in Bangladesh

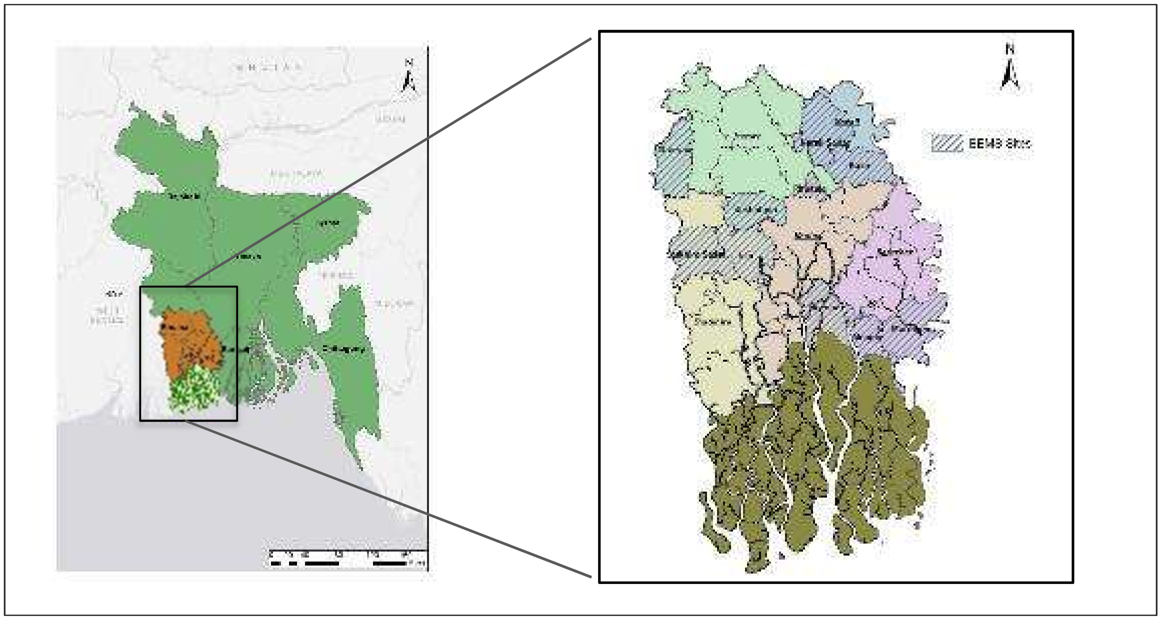
Figure 1.3 presents a map of Khulna *bibhag* or division[5], which is located in southwestern Bangladesh and borders the Indian state of West Bengal to the west and the Bay of Bengal to the south. Khulna is located in the Ganges-Brahmaputra-Meghna delta, which transports massive amounts of water and sedimentation from the Himalayas and drains into the Bay of Bengal. Approximately three-quarters of a billion tons of Himalayan sediment are annually transported to the Bengal basin during the monsoon season (Goodbred and Kuehl 1999).

Khulna houses a significant portion of one of the largest mangrove forests in the world, the Sundarbans. The Sundarbans, which forms a natural buffer between the ocean and coastal settlements, was designated a World Heritage site in 1987. In addition to maintaining the delicate ecological balance by housing diverse flora and fauna species in the region, the forest also serves as a livelihood resource for the coastal population (Hossain 2001). People living near Sundarbans

[5] Division is an administrative geographic unit used by the Government of Bangladesh. It is akin to region in the United States.

venture into the forest for fishing, collecting shrimp fry, and gathering foliage material called "golpata" which is commonly used for thatching (Sarker et al. 2010).

Figure 1.3 Map of Bangladesh (L) and BEMS Sites (R)



Source: Bangladesh Environment and Migration Survey (BEMS)

Although Khulna division houses slightly more than 15.4 million people (Bangladesh Bureau of Statistics 2015), livelihoods are fragile and highly dependent on coastal ecosystems (Pomeroy et al. 2006). Residents' main livelihoods are paddy cultivation, shrimp farming, and forest resource extraction, all of which depend heavily on natural resources and environmental conditions (Kartiki 2011). However, in Khulna division's one large urban area, e.g. Khulna City, livelihoods are related to the diversified trade industry because of thriving ports and tourism.

People living in Khulna experience significant environmental stress emanating from vulnerability to cyclones, coastal flooding, saltwater intrusion, and soil erosion (Khalil 1992; World Bank 2013). As an example, this area was hit by two of the most destructive cyclones in

Bangladesh's recorded history: Sidr in 2007 and Aila in 2009. Cyclone Sidr, which was a category four storm, led to more than 3,400 deaths and affected another 8.9 million people through the loss of homes and livelihoods (Disaster Management Information Center 2007). According to the Government of Bangladesh (2008), Sidr led to US$1.7 billion in total damage and losses, mostly affecting the infrastructural and agricultural sectors. Cyclone Aila hit after two years when this region was still recovering from the aftermath of Sidr. Although Aila resulted in far fewer deaths (approximately 200), it adversely affected the livelihoods of 3.9 million people (Bangladesh Red Crescent Society 2010).

Given these environmental and nutritional health challenges, Bangladesh represents an important context in which to study how closely population and environmental systems are intertwined. Understanding Bangladesh allows us to consider future scenarios where the impacts of climate change and concomitant environmental degradation may collide with a host of demographic challenges. Bangladesh as a whole and the Khulna region in particular underscore the need to shed light on the environmental correlates of pressing health concerns and find effective solutions. As more developing countries, especially those with significant coastal populations, experience the adverse and often life-threatening impacts of climate change, it is imperative that we focus on protecting and promoting the health of people living in such precarious conditions.

Literature Review

Thomas Malthus was one of the earliest writers to consider the relationship between natural environment and population. In *An Essay on the Principles of Population* (Malthus

1798), he connected earth's carrying capacity to population pressures and forewarned that natural checks such as famine, war, disease, and death would eventually curb the exponential growth in population. Malthus' treatise received both strong support and opposition at the time, and evoked strong reactions in the public and scientific spheres. In contemporary scholarship, the publication of *The Growth of World Population* (National Academy of Sciences 1963), *The Population Bomb* (Ehrlich 1968), and *The Limits to Growth* (Meadows et. al 1972) revived Malthusian fears and brought environmental concerns to the forefront of population research. Growing concerns over climate change have further ushered this topic to the top of the global research agenda (Nagel, Dietz and Broadbent 2009).

According to Ruttan (1993), research on environment and population has developed in three successive but overlapping phases. Driven by neo-Malthusian principles, the first wave (1940s-50s) focused on the limited supply of natural resources and its implications for exploding population and economic development and vice versa. The second wave (1960s-70s) grappled with industrial intensification and its byproducts such as pollution, industrial effluents, and pesticides. Management and mitigation of hazardous waste became the focal topic of the 1972 United Nations Conference on the Human Environment held in Stockholm (Martens and Michaels 2002), and rapid industrialization coupled with unprecedented population growth in the global South dominated this phase. The third wave (1980s to present) focuses on anthropogenic climate change, an issue that has gained significant traction in recent years. The publication of the IPCC Second Assessment Report (1995) and more recently the ratification of the Paris Agreement (2016), which commits signatory nations to reduce their greenhouse gas emissions, have created a sense of urgency about managing the causes and consequences of climate change.

Climate change research has spurred global interdisciplinary efforts under the rubric of coupled human and natural systems (CHANS). According to Liu et al. (2007), CHANS offers three propositions for undertaking research on human-environment interactions. First, CHANS focuses on "the patterns and processes that *link* human and natural systems" rather than examining natural and human components separately (Liu et al. 2007:639). Second, CHANS underscores the dynamic and reciprocal link between nature and society under a holistic framework, moving beyond piecemeal, disciplinary-specific understandings to focus on how the natural environment impacts population dynamics and vice versa. Finally, CHANS permits interactions across different scales such that natural and demographic components at different levels influence one another. For instance, an increase in mean global sea level may have regional impacts, particularly on coastal areas, small island developing countries, and atoll nations. On the other hand, local events such as oil spills may engender large-scale ecological and public health catastrophes.[6]

Below I organize the literature review using CHANS as a broad guiding framework. I review literature about how the larger climate system is linked to human health at global and regional levels, and also discuss the direct and indirect processes by which environmental conditions impact health outcomes. I will then discuss how the natural environment coalesces with man-made environmental hazards to influence population health in communities that are both socioeconomically and ecologically vulnerable. Here, I focus largely on drinking water quality, which is a serious public health concern in Bangladesh. Finally, I focus on two key social factors – migration and social support – that may play an important role in buffering the

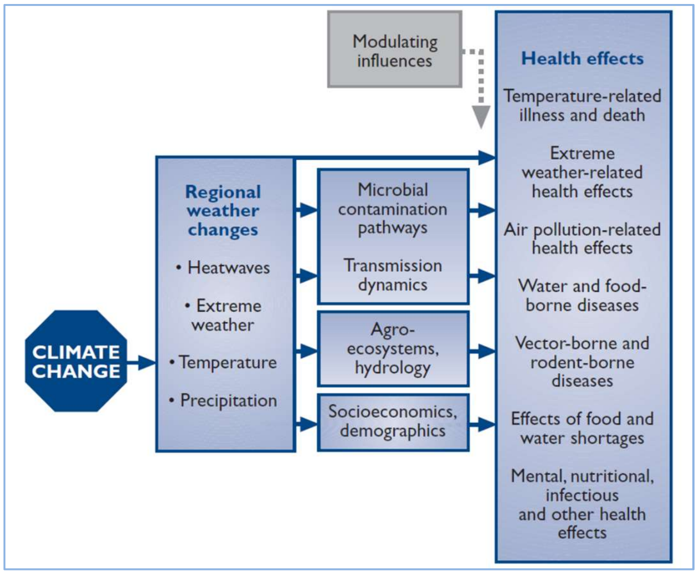
[6] An oil spill in the Sundarban forest in Bangladesh from an oil tanker accident in December 2014 caused major damage to the mangrove ecosystem and jeopardized the livelihoods of communities that depend on natural resources in the Sundarbans (Joint United Nations and Government of Bangladesh Mission 2014).

adverse health impacts of environmental stress. I conclude the chapter by presenting the research hypotheses.

Climate Change and its Health Impacts

There is now a strong body of scientific evidence showing that global climate change is occurring. Over the past few decades, average land and ocean temperatures have risen and the frequency and intensity of extreme events such as flooding, storms and heat waves have increased (IPCC 2014). Variability in the climate system alters the regional and local environments in complex and diverse ways, which in turn directly and indirectly affect human health (WHO 2009; Patz et al. 2005; Campbell-Lendrum and Woodruff 2006). Figure 1.4, which appeared in a WHO report (2003a) on human health and climate change, shows the various mechanisms through which climate factors influence health and well-being. Direct consequences include mortality and morbidities related to exposure to extreme weather conditions, heat waves, floods, droughts, and cyclones. Indirect effects include alterations in the transmission of infectious diseases, food productivity, and demographic parameters. Modulating factors such as socioeconomic conditions affect these direct and indirect pathways.

Figure 1.4 Diagram Showing Pathways that Link Climate Change to Human Health, including Modulating Factors that Influence the Relationship



Source: World Health Organization (2003a:11)

Although there is little doubt about the central role that the global climate system[7] plays in human health, it was only in mid-1990s that scientists began to quantify the health impacts of climate and related changes in the regional environmental conditions. Most notably, the Second Assessment Report (1995) prepared by the IPCC included a full chapter on health risks related to climate change. It presented scientific evidence and estimation of the potential adverse effects of greenhouse gas emissions on a number of health indicators, including vector- and water-borne diseases. Following the IPCC Report, the World Health Organization (2002) released a comprehensive assessment of the health impacts of climate change using the global burden of disease framework, estimating that approximately 1.7 million deaths in 2000 were attributable to unsafe water, sanitation, and hygiene. Strikingly, 99.8 percent of the deaths associated with these factors occurred in developing countries. In the same year, climate change, measured by

[7] The IPCC defines the climate system as "an interactive system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere, forced or influenced by various external forcing mechanisms, the most important of which is the sun. Also, the direct effect of human activities on the climate system is considered an external forcing" (2001:87). Detailed description of the climate system can be found here: http://www.ipcc.ch/ipccreports/tar/wg1/040.htm.

greenhouse gas emission levels, was linked to 2.4 percent of diarrhea cases, 6 percent of malaria infections, and 7 percent of dengue fever incidence. Climate change was also responsible for 154,000 premature deaths worldwide, with half of these deaths occurring in South East Asian Region (SEAR-D)[8]. Therefore, in consensus with the IPCC (1995), the WHO Report reiterated that shifts in the global climate system are strongly linked to growing health risks.

In light of mounting scientific evidence, the Fifth (latest) IPCC Assessment Report (2014) clearly states,

> "Throughout the 21st century, climate change is expected to lead to increases in ill-health in many regions and especially in developing countries with low income, as compared to a baseline without climate change (high confidence)." (2014: 15).

The 2014 report lists four main health impacts: 1) increased risk of death, disease, and injury due to heat waves and fire; 2) increased risk of undernourishment due to decline in food production in developing countries; 3) increased risks of vector-borne and food- and water-borne diseases; and 4) health costs emanating from lost economic productivity due to heat-related illnesses.

Based on the review of the scientific evidence, the report concludes that climate change will negatively affect calorie availability leading to increases in childhood stunting and adult malnutrition, which has cascading effects on mortality and disability in developing countries. This effect is mostly indirect because climate change affects nutritional status by degrading agricultural production and water quality (Ericksen 2008). Some also argue that climate change contributes to obesity by way of increasing food prices, especially for healthier items like fruits and vegetables (Edwards et al. 2011; Husband 2013). Scarcity of affordable healthy foods leads to consumption of processed, high-calorie diet, which in turn contributes to higher obesity risks (Burns 2004; Friel 2010). Although there is limited evidence directly linking obesity to global

[8] SEAR-D countries, as grouped by World Health Organization, include Bangladesh, Bhutan, Korea, India, Maldives, Myanmar, and Nepal.

environmental change, there is a robust scientific discourse on the diverse health impacts of climate change through food insecurity.

Battisti and Naylor (2009) estimate changes in crop yields due to the effects of climate change and conclude that there is a high probability that hottest seasons on record during the 1900-2006 period will be the norm for growing seasons by the end of the 21st century. They further add that in the absence of adaptation measures, unfavorable meteorological conditions will translate to food insecurity by decreasing the quality and quantity of crops. Nelson et al. (2009) estimate that, under this projected climate scenario, about 25 million more children would be at risk of malnutrition and the disease burden would be more concentrated in the developing region compared to a scenario without climate change. Rosenzweig and Parry (1994) and Lloyd, Kovats, and Chalabi (2011) emphasize that the burden of food insecurity due to climate change falls largely on developing countries. By modeling calorie availability estimates from Nelson et al. (2009) and projected CO_2 emissions, Lloyd, Kovats, and Chalabi project the rate of severe stunting to increase by 62 percent in South Asia even after accounting for the effects of economic growth.

As mentioned earlier, compared to rich countries, poorer developing countries are more likely to bear the larger share of the health risks posed by climate variability. Numerous studies found that socioeconomically disadvantaged populations are more affected by environmental hazards than their better-off counterparts (Peduzzi et al. 2012; Brouwer et al. 2007). Peduzzi et al.'s (2012) global assessment of cyclones spanning 1970-2009 found that mortality risk due to tropical cyclones not only depends on storm intensity but also on the governance structure and poverty level of the country. The mortality risks due to climatic events also vary within country. For example, in Bangladesh, flooding is one of the most common natural disasters in terms of the number of people affected and the number of deaths (Islam 2013). An assessment of the impact of seasonal flooding in Bangladesh found that flooding risks depend on the socioeconomic status of the households – poorer households are more likely to be affected by flooding and receive less assistance than the better off households (Brouwer et al. 2007).

Environmental Degradation and Health in Low-lying Communities in Bangladesh

Lack of access to clean water is a major form of environmental stress in Bangladesh. Although the latest national assessment report that 85 percent of Bangladeshis have access to safe drinking water, our multiyear research in rural southwest Bangladesh reveals no reliable access to clean water year round and that the residents do not realize that their water source is unsafe (Benneyworth et. al 2016). Additionally, to examine groundwater compositions in the region, our geo-physical science team collected water samples from Polder 32, which is an embanked area in Khulna and about 60 km north of Bay of Bengal. Water chemistry analysis reveals widespread contamination of groundwater; 100 percent of the samples exceeded the safe level of 2000 μS/cm for salinity and 83 percent exceeded the WHO guideline of 10 μg/L for arsenic (Ayers et al. 2016).

Access to clean potable water is becoming increasingly challenging in the low-lying southwest region where surface and ground water and agricultural lands have become more saline in recent years (World Bank 2015; Dasgupta et al. 2014b). According to the Bangladesh Ministry of Environment and Forest (2006), about 20 million people living in the coastal areas are exposed to saline water sources. Widespread arsenic contamination of groundwater is also a serious issue that has worsened water insecurity (Flanagan, Johnston, and Zheng 2012; Uddin and Huda 2011). Between 35 and 77 million Bangladeshis have been exposed to arsenic through drinking water sources, especially tube wells (Smith, Lingas, and Rahman 2000; Kinniburgh and Smedley 2001). Chronic ingestion of dissolved sodium salts and arsenic has serious health repercussions for populations with limited drinking water alternatives.

Salinity in the low-lying coastal region is attributed to shifts in environmental conditions, including rising sea level, the subsequent increase in tidal surges during flooding, and human activities such as diversion of upper Ganges riverine channel and expansion of commercial shrimp farming. Coastal communities are most severely impacted by sea level rise. According to the IPCC, the global mean sea level rose by 0.19 meters [0.17 to 0.21] between 1901 and 2010, and this rate is larger than the estimated mean rate for the previous two millennia (2014b). Rising sea level results in seawater encroaching inland into coastal settlements and salinizing coastal aquifers and estuaries (Institute of Water Modeling and Center for Climate Change and Environmental Research 2007; Kovats and Akhtar 2008; Vineis, Chan, and Khan 2011). In addition, droughts, variability in rainfall amount and timing, and intense storms diminish the recharge abilities of water bodies (Kumar 2012). Thus, salinity is more acute during the dry season when saltwater from Bay of Bangladesh moves inland by up to 100km (Allison et al. 2003; Rahman and Bhattacharya 2006).

In addition to climate-driven factors, the expansion of shrimp cultivation, which entails construction of brackish water ponds, has aggravated the salinity problem in the region (Rahman and Ravenscroft 2003; Ali 2006). As one of the fastest growing industries in Bangladesh, the export of shrimp has almost tripled from 19 to 55 tonnes annually in 1993-2011(Ministry of Fisheries and Livestock 2013). Southern and southwestern districts[9], including Bagerhat, Chittagong, Khulna, and Shatkhira, account for approximately 95 percent of the total shrimp

[9] District is an administrative geographic unit used by the Government of Bangladesh. It is akin to a state in the United States.

production (Bhattacharya, Rahman and Khatun 1999). A lucrative alternative to traditional paddy cultivation, commercial and small-scale shrimp farming continues to expand rapidly across the coastal region (Hossain, Uddin and Fakhruddin 2013).

Change in land use of this scale and nature has environmental consequences. First, brackish water used in shrimp farms may enter surrounding farmlands and water sources through underground seepage and runoff during inundations (Trent, Thorton and Shanahan 2004; Shahid, Chen and Hazarika 2006). This not only salinizes already scare water resources but also contributes to food insecurity by decreasing crop yields (Hill and Koenig 1999; University of California- Davis Agriculture and Natural Resources 2002). Furthermore, construction of unauthorized sluice gates in embankments to let the brackish water in and out of the shrimp ponds may weaken embankment structures and contaminate surrounding water sources and farmlands with effluents and pathogens (Paul and Vogl 2011).

Direct Health Impacts. Salt intake through water contributes to a wide range of illnesses. High salt consumption is linked to hypertension (Dahl 2005; Murai et al. 2015), stroke (He and MacGregor 2010), and cardiovascular diseases (Strazzullo et al. 2009). However, most studies examine dietary salt intake in developed countries experiencing a high burden of non-communicable diseases, thus little is known about the health impacts of consuming salt contents dissolved in water. The WHO recommends no more than 5g of salt consumption per day (WHO 2013), but there are no such guidelines for salinity levels in drinking water. The one existing specification is that sodium levels higher than 0.2 g/L give water a bad taste (WHO 2003b). Thus, there is no national figure for salt intake in Bangladesh, although emerging studies suggest that excessive consumption of salt from drinking water is a widespread problem in the coastal communities.

For instance, Khan et al. (2011) reports that average sodium intake from drinking water ranges between 5- 16 g/day in the dry season in Dacope, which is a rural low-lying village near the southwest coast of Bangladesh. Using survey data from a random sample of 343 pregnant women residents, these authors found that women who drank water from shallow tube wells had higher average levels of urinary sodium secretion than those who drank rain/filtered water and river/pond water (Khan et al. 2011). In addition, the prevalence of hypertension among pregnant women was greater in the dry season when the salinity levels in water sources were much higher than the rainy season. Following up on this study, the authors conducted a case-control study of pregnant women with pre-eclampsia, eclampsia, and gestational hypertension in the same area (Khan et al. 2014). In addition to supporting the previous finding that shallow tube wells had the highest level of sodium, the authors also report a positive association between salinity level in drinking water and risks of eclampsia and hypertension.

Indirect Health Impacts. Salinization of farmlands adversely affects nutritional health by aggravating food insecurity in economically poor agrarian communities (Abedin, Habiba and Shaw 2014). The Bangladesh Ministry of Environment and Forest (2006) estimated that approximately 830,000 million hectares of cultivable land in the country is contaminated by salinity, albeit at varying degrees (2006). Salinity reduces agricultural production by decreasing the availability of fresh water for irrigation and by degrading the quality of the soil (Rahman and Ahsan 2001; Ali 2006; Abedin, Habiba, and Shaw 2014; Dasgupta et al. 2014a). A 2000 World Bank report states that salinity decreases rice yields by approximately .5 million metric tons in any given year. Widespread salinization of agricultural farms and consequent decline in crop yields has forced farmers to switch to shrimp farming as a source of livelihood. Ironically, the expansion of shrimp farming leads to the diffusion of brackish water into adjacent farmlands, creating a vicious cycle of soil and water salinization and decreased crop production. Hence, declining crop yields combined with shifts to export shrimp production has serious implications for the nutritional health of children and adults living in these areas (Nupur 2010; Hossain, Uddin and Farkhruddin 2013; Bishwajit, Barmon, and Ghosh 2014).

Arsenic in drinking water is another serious public health issue in Bangladesh. Contamination of groundwater by naturally occurring inorganic arsenic is so widespread across the country that Smith, Lingas, and Rahman (2000: 1093) declared it as "the largest mass poisoning of a population in history." The tube well that draws water from groundwater aquifers is one of the main sources of potable water in Bangladesh (Bangladesh Bureau of Statistics and United Nations Children Fund 2010). In the 1970s, the nation was grappling with high child mortality and morbidity rates driven by water-borne diseases, mainly diarrhea and typhoid. Rural households mostly relied on surface water from rivers and ponds, which contained high levels of disease-causing pathogens. In response, the national government initiated a drive to install shallow cost-effective tube wells in the rural areas (Smith, Lingas and Rahman 2000). Tube well water is cleaner since it contains lower levels of microbes and pollution. Currently, about three-quarters (73 percent) of the rural population relies on tube wells as a primary source of drinking water (United Nations Children Fund 2010).

Although water from tube wells is generally considered free from disease causing microorganisms, one national survey found that 27 percent of all shallow tube wells had very high levels of arsenic (>50 μg/L) and 46 percent well exceeded the 10 μg/L WHO standard for safe drinking water (British Geological Survey and Department of Public Health Engineering 2001). In addition, recent statistics show that about 80 percent of the aquifers in Bangladesh's southwest low-lying region have some degree of arsenic contamination (Abedin, Habiba, and Shaw 2012). Hence, chronic exposure to high levels of arsenic through drinking water sources is pervasive and health consequences have started to emerge.

Health Impacts. Arsenic, a toxic trace material, can cause severe, long-term damage to vital organs (World Health Organization 2001). Skin lesions are a hallmark symptom of arsenic poisoning and indicate high risks for a variety of cancers and other ailments. Arsenic is associated with increased risk for cancers of the kidney (Chen et al. 1992; Yuan et al 2010), skin (Tseng 1977; Yu, Liao, and Chai 2006), liver (Liu and Waalkes 2008), and lungs (Celik et al. 2008). Prolonged exposure to arsenic through drinking water sources is also linked with cardiovascular diseases (Navas-Acien et al. 2005; States et al. 2009; Chen et al. 2011) and neurologic conditions (von Ehrenstein et al. 2007; Brinkel, Khan, and Kraemer 2009). Others have linked arsenic to low birth weight (Nordstrom, Beckham and Nordenson 1979) and low body weight among adults (Goebel et al. 1990; Grashow et al. 2014).

Using data from HEALS, a prospective cohort study set in Araihazar, Bangladesh, Argos et al. (2010) evaluated the health effects of arsenic exposure and found that exposure translates to higher mortality and morbidity risks. More specifically, 21 percent of all-cause mortality and 24 percent of chronic disease mortality were attributed to drinking water that contained 10 μg/L or more of arsenic. Similarly, Sohel et al. (2009) found that arsenic exposure significantly elevated the risks of nonaccidental deaths in Matlab, Bangladesh. Even the lowest dose of exposure (10-

49 μg/L) increased the risks of death by 16 percent. Overall, research has linked arsenic to a host of acute and chronic conditions that are severe and life threatening.

Environmental Stress and Migration

Adaptation strategies in response to environmental stressors are crucial to the survival and well-being of children and adults living in environmentally and socio-economically compromised locations. In countries like Bangladesh, adaptive measures include growing saline resistant crops (Rabbani, Rahman, and Mainuddin 2013), modifying agricultural calendars to sync with the changing weather patterns (Meze-Hausken 2004), shifting land use from paddy lands to shrimp farms (Islam 2008; Azad, Jensen, and Lin 2009), seeking non-agricultural employment (Kartiki 2011), and sending one or more household members outside the village to work (McLeman and Smit 2006; Bardsley and Hugo 2010; Black et al. 2011; Gray and Mueller 2012). Among these responses to environmental pressures, migration is often among the most viable. Rather than signifying failure to adapt, migration is increasingly recognized as a feasible pathway to disperse risks and diversify livelihood portfolio.

Studies have examined the impact of environmental conditions on mobility decisions and patterns in several developing countries. Most notably, research in Africa focuses on drought and temperature/rainfall variability (e.g. Findley 1994; Ezra and Kiros 2001; Henry, Schoumaker, and Beauchemin 2004; Dillon, Mueller, and Salau 2011; Gray and Mueller 2012). Findley's (1994) study on the impact of drought on migration in Mali reveals that while the level of migration did not change during the drought period of 1983-1985, patterns of migration markedly altered and short-cycle circular migration became twice as large during the drought period (29 vs. 63 percent migrated). In addition, preferred migration destinations shifted from

France to domestic destinations within Mali and to other African nations. Findley also finds that women and children migrated more than men during droughts.

Similarly, Ezra and Kiros (2001) use a household survey administered in rural, drought prone areas of Ethiopia to examine rural out-migration. They find that community vulnerability to food crises along with individual- and household-level factors (such as age, sex, relationship to and education of household head, and housing quality) significantly predict out-migration. Using a longitudinal data from rural highlands in Ethiopia, Gray and Mueller (2012) also find evidence linking drought to population mobility in Ethiopia. Dillon, Mueller, and Salau (2011) draw attention to another African nation, Nigeria, where they find a significant association between temperature variability and internal migration that households undertake to protect against *ex ante* and *ex post* agricultural risk. In Sahelian region of Burkina Faso, Henry, Schoumaker, and Beauchemin (2004) find that the relationship between environmental conditions and migration is more nuanced than previously established. Their analysis shows no effect of rainfall conditions on the risk of first migration overall, but when they distinguish destinations by rural, urban, and international, they find that people residing in rural drier areas have higher odds of migrating to other rural destinations than those living in areas with higher precipitation.

Distinction by climatic features of areas is important in a study that examines the association between rainfall patterns and U.S. migration from rural Mexico. Nawrotzki, Riosmena, and Hunter (2013) report a non-linear association between precipitation and out-migration; the likelihood of emigration declines with a decrease in rainfall until the turning point is reached at a 16 percent decrease in rainfall. After that, further declines in rainfall increase the probability of out-migration and the rate is highest at a rainfall deficit of 40 percent. Moreover, rainfall decline is associated with a significant increase in out-migration only for dry states. In the Ecuadorian Andes region, Gray (2009) stresses that the determinants of migration vary by destination in that local or short distance migration is more sensitive to environmental conditions whereas long distance/international moves are less responsive to those factors.

Studies also use climate models to assess the impacts of projected meteorological conditions on human mobility. For example, Barbieri et al. (2010) estimate the long-term relationship between climate change, economic factors, and migration in Northeast Brazil. Based on the predicted levels of carbon emissions and subsequent rise in temperature, these authors find that the future climate scenarios will adversely impact economic outputs, which in turn will push people to migrate. Feng, Krueger, and Oppenheimer (2010) examine the role of climate change and its impact on crop yields in Mexico-U.S. migration and show that changes in crop yields attributable to climate change significantly influence emigration rates. Using forecasted temperature scenarios, these authors estimate that climate change will push between 1.4 and 6.7 million Mexicans to migrate to the United States because of reduced agricultural output.

In Asia, studies examine out-migration in response to environmental conditions such as flooding, temperature changes, and rainfall variability (e.g. Massey, Axinn, and Ghimire 2010; Yu et al. 2010; Bohra-Mishra, Oppenheimer, and Hsiang 2014; Mueller, Gray, and Kosec 2014). One recent study is on Indonesia. Bohra-Mishra, Oppenheimer, and Hsiang (2014) investigate the impact of climatic variation and natural disasters on interprovincial household migration using panel data from the Indonesian Family Life Survey. The authors use variation in temperature and precipitation as well as a set of natural disasters, including earthquake, eruption, flood, and landslide, as measures of environmental conditions. They find that temperature and precipitation both have nonlinear effects on migration, with the former having larger effects than the latter. When average temperatures were below 25°C, an increase in temperature reduced outmigration, but when average temperatures exceeded 25°C, an increase in temperature increased the probability of household outmigration. Similarly, for precipitation, the turning point value was at 2.2 m in average annual precipitation. Only one natural disaster, landslides, had a marginally significant, small, positive effect on outmigration.

Researchers have conducted similar studies in South Asia. Massey, Axinn and Ghimire (2010) investigate the connection between out-migration in Chitwan, Nepal, and environmental change, as measured by declining land cover, increasing times to gather organic inputs, increasing population density, and perceived declines in agricultural productivity. They find that the effects of environmental conditions were larger for local moves than distant ones. With regard to local mobility, the odds of moves for those who perceived agricultural productivity as declining were 31 percent higher than those who did not; a one-percent point increase in flora cover in the neighborhood decreased mobility odds by 2 percent; and a hundred minute (1 hour, 40 minutes) increase in the time to gather firewood raised mobility odds by 10 percent. As for distant moves, only perceived decline in agricultural productivity and time to collect fodder had modest significant effects. Massey and colleagues emphasize that although the effects of environmental factors are sizeable, social and human capital also have consistent large effects on mobility and stress the environment is just one of many important factors in migration decision-making.

More recently, Mueller, Gray and Kosec (2014) test the environment-migration link in Pakistan using Pakistan Panel Survey data. Using multiple weather variables – cumulative rainfall during the wheat cultivation season, average temperature to gage heat stress, flood intensity, and moisture index – the authors assess the impact of weather variations on mobility of men and women in rural Pakistan. Although rainfall had minimal impact and flooding had no significant association with outmigration, moisture and extreme temperatures were associated with lower migration rates. Additionally, the authors speculate that heat stress may indirectly influence migration through its effects on agricultural and non-agricultural income.

In rural Bangladesh, Gray and Mueller (2012) have studied the impact of natural disasters – flooding and crop failure unrelated to flooding – on long-term local and long-distance migration using longitudinal data covering a 15-year period. Controlling for sub-district and household level variables, community exposure to flooding had a significant non-linear effect on mobility. Moderate levels of flooding increased the odds of local moves by 57 percent and marginally decreased the odds of long-distance migrant trips by 28 percent, compared to low flooding years. Compared to periods without crop failures, severe crop failure increased the odds of overall mobility by 138 percent, and the odds for local mobility were 197 percent higher and for long-distance mobility 82 percent higher. Importantly, the authors report that these effects varied by gender and socioeconomic status. Compared to years without flooding, women and the poor had higher odds of migrating in years with moderate flooding. Crop failure significantly affected mobility, increasing women's mobility by 178 percent and men's by 91 percent.

Donato et al. (2015a) use Bangladesh Environment and Migration Survey data[10] to examine whether social capital and meteorological conditions are associated with making a first migration trip. With regard to social capital, those who have migrant parents and/or siblings have higher likelihood of making a first internal or international migration trip than those who do not have such connections, and the difference between the two groups is larger for international than internal migration. Additional analysis shows that having parent or sibling with international

[10] Bangladesh Environment and Migration Survey (BEMS) is a new, primary data source that I use in my dissertation. I describe the data set in detail in the Data and Methods section in this proposal.

migration experience increases the likelihood of making a first unauthorized trip (Donato et al. 2015b). With respect to meteorological factors, only temperature has a significant effect – being from an area that has cool temperatures lowers the risk of making a first internal trip. Effects for rainfall on internal and international migration trips were not significant.

Because migration is linked to natural disasters and to anthropometric-related environmental deterioration, studies focus on how environmental events such as cyclones affect population mobility. A qualitative case study by Kartiki (2011) in coastal villages in Bangladesh offers insights about people's movement post disasters. Although difficult to isolate environmental factors from economic ones as drivers of migration, Kartiki finds that climate factors may "increase the impetus towards migration" (2011: 28). One elderly woman describes the migration process in this way:

> "When I got married we had a big family but not enough land to farm. Nature has never been our friend here. But even after a storm or a heavy flood we managed. Then came the sons and their wives and then their children. Now when a disaster strikes, we have no option but to send our children to work elsewhere…" (Kartiki 2011: 28).

In situations like this one, which are common in impoverished parts of Bangladesh, the combination of population pressures, landlessness, limited livelihood options, and environmental stressors motivate people to migrate. Kartiki also reports that the seasonality of agriculture allows smaller farmers and the landless to migrate temporarily to urban areas to earn extra income working as construction workers, rickshaw pullers, and mill laborers. Although a small number of people also migrated permanently to India, Kartiki cautions that migration arising post large disasters may not be an adequate or effective adaptation strategy as migrants sent negligible inconsistent remittances because they had to pay off hefty fees to migrate and earn meager wages as unauthorized workers.

In 2011, the United Kingdom Government's Foresight Project commissioned a review on environmental change and migration in Bangladesh to shed light on population movement in hazard prone environments, especially the coastal and deltaic floodplains (Government Office of Science 2011). While the loss of life due to climatic hazards declined substantially in the last 2-3 decades, damage to homes, farmland, and assets have not. In addition, after experiencing adverse environmental events, men migrated outside their village to secure livelihoods while the rest of the family stayed behind. Hence, mobility under such scenarios occurred for reasons of safety, income generation, and recovery, but is mainly short-term and temporary, except when people incurred a total loss of homestead and land. In such extreme circumstances, they tended to move to a new location permanently.

In another important series of briefing papers, authors highlight how climate-related migration reduces vulnerability and builds resilience. There are three briefing papers in the series; the first highlights growing environmental challenges that residents in study districts perceive and experience such as extreme temperatures, water stress due to rainfall deficits and salinization of water resources, drought, flooding, and riverbank erosion (Sussex Center for Migration Research and Refugee and Migratory Movements Research Unit Bangladesh 2013a). These environmental conditions severely threatened livelihoods in impoverished rural communities. In response, residents in affected areas sent their sons and daughters for short and long periods of time to work as shrimp farmers, vendors, rickshaw pullers, and wage laborers. Thus, in this context, migration is "an effective adaption strategy to offset the impact of climatic stresses and shocks" (2).

The second brief (2013b) differentiates among internal migration; internal displacement; short-term contractual international labor migration; cross-border migration; and long-term permanent migration to the West. While displacement, internal migration, and migration to India are more sensitive to climate factors, permanent migration and short-term international labor migration appears to be less so and instead driven by livelihood needs and desire to improve quality of life.

The final brief (2013a) projects the long-term movement of people from sub-districts that experience flooding, storm surges, and riverbank erosion. It estimates that approximately 9.5 million people will migrate between 2011 and 2050 from sub-districts experiencing these three environmental stressors. Together the briefs offer an overview of migration in Bangladesh and examine how environmental stress leads to migration as a form of adaptation for many residents, especially those in coastal Bangladesh.

The Role of Social Factors in Environment-Health Relationship

Until recently, the natural environment has received only intermittent attention in contemporary sociological literature (Dunlap 1997; Buttel 2002). In the last 30 years, studies in environmental sociology and the sociology of natural resources have shed light on the intersection of social factors and environmental processes. In contrast, for many decades studies on health have examined the social environment characterized by neighborhood disorder (Ross and Mirowsky 2001; Burdette and Whitaker 2005), income distribution (Wilkinson 1996; Kawachi and Kennedy 1997), occupational setting (Schnall et al. 2000; Stansfelds et al. 1999), and degree of social cohesion (Kawachi and Berkman 2001; Roux and Mair 2010).

Although sociological studies have greatly expanded our understanding of how social factors influence population health, they are incomplete because they often overlook or take for granted the natural domain. But growing interest about climate change and increasing data availability that includes social and environmental variables have led social scientists to integrate the two areas. For example, patterns of rainfall are linked to household migration decision-making (e.g. Hunter, Murray, and Riosmena 2013; Milan and Ruano 2014); impacts of natural disasters vary by gender and socioeconomic status (Neumayer and Plümper 2007; Singer and Donato 2005, respectively); and water scarcity is tied to political turmoil within and between nations (Postel 1993). One issue that has yet to be explored in human-environment studies is whether and how social factors protect residents from adverse health impacts of deteriorating environment. Two important social resources – migration and social support –may play important roles by protecting and promoting population health and well-being, especially in environmentally compromised locations.

Migration and Health

Research suggests that migration disrupts and reorganizes the dynamics of households and communities in significant ways (Hondagneu-Sotelo 1992; Parrado, Flippen, and McQuiston 2005; Massey 1990; Taylor et al. 1996). Whether motivated by economic conditions or environmental push factors or a combination of both, migration is consequential to the health and well-being of migrants and their families (Kanaiaupuni and Donato 1999; Landale, Oropesa, and Gorman 2000; Frank and Hummer 2002; Thomas 2007; Donato and Duncan 2011; Lu 2013). In general, studies on migration and health have focused on migrant health in destinations; health of children living in migrant versus nonmigrant households; and health impacts of remittances. In recent years, research has also shed light on the consequences of migration for the health of family members who stay behind in the origin community. Below I discuss key findings from these studies.

There is a large body of literature on immigrant health in destinations. Many studies discuss migrant health selectivity and whether immigrants are in better health than natives (e.g. Franzini, Ribble and Keddie 2001; Palloni and Arias 2004; Elo et al. 2004; Antecol and Bedard 2006; Hummer et al. 2007). In the United States, this phenomenon is popularly known as the Hispanic paradox, which refers to similar or better mortality rates and health outcomes of Hispanic immigrants compared to U.S. natives, despite lower socioeconomic status.

Migration scholars examine health differences by characteristics related to household migration. Studies comparing the health and survival of children and adults living in migrant and non-migrant households have yielded insightful yet mixed findings. Overall, evidence suggests that the migration of household members, especially mothers, is a significant predictor of child health. Household migration status has positive and negative associations with childhood/adult mortality and morbidity – the results vary by geography, unit of analysis, and type and duration of migration.

Omariba and Boyle (2010) use DHS data from 52 countries, including Bangladesh, to examine the association between mothers' migration status and infant mortality. Children born before migration and within five years of migration have higher odds of surviving than children of rural non-migrants. Yet the association reverses for children born after five years of rural-urban migration; they have higher odds of dying than children of rural non-migrant mothers. The authors argue that the favorable survival outcome is largely attributed to migrant selectivity, e.g. that migrants tend to have higher SES and better health. Other studies examine how mother's migration affects child survival in particular countries. Ssengonzi, De Jong, and Stokes (2002) use DHS data for Uganda; they describe within-group differences in under-five mortality rates of children depending on mother's migration status. Children of nonmigrants mothers in both rural and urban areas had the worst survival rates compared to children of migrant mothers, net of other factors.

Studies also show that children of migrant mothers experience worse health outcomes, especially during the first few years after migrating. Pooling DHS data for 17 countries, Brockerhoff (1994) examines whether internal migration is related to better child survival rates. He reports that children of women who were internal migrants had comparable or higher mortality risks than the children of women who did not migrate. Early in the migration period, children's risks of death increased sharply and were substantially higher than those for urban and rural nonmigrant children. However, children born to rural-urban migrant women in urban destinations had better survival rates than those born to rural nonmigrant mothers.

Antai et al. (2010) carried out a similar analysis for Nigeria and found that children of urban and rural nonmigrant mothers had lower mortality risks than children of rural-urban migrant mothers. Children who were less than five years of age and had rural-urban migrants as parents had 37 percent higher risks of death than children of urban nonmigrant mothers. In Bangladesh, Islam, and Azad (2008) also report that children of rural-urban migrants had higher mortality risks than children of urban non-migrants. Mortality risks were especially high for recent migrants who moved to their current location less than 10 years before the survey period. However, these risks declined with longer residence in the urban destination, a finding consistent with Brokerhoff (1994).

Kiros and White (2004) studied the relationship between parental migration and children's immunization in Ethiopia and argued that the type of migration, whether rural-to-rural or rural-to-urban, and who migrates – father or mother, matters. Examining migration types and who migrates, the authors found that father's migration had no significant impact on child's immunization but mother's rural-to-rural migration had a strong and negative effect on child immunization.

Migration entails economic and social transfers between origins and destinations and these may influence the health status of family members. The new economics of labor migration theory stipulates that families and households make decisions to send one or more members to work outside to diversify risks and supplement income (Stark and Bloom 1985; Massey et al. 1993). This theoretical framework helps connect migration to its consequences for the ones who remain behind (Hamilton, Villareal, and Hummer 2009; Lu 2010). Nawrotzki, Riosmena, and Hunter (2013) argue that households use migration as an *ex post* adaptation strategy to minimize the effects of crop failure due to climatic shocks in absence of insurance system. In the context of limited livelihood options and without a safety net, remittances that migrants send affect the economic situations of households. Studies indicate that large portions of remittances are spent on consumption goods, such as food and other regular household expenses (Adams 2005), and education and capital investments (Mora and Taylor 2006). In some cases, remittances increase food security, improve sanitation, and enable the families to seek healthcare (Amuedo-Dorantes, Sainz and Pozo, 2007).

Social remittances is another mechanism that links migration to the health of those who stay behind (Levitt 1998). Migrants are conduits of information and transfer knowledge gathered from migration experiences and destination places to origin family members (Lindstrom and Hernandez 2006; Levitt and Lamba-Nieves 2011). Such information influences attitudes and practices related to nutrition, sanitation, and health services utilization among other things (Lu 2013). However, it is important to note that transmission of information entails communication of both healthy and unhealthy behaviors from destination to origin (Granovetter 1983; Goldman and Schurman 2000; Palloni et al. 2001).

Other studies have also examined the health consequences of migration for origin family members. Much of this scholarship is focused on migration in the Western Hemisphere, and especially in Mexico, where approximately four percent of children under 15 years of age (1.3 million) are living without their father due to migration (Nobles 2013). Studies examine how migration affects infant/child survival at the origin (Kanaiaupuni and Donato 1999; Hamilton, Villarreal, and Hummer 2009; Yabiku et al 2012), perinatal health (Frank and Hummer 2002; Hildebrandt and McKenzie 2005; Lindstrom and Franco-Munoz 2006); and children's physical health (Antón 2010; Creighton et al. 2011; Carletto, Covarrubias, and Maluccio 2011; Schmeer 2009; Donato and Duncan 2011; Smeekens, Stroebe, and Abakoumkin 2012).

Using data from the Mexican Migration project, Kanaiaupuni and Donato (1999) examine how migration patterns influence infant mortality in five main sending communities – Guanajuato, Jalisco, Michoacan, Nayarit, and Zacatecas – in Mexico. They find that as migration initially increases, infant mortality risks rise. However, after migration becomes a sustained activity in the community, infant survival improves. Thus, the effects of migration unfold over time and health impacts vary across different stages of community migration. Likewise, Hamilton, Villarreal, and Hummer (2009) examine the association between U.S. migration experience and infant mortality in Mexico. They analyze data from the 2000 Mexican Census long form, which included a migration supplement administered to 10 percent of all Mexican households. Restricting the sample to women aged 15-49, the authors find that infants born to women who had made a recent U.S. trip had 40 percent lower odds of dying before reaching their first birthday than infants whose mothers did not have such experience. On the other hand, infants in households with one or more recent migrants had higher odds of dying than those in households without recent migrants. These associations were stronger for rural than urban subsamples. In addition, infants born to rural women who received remittances had 20 percent lower odds of dying than infants with mothers who did not receive any remittances. Remittances had no significant impact on child survival in the urban subsample.

Other than Mexico, Yabiku et al. (2012) analyze data from a longitudinal survey of married rural women aged 18-40 living in southern Mozambique to study whether male labor migration affects under-five mortality. The authors initially found no significant difference in under-five mortality rates between households with and without migrants. However, when they categorized migrants as successful and unsuccessful based on the amount of remittances sent home and spouse's perceptions, there were significant differences. Children of successful migrants had the lowest mortality rates, followed by children born to nonmigrants and unsuccessful migrants.

Frank and Hummer (2002) investigate how international migration influences the risk of low birth weight of Mexican infants. Using data from the 1997 Ecuesta Nacinal de la Dinámica Demográfica (ENADID), a nationally representative survey, the authors find that infants in migrant households had lower odds of low birth weight than those in nonmigrant households. Among migrant households, those who received remittances were 40 percent less likely to have babies with low birth weight. Additionally, even migrant households that did not receive remittances had 15 percent lower odds of having low birth weight babies compared to nonmigrant households. Hildebrandt and McKenzie (2005) use the 1997 ENADID data to further examine how household migration impacts mortality rates and birth weight. Using the instrumental variable approach, the authors find that migration experience resulted in lower mortality rates and higher birth weight among infants in Mexico. Furthermore, children in migrant households were more likely to be delivered by a doctor than their nonmigrant counterparts. However, infants in migrant households were less likely to be breastfed, vaccinated, and taken to a doctor at least once in the first year.

Research on the impact of migration on child health outcomes other than mortality has yielded a diverse set of findings. Antón (2010) uses data from the Survey on Living Conditions 2005-2006 to investigate whether remittances impact nutritional status of under-five children in Ecuador. The author reports positive and significant impact of remittance income on short-term nutritional status as measured by weight-for-age z-score (underweight); the receipt of remittances increased the z-score by 0.74 SD on average. The effect of remittances on long-term nutritional status, as measured by height-for-age z-score (stunting), was not significant. Carletto, Covarrubias, and Maluccio (2011) carry out a similar study examining the link between U.S. migration and child growth in rural Guatemala. Using primary, cross-sectional household survey data from Huehuetenango region, a principal sending area in the western highlands, migration is positively associated with child growth. Children in households with a migrant had .5 SD higher height-for-age score, indicating a lower likelihood of stunting, than those who lived in households without migration experience.

Donato and Duncan (2011) examine how parental migration affect child health and well-being among Mexican families using bi-national data from Health and Migration Survey (HMS). They consider how social relationships influence the association between parental migration status and child health among families that currently living in the U.S., those that migrated but returned to Mexico, and those who never migrated. Findings show that children in current migrant households were much more likely to have good health than those in nonmigrant and return migrant households.

A handful of studies also report negative physical health consequences of migration. For instance, Schmeer (2009) examines the relationship between father absence due to migration and child illness in rural Mexico. Using longitudinal data from the Education, Health and Nutritional Program, the author reports children whose father was absent had 39 percent higher odds of being ill and 51 percent higher odds of having diarrhea compared to when father was present. Creighton et al. (2011) use data from the Mexican Family Life Survey to examine the impact of migrant networks on children's (aged 3-15) overweight status. Children living in households with migrant network ties had higher risks of becoming overweight or obese compared to children in households with no migrant networks, after controlling for individual and household characteristics. Smeekens, Stroebe and Abakoumkin (2012) examine the physical and mental health consequences of parental migration on adolescents in the Philippines and find that adolescents with a parent abroad reported poorer physical health than their counterparts who had both parents at home.

Fewer studies examine the impact of migration on the health of family members other than children. In the Asian context, studies on Bangladesh, Indonesia, and Thailand aim to understand the migration-health link in the region, which sends a large number of migrants worldwide (Hugo 2006). For instance, Kuhn (2005) examines the relationship between adult children's migration and the health of the parents in rural Matlab, Bangladesh. Using data from Matlab Health and Socio-Economic Survey (MHSS) and Demographic Surveillance System (DSS), he finds that son's migration is positively and significantly associated with parents' survival and physical functioning but the effect of daughter's migration was not statistically significant. Kuhn and his colleagues (2011) further test whether children's migration is consequential to the health of the elderly who remain behind in Indonesia. Using the Indonesian

Family Life Survey, a panel survey of individuals and households in Indonesia, they find results consistent with findings from Matlab, Bangladesh: having a migrant child is associated lower risks of mortality and fewer negative health outcomes.

Similarly, Lu (2013) uses a longitudinal data from the Indonesian Family Life Survey to investigate whether household migration status influences nutritional status of adult family members who stay behind. She finds that adults in migrant households have lower odds of being underweight than those in nonmigrant households. Importantly, the improvement in nutritional status was observed only for households with labor migrants, indicating that remittances may be a mechanism that link migration to nutritional status.

Adhikari, Jampaklay, and Chamratrithirong (2011) utilize a national survey of older persons in Thailand to investigate the impact of children's migration on the physical and mental health of elderly parents in origins. They find that having a migrant child increased the risks of poor mental health. In addition, they find no evidence of an association between child migrant status and physical health outcomes, including chronic conditions, perceived quality of health, and illness. However, having a migrant child significantly increased the odds (OR= 1.22) of seeking professional health care.

Although these studies provide rich empirical and theoretical insights into how migration and health are related in different parts of the world, they do not specifically consider whether migration is related to, or protects, health when migration occurs under environmental stress. Climate change research explores various institutional level strategies as a means to protect lives and promote health in the face of environmental adversity, but it often shortchanges individual- and community-level adaptation in the form of migration. Hence, my dissertation offers an indepth examination of whether and how migration affects health in environmentally and socioeconomically compromised settings.

Social Support as a Coping Resource

Social relationships influence mental and physical health in significant ways (Berkman et al. 2000; Umberson and Montez 2010; Thoits 2011). The quality and quantity of social relationships are associated with mortality risks and a range of health outcomes, such that those who are more engaged in social relationships have lower risks of death than those who are less involved (Berkman and Syme 1976; House, Landis, and Umberson 1988; Brummett et al. 2001). Studies also show that several physical health conditions, such as of obesity, cardiovascular diseases, high blood pressure, and compromised immune functions, are associated with individual's social ties and affiliation (Kawachi et al. 1996; Uchino 2004; Christakis and Fowler 2007; Ertel, Glymour, and Berkman 2009). Although most studies show positive health returns, they also document negative consequences of social support depending on the nature and extent of the relationships (Walen and Lachman 2000; Kassel, Stroud, and Paronis 2003; Ross and Mirowsky 2003; Christakis and Fowler 2007). For example, Umberson et al. (1996) shows that marriage improves the health of men but not women. Yet, whether positive or negative, scholars agree that social relationships play an integral role in the health and well-being of individuals.

Even though related and often intertwined, social integration, social support, and social networks represent different aspects of an individual's association with other social entities (Dasgupta 2003). Durkheim (1951) theorized that levels of social integration and cohesion affect suicide rates. Although often viewed as an individual pathology, he found that suicide is patterned by social facts such as the degree of communal integration and regulation. His thesis was the first to implicate social factors as correlates of mental and physical health, and scholars now argue that social conditions are “fundamental causes of disease” (Link and Phelan 1995:80). These social conditions influence social ties and networks and they affect health through different mechanisms (Berkman et al. 2000). One key psychosocial pathway that links social context to health outcomes is social support derived from social relationships or networks (Umberson and Montez 2010; Thoits 2011).

There is strong research evidence that social support improves coping with stress and overall health status, and lowers mortality risks (Lin, Ye, and Ensel 1999; Cohen 2004; Uchino 2004). Umberson and Montez (2010) define social support as “the emotionally sustaining qualities of relationships (e.g., a sense that one is loved, cared for, and listened to)” (S56). Weiss (1974) divides social support into subtypes – emotional, instrumental, appraisal and informational. Emotional support refers to “love and caring, sympathy and understanding and/or esteem or value available from others” (Thoits 1995). Instrumental support is tangible and is monetary and non-monetary aid or assistance, and appraisal support entails providing advice and feedback to help with decision-making. Finally, informational support includes extending information and advice to help during the time of need. Thus, studies point out that social support in its various forms is an indispensable resource that may build resilience and protect health when faced with environmental adversities.

Social support research has flourished in recent decades; however, the vast majority of studies focus on developed countries and on health conditions that are mostly associated with those countries. Thus, few studies consider how social support operates in developing countries (Schwarzer and Leppin 1991; Yip et al. 2007; Story 2013). Because resources such as income and financial assets, health infrastructure, and government support are limited in these settings, social support may prove to be a valuable resource as families cope with stress or crises (Adams, Madhavan, and Simon 2002).

A handful of studies assess the social support- health relationship in non-Western settings. For example, a comparative study of social support and health among older adults in Canada, Brazil, and Colombia report a positive association between social support and self-reported health and quality of life (Belanger et al. 2016). In addition, the sources of support matter; for Canadians, support from friends correlated with better health whereas support from family, including children and partner, was related to better quality of life for Colombians and Brazilians. Another study focused on the role of social capital, including support, among individuals and households during times of self-care treatment of diarrhea in rural Bangladesh (Edgeworth and Collins 2006). The authors found that the treatment was more successful when social capital related resources such as social support and health information were available.

A number of studies focus on nutritional health. Using the Indonesia Family Life Survey, Nobles and Frankenberg (2009) investigate how participation in community activities among low SES mothers affects children's nutritional health (height-for-age score). The authors find that mother's participation in volunteer organizations is positively associated with children's nutritional status. Other research on developing countries also shows that families often derive social support from voluntary community associations (e.g. Barber et al. 2002).

Similarly, Harpham, De Silva, and Tuan (2006) assess how social support is associated with child health using multiple child health measures, including physical health status, height-for-age, and weight-for-age for one-year old and eight-years old children in Vietnam. They find that mothers who received support from formal and informal networks had higher weight-for-age scores and lower incidence of illness among young children, after accounting for maternal, paternal, child, and community characteristics. However, no such effects were found for older children.

Carvalhaes, Benicio, and Barros (2005) examine the relationship between social support and malnutrition (weight-for-age score) by conducting a case-control study in Botucato, a municipality in Southeastern Brazil. Having financial support significantly improved the nutritional status of children, but this association was only significant for low-income families and not for their high-income counterparts. Effects for other social support variables, such as the presence of relatives, participation in church and neighborhood organizations, receiving emotional support, and receiving support in the events of electricity cuts and water shortages, were insignificant. Surkan et al. (2007) also focus on Brazilian children in the northeastern part of the country. Their findings reveal that mothers who received material and affectionate support from others had children with higher average weight-for-height and weight-for-age scores than children whose mother lacked such support.

In addition, Adams, Madhavan, and Simon (2002) find mixed evidence regarding the health impacts of social support in Mali. Using survey data from a comparative study of women's social networks and maternal/child health, they examine whether women's social networks influence under-five child mortality in two ethnic groups, i.e. Bamanan and Fulbe. Among Fulbe women, they find practical, cognitive, and emotional support derived from maternal networks decreased the odds of child death. However, social support from maternal networks did not contribute to child survival among Bamanan women.

These studies, along with an expansive body of literature on social support, demonstrate the health promoting qualities of social support in various settings. However, there is limited scholarship on how social support influences child and adult health in environmentally stressed communities. To that end, my dissertation examines whether social support bestows protection on individuals in Bangladesh who experience poor health due to adverse environmental conditions.

Research Hypotheses

Based on prior studies, I present four sets of overarching hypotheses:

1. Physical environment will be a significant predictor of childhood and adult nutritional status and the double burden of malnutrition. Specifically, urban residence will increase the odds of being overweight and/or obese whereas living in rural areas will increase the odds of being underweight. Coastal proximity will also be important; living close to the coast will increase the odds of being underweight among adults, and stunting, wasting, and underweight among children.
2. Adverse environmental conditions will be associated with poor physical health outcomes of men and women living in southwest Bangladesh. Perceived environmental stress will be associated with poor self-reported adult health and undernutrition. Salinity in tube well water will be positively associated with adult undernutrition and poor health, and arsenic contamination in tube well water will be associated with malnutrition and poor self-reported health.
3. Migration will moderate physical environment-health association. Migrant status will protect against undernutrition among adults and against stunting, wasting, and underweight among children. Household migration experience will also mitigate the negative health impacts of perceived/actual environmental stress. Specifically, the number of migration trips made by household members and whether they receive

remittances will moderate the effects of perceived environmental stress, salinity level, and arsenic contamination on self-reported quality of health and nutritional status.

4. Social support will moderate the relationship between perceived/actual environmental stress and health in southwest Bangladesh. Social support will buffer the negative health consequences of perceived environmental stress, and salinity and arsenic contamination of tube well water. Monetary support will have the largest moderating effect followed by smaller effects for practical support and emotional support.

CHAPTER II

DATA AND RESEARCH DESIGN

In this dissertation, I use primary and secondary data sources that include survey, spatial, and water chemistry data. The data are from two sources: Bangladesh Demographic and Health Survey (BDHS) and Bangladesh Environment and Migration Survey (BEMS). The BDHS, which is implemented by ICF International, is a nationally representative data set funded and made publicly available by the United States Agency for Development (USAID). In contrast, the BEMS surveyed a representative sample of households in 11 communities in southwestern Bangladesh; it was part of an interdisciplinary project at Vanderbilt University (2011-2016) funded by the U.S. Office of Naval Research. Below I describe the data sources, the key variables under study, and the overarching analytic model for the empirical chapters that follow.

Bangladesh Demographic and Health Survey (BDHS)

The Demographic and Health Survey (DHS) is a cross-sectional, nationally representative survey carried out every 4 to 5 years in approximately 90 middle- and low-income countries using standardized questionnaires and comparable sampling techniques. The DHS collects information from women of reproductive age and covers a gamut of health-related topics such as maternal and child health, healthcare seeking beliefs and practices, marital and fertility history, socio-economic and demographic characteristics, and gender norms. DHS data also include anthropometric measurements for women, men, and children; these data permit estimation of nutritional status. In various years, DHS data also record the geographical coordinates of sampled communities. Although DHS data do not contain detailed migration histories, in some years and for some countries DHS data include questions about current and past residences. Brockerhoff (1994), Islam and Azad (2008), Omariba and Boyle (2010) have analyzed responses to these questions to establish respondents' migration status at the time of the survey.

For my analysis, I use the 2007 DHS data available for Bangladesh. Although data are available for subsequent years, e.g. 2011 and 2014, the more recent data do not include questions on past and current residence, which are central to my analysis because they capture migration. The 2007 BDHS interviewed approximately 11,000 women of reproductive age, i.e. ages 15 to 49, from 361 communities, and collected their health data and anthropometric measurements. The survey also collected information on their children (n=5,700) who were five years or younger at the time of the survey. The BDHS includes a separate GIS file, which contains geographical coordinates of the surveyed communities.

Key Measures

Table 2.1 lists the focal variables from the 2007 BDHS used in my dissertation analysis.[11] The dependent variable is nutritional status, which is derived from information about height, weight, and age. Experts recommend measuring child and adult nutritional health in four ways: collect anthropometric measurements, implement biochemical testing, evaluate through clinical examination, and analyze dietary intakes (World Health Organization Expert Committee 1995; Shetty 2003; Lieberman 2017). Because using all four methods is not always cost-effective, especially in the context of global health, the Centers for Disease Control, World Health

[11] The control variables are not described in this table.

Organization, and other public health organizations primarily use anthropometric measurements, mainly BMI and related indices, to assess child and adult nutritional health (Tuffrey 2016).

Table 2.1 Description of Key Variables Used in the Analysis, Bangladesh Demographic and Health Survey (2007)

Key Variables	Description	Values
Health Outcomes		
Nutritional status	Adults: Body mass index: Respondent's weight (kg) divided by the square of height (meters) Body weight status	Continuous numeric Underweight Normal weight Overweight
	Children: Stunted (Height-for-age index) Underweight (Weight-for-height index) Wasted (Height-for-weight index)	No= 0 Yes=1
Environmental Predictors		
Rural or urban community	Communities designated as "urban" or "rural" by the Government of Bangladesh	Rural = 0 Urban = 1
Coastal proximity (in km)	Distance between surveyed community and the nearest coastline	Continues numeric
Moderator		
Migration Status	Based on the information of previous residence and current residence, migration status of the survey respondent is established. Migration entails crossing administrative boundary lines.	Nonmigrant = 0 Migrant = 1

Source: Bangladesh Demographic and Health Survey (2007)

Trained BDHS interviewers used SECA 874 digital scales to measure weight (in kilograms) and Shorr boards to measure height (in centimeters) of women respondents and their children.[12] For women, I calculate two weight-based health outcomes: body mass index (BMI) and body weight status. BMI, also known as Quetelet's index, is an international standard for nutritional health assessment and used extensively by the World Health Organization, National Institutes of Health, and Centers for Disease Control and Prevention. I calculate BMI by dividing respondent's weight (in kilograms) by the square of their height (in meters); hence it is a continuous variable with positive values.

To account for the double burden of malnutrition in Bangladesh, I use a second variable – body weight status– from BMI estimates. Body weight status consists of three levels: underweight, normal weight, and overweight. Based on the global criteria for nutritional status for Asian populations established by the World Health Organization (WHO 2004), I classify respondents with BMIs of 18.5 or less as underweight; 18.5 to 22.9 as normal weight; and 23 and greater as overweight.[13] Thus, body weight status is a categorical variable in which the categories are not ordered or ranked. As a result, both low and high BMI scores are considered unhealthy.

I use body weight status as a second dependent variable because it measures nutritional health in terms of underweight, normal or healthy weight, and overweight. The Centers for Disease Control and Prevention and World Health Organization use these weight status categories derived from BMI to assess mortality and morbidity risks associated with poor nutritional health (WHO 2004; CDC 2017). In addition, body weight status helps to measure the double burden of malnutrition by capturing both undernutrition and overweight within a population. Finally, focusing on body weight status allows me to simultaneously estimate the

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[12] SECA scale and Shor board, which are used extensively to collect anthropometric data, are recommended by the World Food Program (WFP) and Centers for Disease Control and Prevention (CDC) for nutritional health research (United Nations High Commissioner for Refugees n.d.).

[13] By comparison, the Centers for Disease Control and Prevention's criteria for the nutritional status of the U.S. population define underweight as BMI below 18.5, normal weight as BMI of 18.5-24.9, and overweight as BMI of 25.0-29.9 (Centers for Disease Control and Prevention 2017).

likelihood of being underweight or overweight and how that compares to the benchmark of normal weight without splitting data into subsamples and compromising the power of the analysis.

For young children, i.e. those who are five years or younger, I use three outcomes that reflect different aspects of nutritional health and well-being: whether they are stunted, wasted, or underweight. Using height, weight, and age information, I calculate the height-for-age index, an internationally recognized indicator, to reflect "the cumulative effects of undernutrition and infections since and even before birth" (WHO 2010: 1). Children who fall below two standard deviations of the WHO Child Growth Standards median are stunted. Hence, the outcome variable is binary, coded as stunted (=1) or not (=0). I calculate the second measure, wasted, from the weight-for-height index. Because this index reflects acute malnutrition due to inadequate food consumption and the presence of infectious diseases, especially diarrhea, I define a child as wasted if his or her height-for-weight measure falls below two standard deviations of WHO standards. Like stunted, wasted is coded as 1 and 0. Finally, I measure underweight, which captures the compounded effects of both chronic and acute malnourishment, by using the weight-for-age index such that children who fall below two standard deviations of WHO standards are categorized as either underweight (=1) or not (=0).

To measure physical-environmental conditions, I use two variables from the BDHS data: whether respondents live in a rural or urban area and the distance of the community of residence from the nearest coastline. I code urban (=1) or rural (=0) to be consistent with the Government of Bangladesh's classification system for the administrative geographic units. The second variable is coastal proximity, constructed from the latitude and longitude coordinates of surveyed communities. Using the "Near" tool in ArcGIS Desktop software, I generate the metric distance (in kilometers) between a point (i.e. BDHS study site's GPS location) and a line (i.e. the coastline). To account for the curved surface of earth, I use geographic coordinate system such that the line representing the distance is not a straight line per se but the spherical distance. The estimated distance between the community and the Bay of Bengal coastline denotes proximity to the coastal environment.

As mentioned earlier, I examine the effect of migration as a moderator of the relationship between the physical environment and nutritional status. To do this, I create a migrant status variable by using questions about respondents' current and past residences. The 2007 BDHS asked women about the current place of residence and whether respondents moved to their present location from another administrative region in Bangladesh. Based on these two questions, I create a dummy migration variable coding those who migrated to their current location from another administrative district as 1 and those who have never moved as 0. In models that predict nutritional status for children, I use their mother's migrant status to test whether mother's migration is beneficial to children's nutritional health.

For the women's analysis, I include the following demographic controls: age (in years), marital status, employment status, education (in years), number of children under the age of five, and relationship to the household head. I use household wealth index to measure socioeconomic status. The wealth index is a composite measure of the standard of living derived from respondents' self-reports about household ownership of assets, materials used in house construction, and access to water resources and sanitation facilities. The DHS uses principal components analysis (PCA) to construct the index and categorizes households into one of five wealth groups (quintiles) (see Vyas and Kumaranayake 2006 for an overview of using PCA for constructing SES indices). In countries like Bangladesh, because there are no data that adequately capture income and expenditures (Rustein 2008; Psaki et al. 2014), the wealth index offers a robust measure of relative socioeconomic standing of households.

Finally, I include lifestyle variables such as frequency of watching television, listening to the radio, and reading newspaper and magazines. For the children's analysis, I include child-level demographic variables such as their age, sex, and birth order as well as maternal (women's) demographic characteristics. I also include household wealth index as a proxy for family's socioeconomic status in the children's analysis.

Bangladesh Environment and Migration Survey (BEMS)

The BEMS is part of an interdisciplinary research project that spans research areas in environmental science, geology, geographic information systems (GIS), political science, psychology, and sociology. BEMS data include surveys of households, migrants, and communities. For my dissertation, I use data from the household survey (BEMS-HH), which was fielded to self-identified household heads and spouses in approximately 200 randomly selected households in 11 study communities or *mauzas*[14] (equivalent to U.S. census blocks) in Khulna division[15] in southwest Bangladesh. In addition to the household module, the BEMS team fielded a community questionnaire (BEMS-C) to community leaders and a migrant questionnaire (BEMS-M) to migrants who originated from the BEMS-HH sites but were living in Dhaka or Khulna as migrants at the time of the survey. However, in my dissertation I only use BEMS

[14] According to the Bangladesh Population and Housing Census report (2011), mauza is the lowest administrative unit with a separate jurisdiction in revenue records. A mauza may consist of one or more villages (Bangladesh Bureau of Statistics 2015).

[15] Bangladesh is divided into eight major regions called divisions: Barisal, Chittagong, Dhaka, Khulna, Mymensingh, Rajshahi, Rangpur, and Sylhet.

household survey data. BEMS data collection occurred between November 2013 and March 2014.

BEMS' main objective is to collect and analyze data to understand causes and consequences internal and international migration in southwest Bangladesh, with a special emphasis on the environmental drivers of out-migration. BEMS data were collected using the ethnosurvey technique developed by the Mexican Migration Project and later adapted by Latin American Migration Project and other studies (Donato and Massey 2016). The ethnosurvey combines ethnographic and survey methodology to gather reliable and detailed information on migration behavior and other demographic processes that standard surveys have often failed to capture (Massey 1987; Massey and Zenteno 1999). The strength of ethnosurvey lies in its use of multi-method design combined with semi-structured interviewing process. The methodology employs representative survey sampling techniques, which entails administering surveys to randomly selected households in study sites. It implements a flexible and unobtrusive interviewing approach combined with standardized questionnaire which permits collection of same information from each respondent. As such, the ordering and wording of questions may vary but the recording and reporting of survey data remain uniform.

In addition to migration and border crossing data, the BEMS ethnosurvey gathered information on livelihood activities, household attributes and property holdings, perceptions about water quality and environmental change, and social support. It also asked questions about health, including chronic conditions, quality of physical health, and psychological distress. The enumerators also measured height and weight of the household head, spouse and their children using SECA scale and Shorr board – the same instruments used in Bangladesh Demographic and Health Surveys.

The BEMS team worked with a Bangladeshi survey research firm, Mitra and Associates, to collect ethnosurvey data in the initial pilot of two sites and subsequently for nine others. The firm has considerable experience with large research projects, including complex household surveys, and is one of the key entities involved in the implementation of the Bangladesh Demographic and Health Surveys. Mitra assisted with all phases of BEMS data collection and entry. In addition, we worked with the firm to translate and format survey instruments and other related training and coding materials. Mitra hired native Bangladeshi enumerators to administer the pilot and non-pilot surveys. Prior to data collection, we trained the enumerators over a three-week period in Dhaka, Bangladesh. Those enumerators collected all the data for this project, including anthropometric information and GPS points of sample households. After data were collected, Mitra implemented quality checks, entered the data into an electronic database from paper-and-pencil surveys, and submitted the final data sets to BEMS team.

Enumerator training was rigorous. For the pilot, I was present at the training to answer questions about the instruments and data collection protocols. Following this training, enumerators carried out a pretest of the household and community questionnaires in a nearby rural community. This pilot yielded important insights about administering the ethnosurvey, asking for certain information, and practical aspects of fieldwork. Throughout the pretest, I was available either in person or by phone to address any issues raised by enumerators. After completion of the pretest, Mitra entered the data and submitted the data set to the BEMS team for review. Based on our assessment of this data and feedback from the field staff, BEMS team revised and finalized the survey instruments.

Using a complete census in each study site as the sampling frame, we randomly sampled 200 households. For sample sites that had less than 200 households, we administered the ethnosurvey to all households. Enumerators were grouped into four teams with each team consisting of 9-10 enumerators. In addition, four quality control officers visited the teams on a rotating basis. I traveled to seven of the nine study sites and spent between 3-4 days in each site to observe the administration of the household and community surveys. While in the field, I also cross-examined the completed surveys and provided feedback to enumerators and team leaders. Additionally, I gathered rich fieldnotes and took pictures of the communities to capture the natural and man-made landscapes.

As part of the household survey, the BEMS also gathered GPS coordinates of sampled communities to link survey data to water samples collected by environmental scientists. Under the guidance of the physical science team at Vanderbilt University, a team of two environmental scientists from Khulna University in Bangladesh visited 8 of the 9 non-pilot study sites[16] and obtained water samples in July/August 2014. In each study site, the team randomly sampled water sources, mostly tube wells; the number of samples depended on the geographical size of the *mauza.* The samples were then transported to Vanderbilt University for further analysis. The University's Civil Engineering lab then tested the water samples for salinity and arsenic content in addition to a variety of cations and anions that comprise most of the dissolved solids in groundwater.

Table 2.2 presents the number of water samples collected from each *mauza* and the average corresponding levels of salinity and arsenic. The water chemistry data that I use in my analysis consist of information from 118 randomly selected tube wells. I only include tube wells because in rural areas, 97 percent of the population relies on tube well water for drinking and other domestic uses (Bangladesh Bureau of Statistics and UNICEF 2010). I exclude three

[16] The environmental team did not collect water samples from Narail Sadar *mauza.*

samples that were collected from tidal channels (n=2) and surface pond (n=1) because salinity and arsenic contents in these water bodies are significantly higher than in tube wells. Additionally, quality of water from these sources is known to vary considerably season to season (Benneyworth et al. 2016).

Table 2.2 Summary of Water Chemistry Data: Salinity and Arsenic in Tube Well Water in 8 BEMS sites

Upazila	Salinity (µS/cm)	Arsenic (µg/liter)	No. of samples
Kalia	2904	1	13
Keshabpur	1189	83	15
Mongla	7509	1	15
Morrelganj	3696	14	9
Phultala	990	4	15
Shatkhira Sadar	1715	71	14
Sharsha	935	27	15
Tala	2672	161	22
Total			118

Source: BEMS water chemistry data

As shown in Table 2.2, I rely on a total of 118 water samples ranging from 9 in Morrelganj to 22 in Tala; this includes 13 samples from Kalia, 14 from Satkhira Sadar and 15 each from Keshabpur, Mongla, Phultala and Sharsha. Salinity, which measures the amount of dissolved salts in a given volume of water, is calculated from specific conductivity (SpC) and reported in microsiemens per centimeter (µS/cm) unit (Ayers et al. 2017). In general, fresh groundwater has conductivity of less than 300 µS/cm (Kemker 2014). However, the average salinity of BEMS water samples is 2701, which is above the safe levels for drinking. Although there are no official guidelines about salinity levels in water, prior hydrogeological studies specify 2000 µS/cm as the upper threshold for drinking water (Ravenscroft 2003; Uddin and Kaudstaal 2003; Ravenscroft et al. 2005). Therefore, using this standard, I create a salinity variable which describes water samples as saline if their salinity is 2000 µS/cm or higher (equal to one); if less than this cutoff, water samples are coded as fresh (equal to zero). One caveat to this measurement of salinity is that it reflects average salinity at the *mouza* level. Mongla has the highest average salinity of 7509 µS/cm and Sharsha has the lowest with 935 µS/cm. The rest fall in between. The average salinity for Kalia, Mongla, Morrelganj and Tala exceed the safe level of 2000 µS/cm whereas the remaining four – Keshabpur, Phultala, Satkhira Sadar, and Sharsha – fall below this threshold.

Arsenic contamination is measured by the amount of arsenic particles in water and reported in micrograms per liter (µg/L) unit. In natural waters, concentrations of 2µg/L or less are considered as an acceptable level (WHO 2011). However, the Environmental Protection Agency (EPA 2002) and the World Health Organization (WHO 2011) state that the concentration of arsenic in drinking water should not exceed 10 µg/L. Table 2.2 shows that the average arsenic level for the BEMS sample is 45.3, which is four times the safe level value of 10 µg/L for drinking water.[17] On average, Kalia and Mongla have negligent amounts (1 µg/L) of arsenic whereas Tala has an astoundingly high level of contamination (161 µg/L). Phultala (4 µg/L) and Morrelganj (14 µg/L) are within safe levels but the remaining sites – Keshabpur (83 µg/L), Satkhira Sadar (71 µg/L) and Sharsha (27 µg/L) – also exceed the safe limits.

Research Sites

The study area is situated in the southwest part of the country with the Bangladesh-India border to the west and the Bay of Bengal to the south. Recall, Figure 1.3 shows Bangladesh with the study area highlighted in orange. The inset on the right-hand side of the map zooms in on the five southern districts in Khulna division where the study sites are located: Bagerhat, Jessore,

[17] Since the values of arsenic have a wide range, I also computed the median for arsenic contamination. For the full sample, the median level of arsenic contamination is 21, which is twice the safe level for drinking water.

Khulna, Narail, and Shatkhira. In each district, we then selected two sub-districts or *upazilas*[18] (see labeled and striped areas).

We chose two Kalabogi and Kamarkhola *mauzas* in the Dacope *upazila* as pilot sites and collected the data in October 2013. These *mauzas* are located in Polder 32, an embanked area approximately 60 km north of the Bay of Bengal. The polder, which is 12 miles long and 4 mile wide, was devastated by cyclone Aila in 2009 (Mehedi 2010). Although both pilot sites are rural and located in close proximity to one another, they are slightly different in geographical and socioeconomic parameters. Kamarkhola is the northernmost *mauza* whereas Kalabogi is the southernmost *mauza* in Polder 32. Field observations and data from the physical science team revealed that Kamarkhola is only slightly better off than Kalabogi. For instance, Kamarkhola has lower average arsenic in their water sources than Kalabogi (39 µg/L vs. 72 µg/L) (Benneyworth et al. 2016). In addition, over half of the households (52%) in Kamarkhola owned their own water source whereas only 39 percent owned a private source in Kalabogi (Benneyworth et al. 2016).

Following completion of pilot data collection and analysis, the BEMS team revised the study instruments. The revisions were minimal and entailed making changes to the questionnaires such as rewording some of the items and modifying response options. The overall format of the questionnaires and the sampling strategy remained unchanged. We then implemented the main study, collecting ethnosurvey data from nine additional sites in five southern districts in Khulna division. The five districts include Bagarhet, Jessore, Khulna, Narail and Shatkhira. We purposively chose Phultala upazila in Khulna district as an economically developed and environmentally less compromised counterpart to the pilot sites in Dacope. We

[18] *Upazila* is equivalent to county in the U.S. administrative system.

further chose eight *upazilas* from the remaining four districts by examining how they vary by economic development and environmental stress.

To measure economic development (ED), we used data from the 2010 Bangladesh census and created an index based on adult literacy rate and access to electricity. The ED index represents averaged *upazila* levels of adult literacy and prevalence of household electricity. We then computed grand mean, which is the average ED for all *upazilas* in the five districts. Next, we stratified the *upazilas* into two groups: those above and below the grand mean representing higher and lower ED, respectively. Finally, we randomly chose one *upazila* from high ED group and one from low ED group for each district.

Since the *upazilas* are still big geographic units, we selected one *mauza*, which are smaller geographic units akin to communities, within each of the selected *upazilas*. *Mauza* selection entailed two steps. First, we split all *mauzas* in high ED *upazilas* into two groups – those with ED scores higher than the average *upazila* score and those with lower than average ED scores. From the higher ED score group, we randomly selected one *mauza.* Likewise, from the sampled low ED *upazilas,* we randomly selected one *mauza* with ED score below the average *upazila* score. As a result, the study sample includes four high ED *mauzas* selected from the sampled high ED *upazilas* and four low ED *mauzas* from the sampled low ED *upazilas.*

To measure environmental stress, we used data about soil salinity from the Integrated Agricultural Productivity Project (World Bank 2009). The project created a measure of soil salinity, which we use to represent environmental stress. Furthermore, a north-south geographic transect was used as a proxy indicator of environmental stress with environmental vulnerability decreasing as one moves inland (north) away from the coastal south (CSIRO, WARPO, BWDB, IWM, BIDS and CEGIS 2014). Hence, the site selection procedure ensured heterogeneity in terms of socioeconomic and environmental conditions.

Table 2.3 List of Bangladesh Environment and Migration Survey (BEMS) Sites and their Attributes

District Upazila	Total No. of Households	Average Soil Salinity	Economic Dev. Index	% Hindu	Sample Size	Selected *Mauzas*
Khulna						
*Dacope**	36,597	3.9	40.0	55.7	200	Kalabogi & Kamarkhola
Phultala	19,555	3.0	67.5	10.6	200	Tajpur
Bagarhat						
Morrelganj	75,968	2.6	40.5	10.6	134	Godara
Mongla	32,383	3.6	49.3	21.0	200	Bidyarbahan Digraj
Jessore						
Keshabpur	62,309	2.8	46.8	18.0	200	Daskahania
Sharsha	82,835	1.0	51.3	2.5	161	Katsikra
Narail						
Kalia	48,579	2.5	46.6	16.1	200	Par Bishnupur
Narail Sadar**	62,795	2.5	53.0	27.2	200	Mahishkhola
Shatkhira						
Tala	299,820	2.4	44.7	25.7	200	Kahalishkhali
Satkhira Sadar	109,105	2.8	55.4	12.8	200	Kultia
				Total	**1895**	

Data sources: 2010 Bangladesh Census; World Bank (2009); BEMS
*Pilot site
** Narail Sadar is not included in the analysis because water samples were not collected from this site.
Note: Low economic development (ED) upazilas are in italics.

In total, we collected data from self-identified household heads and their spouses in 1,895 randomly sampled households. Table 2.3 describes the study sites and their relevant demographic, economic, and environmental characteristics. As discussed earlier, we chose two *upazilas* within each of the four districts– one above the grand ED mean and one below; the low ED *upazilas* are listed in italics in the table. The pilot sites in Dacope (in Khulna district) is the most impoverished site with the lowest ED score of 40. Dacope is also environmentally vulnerable; it is located in close proximity to the Bay of Bengal and only buffered by the mangroves. As such, these sites are highly vulnerable to coastal surges, soil erosion, flooding, and cyclones. The average soil salinity score is 3.9, which is the highest among the study sites. Housing over 36,000 households, Dacope's religious make-up is distinct from the rest of the country – over 55 percent of population is Hindu.

Our purposively chosen site, Phultala *upazila*, is a more developed and less environmentally compromised counterpart to the pilot sites in Dacope. Phultala is characteristically urban with established educational and medical institutions, improved water and sanitation facilities, and thriving local markets. Furthermore, Phultala is connected to Khulna city, one of the major cities in Bangladesh, by a paved highway. Phultala has the highest ED score (67.5) in our sample. There are approximately 20,000 people living in the *upazila*; approximately 11 percent of this population identifies as Hindu. We randomly selected Tajpur *mauza* from Phultala *upazila* for the study.

In Bagerhat district, we selected Morrelganj and Mongla *upazilas*. As the southernmost sites in our sample, they are prone to coastal hazards such as land erosion, saltwater intrusion and cyclones. Morrelganj is more than twice the size of Mongla (75,968 vs. 32,383 households, respectively), and they vary in soil salinity, economic development, and religious composition. Mongla scores higher in soil salinity (3.6) than Morrelganj but the former is economically more developed than the latter (ED scores of 49 vs. 41). Mongla is close to a thriving seaport and the economy is dependent largely on trade and fisheries. In constrast, Morrelganj is agrarian and rural with a vast expanse of agricultural land. In Morrelganj, we randomly selected Godara *mauza* as the research site. Since Godara consisted of less than 200 households (n=134), we surveyed the entire mauza. In Mongla, we randomly selected Bidyarbahan Digraj *mauza*, where we randomly sampled 200 households.

Jessore district is on the northwest side of the region. Both Keshabpur and Sharsha *upazilas* are less exposed to environmental stress than other study sites primarily due to their location. Socioeconomically, both *upazilas* are average with Sharsha being slightly better off than Keshabpur (ED scores of 51 vs. 47). However, Keshabpur, is closer to the coast and more saline (2.8) than Sharsha (1.0). With regard to religious composition, Keshabpur has a larger Hindu population (18%) than Sharsha (2.5%). Sharsha is also distinct from Keshabpur and other study sites because Benapole land port, which is one of the busiest crossing points between India and Bangladesh, is located in this *upazila*. The port is heavily secured by armed forces on both sides of the border. At this junction, immigration and customs officials strictly monitor the legal movement of people and goods between the two countries. The randomly selected *mauza* in Sharsha, Katsikra, is relatively small and hence, we surveyed all households in the *mauza* (n=161). In Keshabpur, our randomly selected *mauza* is Daskahania.

Narail is located in the northeast corner of the study region. Kalia and Narail Sadar have comparable salinity-related stress with both sites scoring 2.5 on the soil salinity index. Kalia, however, is more rural and socioeconomically disadvantaged than Narail Sadar. The economic development index score for Kalia is 47 whereas for Narail Sadar, it is 51. Furthermore, Kalia is not easily accessible by road. Approximately one-quarter (27 percent) of Narail Sadar residents are Hindu whereas less than one-fifth (16 percent) of the population in Kalia is Hindu. We randomly selected Par Bishnupur *mauza* from Kalia and Mahishkhola *mauza* in Narail Sadar.

Located in the southwest corner of Khulna division, Satkhira *upazila* borders India. This area was hit with cyclone Aila, in 2009, and it is still recovering economically and environmentally. We chose Tala and Satkhira Sadar in this *upazila*; both are exposed to coastal vulnerabilities due to their proximity to the Bay of Bengal. Demographically, with 300,000 households, Tala is the largest site in our sample. Comparing the economic development indices, we see that Satkhira Sadar (55) is more economically developed than Tala (45). The religious make-up of the *upazilas* also differs; approximately a quarter (26%) of Tala's population is Hindu whereas only 13 percent of the Satkhira Sadar's residents are Hindu. We chose Kahalishkhali and Kultia *mauzas* from Tala and Satkhira Sadar, respectively.

Key Measures

Table 2.4 lists and describes the main BEMS variables I use in the analyses. I focus on three outcome variables to measure health and well-being – body mass index (BMI), body weight status, and self-reported health. As described in the earlier BDHS section, I calculate BMI as a continuous variable from height and weight data. Recall that I derive body weight status from BMI by categorizing respondents into underweight (BMI <18.5), normal weight (18.5<=BMI<23) and overweight (BMI >=23) groups.

In the survey, we ask respondents to assess the quality of their health over the past year and report whether they were healthy, fairly healthy, or unhealthy. This measure of self-rated health is used by many researchers to assess overall health (e.g. Jylha 2009; Altman, Hook, and Hillemeier 2016). For the analysis, I collapse healthy and fairly healthy into one category. Hence, self-reported health is a binary variable and coded as 0 if respondents reported themselves as healthy or fairly healthy, or 1 if they reported being unhealthy. I reverse code this variable to reflect poor health because I am interested in the negative health impacts of environmental conditions and whether social resources are protective under such circumstances.

I use three environmental predictors: two objective measures of water quality and a measure of subjective perceptions about environmental stress. The two objective measures are salinity and arsenic content in tube well water. As described earlier, I use specific conductivity (SpC), which indicates how well water conducts electrical current to determine salinity level. Recall, following (Ravenscroft 2003; Uddin and Kaudstaal 2003; Ravenscroft et al. 2009), I specify 2000 µS/cm as the threshold for safe drinking water and code water sources that have an average salinity of 2000 µS/cm or higher as saline and those below as fresh. Based on this cut-off, Kalia, Mongla, Morrelganj and Tala are coded as saline communities whereas Keshabpur, Phultala, Shatkhira Sadar, and Sharsha are non-saline or fresh.

Table 2.4 Description of Key Variables used in the Analysis, Bangladesh Environment and Migration Survey

Key Variables	Description	Values
Health Outcomes		
Adults	Body mass index: Respondent's weight (kg) divided by the square of height (meters)	Continuous numeric
	Body weight status	Underweight Normal weight Overweight
	Self-reported health	Healthy/Fairly healthy = 0 Unhealthy = 1
Environmental Predictors		
Salinity	Salinity in tube well water measured by specific conductivity (µS/cm)	Fresh = 0 Saline = 1
Arsenic	Amount of arsenic in tube well water (µg/L)	Low arsenic= 0 High arsenic = 1
Perceived environmental stress index	Index measure created from a series of 10 questions on perceived environmental conditions	1-10
Moderators		
Household migration trips	Number of migration trips, internal and international, made by household members prior to the survey	Continuous numeric
Remittances	Whether the household receives remittances	No = 0 Yes = 1
Social support	Practical support Emotional support Monetary support	No = 0 Yes = 1.

Source: BEMS household survey

In addition, following the Environmental Protection Agency (EPA 2002) and the World Health Organization (WHO 2011) guideline that arsenic in drinking water should not exceed 10 μg/L, I code study sites with average arsenic content of 10 μg/L as high arsenic and those below the cut-off as low arsenic communities. Based on this definition, Keshabpur, Shatkhira Sadar, and Tala are high arsenic and the rest are low arsenic communities.

The third environmental variable captures household heads' perceived environmental stress using answers from a series of questions that ask whether respondents noticed a decrease, increase, or no change in 10 different environmental conditions over the past 10 years. The environmental conditions include temperature; amount of rainfall during monsoon; amount of rainfall during other seasons; severity of floods; severity of drought; salinity of groundwater; severity of cyclones; diversity of trees and plants in the village; erosion of river banks; and salinity of river water. I use these items to create a summary index. For every item the respondent reports as deteriorating, I assign the value of 1. For instance, if the respondent reports an increase in the average temperature, I assign numeric value of 1 and in the case of decrease or no change I assign 0. Following the same logic for the remaining nine environmental items, I sum these responses into one index that ranges from 0 to 10.

Moderators

My BEMS analysis centers on two moderators: migration and social support. Table 2.4 describes two variables that measure migration. First, from the household migration history, I counted all internal and international migration trips made by the household members prior to the survey date. As such, the household migration variable is a continuous numeric variable and reported as number of trips. The second migration variable is whether households receive remittances from within Bangladesh, India, or other countries. The remittance variable is binary and coded as yes =1 if any amount of remittances was received in the past 12 months and no=0 if no household member received remittances.

The second key moderator, social support, includes three variables: practical, emotional support, and monetary or material. Practical support refers to routine help such as running errands and helping during the harvest season; emotional support includes offering advice and comfort; and monetary or material support consists of providing tangible goods, including money, food items, and transport. Because I want to test whether social support protects health, I recode the variables into binary measures- whether the respondents received each kind of support. Hence, those who received support at least once in the preceding year is coded as yes=1, and those who received none as no=0.

Control Variables

I use the following demographic controls: age, sex, religion, self-reported health at first marriage, human capital index, and home materials index. Age is reported in years; sex is either male or female, and religion is Islam (=0) or other religion (=1). Health at marriage is a self-reported health status. BEMS asked the respondents to recall the quality of their health at the time of their first marriage and report whether they were healthy, fairly healthy, or unhealthy. Like the self-rated health dependent variable, I recoded health at the time of first marriage as binary, collapsing fairly healthy and healthy into one category and coding it as 0 and then coding unhealthy as 1. This variable permits me to control for prior or baseline health status.

Human capital index (HCI) is a summary index calculated from household head's demographic characteristics. I use the following three variables to construct the index: whether the head can write a letter; whether s/he completed primary education, and whether s/he works in skilled occupation. I use responses to these yes/no questions to create the index which ranges from 0-3 with 0 being the lowest and 3 being the highest level of human capital in the household. The human capital index has good internal consistency with Cronbach's alpha of 0.72 which is above the cutoff of 0.70 (Nunnally 1978).

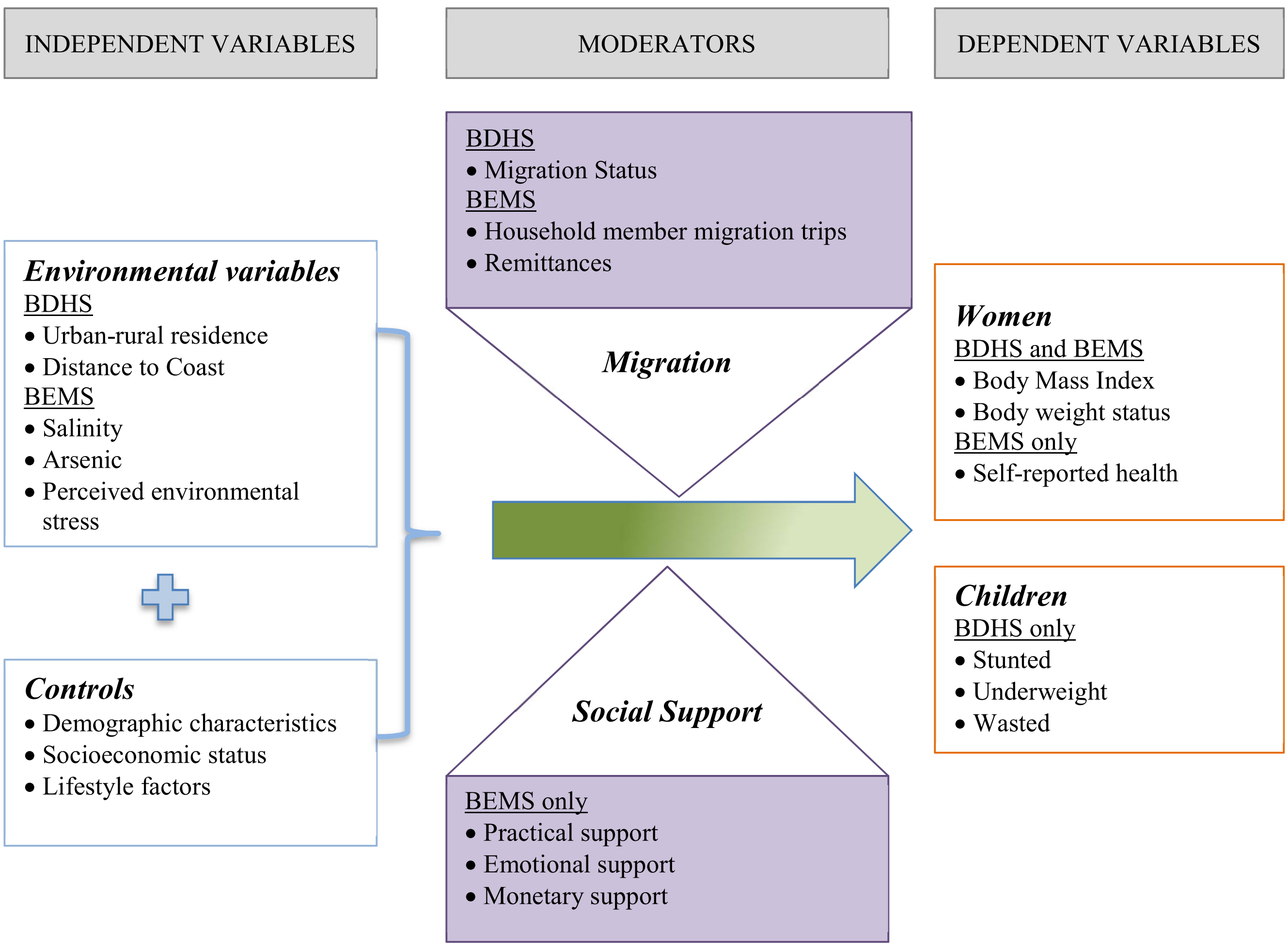
I use three variables that characterize the build of the house to construct home materials index (HMI): whether home has finished or cement floor; whether home has cement roof, and whether home has brick and/or cement walls. Similar to human capital index, this summary variable ranges 0-3 with 0 being the lowest level and 3 being the highest. The Cronbach's alpha for this index is 0.74 suggesting, like the human capital index, the home materials index has good internal consistency.

Analytic Plan

Figure 2.1 lays out an analytic model that broadly illustrates the linkages between the variables described above. Using data from the BDHS and BEMS, I use an inductive approach to assess the model and build incremental analytic models based on observed data. My selection of dependent variables, focal predictors, and moderators is guided by univariate and bivariate results. I describe this approach as part of the model building process in each chapter.

As shown in Figure 2.1, there are two sets of independent variables listed on the left: physical/environmental variables and demographic controls. The dependent variables are on the far right side and include a suite of physical health outcomes for children and adults. The center of the diagram depicts two moderating factors – migration and social support – that purportedly impinge on the relationship between environment and health. The arrow going from independent to dependent variables represents the postulated effects of environmental factors on health outcomes, controlling for the demographic characteristics. The changing shade from dark to light denotes the moderation effects such that poor health related to environmental conditions is attenuated after social support and migration-related resources are included in the models.

Figure 2.1 Analytic Model showing the Relationship between Independent, Dependent, and Moderating Variables



I use this model as a guiding framework for a more detailed analysis in the following three chapters. At the beginning of each chapter that follows, I describe and then present the analysis. To summarize, in Chapter III, I use the 2007 BDHS to investigate how urban/rural residence and coastal proximity affects BMI and the odds of being underweight, normal weight, and overweight among women across Bangladesh. I also examine whether migration is associated with the odds of being underweight or overweight. I extend the analysis to children under five and investigate whether and how the geographical attributes of community of residence affect children's nutritional status and whether mother's migrant status offers protection.

Chapter IV uses BEMS data to examine the relationship between the environmental variables and health outcomes listed in Figure 2.1. The analysis focuses on migration as a moderator of this relationship. Migration is measured by the total number of trips made by household members and remittances received in the previous year. Chapter V also uses BEMS data but focuses on the moderating effect of social support. I examine whether and how each type of social support – practical, emotional, and monetary – protects against poor nutritional health given environmental conditions related to salinity, arsenic, and perceived stress.

CHAPTER III

ENVIRONMENT, HEALTH, AND MIGRANT STATUS: FINDINGS FROM 2007 DEMOGRAPHIC AND HEALTH SURVEY

In this chapter, I use data from the 2007 Bangladesh Demographic and Health Survey (BDHS) to investigate how the physical environment characterized by its geographical attributes such as urban or rural location and proximity to the coastal environment influence women's and children's nutritional health. Moreover, I assess whether and how the migrant status moderates the health impacts of the physical environment. The analysis entails testing two sets of hypotheses. The first set pertains to ever-married women of reproductive age (15-49 years) in Bangladesh and the second set focuses on their young children under the age of five.

In the following paragraphs, I present the research hypotheses and describe my analytic approach, including research strategy and data used, to test those hypotheses. Next, I report findings from my analysis. After presenting results for women and children, I conclude with the summary of main findings.

Hypotheses

The overall goal is to investigate the distinct ways in which geography and migration interact to shape women's and children's nutritional health across Bangladesh. Based on prior research, I expect the physical environment to play a significant role in explaining the variation in women's BMI and body weight status, and children's nutritional health as measured by stunting, wasting, and underweight. The hypotheses for women address Bangladesh's growing prevalence of double burden of underweight and overweight. For children, the focus remains on undernutrition. Because children, especially those under the age of five, have not experienced prolonged exposure to the physical environmental conditions as their mothers, I expect environment effects will be much smaller for them than for women. The research hypotheses are as follows:

Women:

H1a: Women living in urban areas are heavier (higher BMI and higher odds of being overweight) than women living in rural areas. Conversely, women living in rural areas are lighter (lower BMI and higher odds of being underweight) than their urban counterparts.

H1b: Women living closer to the coast have lower BMI and higher odds of being underweight than women living farther from the coast. Conversely, women living away from the coast have higher BMI and lower odds of being underweight.

H1c: The effects of rural residence and coastal proximity on BMI and the odds of being underweight are smaller for migrant women than nonmigrant women.

Children:

H2a: The odds of being stunted, underweight, and wasted are higher among children living in rural communities than those living in urban communities.

H2b: The odds of being stunted, underweight, and wasted are higher among children living near the coast than those living farther from the coast.

H2c: The effects of rural residence and coastal proximity on the odds of children being stunted, underweight, and wasted are smaller for children of migrant mothers than those of nonmigrant mothers.

Analytic Plan

The women's analysis is organized around two dependent variables - BMI and body weight status. By assessing how the environmental predictors regress on women's BMI, I examine whether and how urban/rural residence and coastal proximity contribute to the linear change in BMI. I further investigate whether environmental factors contribute to the double burden of malnutrition by focusing on body weight status, the second dependent variable. I then consider the role of migration – does migration contribute to good nutritional health? Additionally, does migration protect against the negative health impacts of unfavorable environmental conditions? The analytic plan to answer these questions is as follows:

Prior to testing the research hypotheses, I examine the distributions of variables used in the analysis. I begin by presenting means and standard deviations for continuous variables and percentages for categorical variables in Table 3.1. I then estimate two sets of bivariate associations: first, between the dependent variables and geographic attributes, and second between the dependent variables and migration (moderator) variables. Table 3.2 presents bivariate analysis that assesses the nature and strength of associations among key variables, and offers directions for model building in the subsequent multivariate analyses.

I proceed to test the research hypotheses by estimating a series of multivariate statistical models. I use ordinary least squares (OLS) regression to predict BMI and multinomial logistic regression (MNLR) to predict body weight status. The modeling strategy, which includes the variables and model building process, is the same for both BMI and body weight status. The OLS regression models the relationship between explanatory variables and the mean of the dependent variable, BMI, by fitting a linear equation to observed data. The notation for multiple regression is as follows:

$$Y_i = \beta_0 + \beta_1 (x1)_i + \beta_2 (x2)_i + \beta_3 (x3)_i + \ldots + \beta_K (xK)_i + \varepsilon_i \qquad (1)$$

In the above equation, Y_i represents the dependent variable BMI; β_0 is the intercept; and β_K is the slope or coefficient. xK denotes the independent variables, which includes the set of geographical predictors and demographic controls. The final term ε_i is the statistical error or noise. Equation 1 represents the base model. Table 3.3 presents coefficients from the OLS analysis.

Likewise, Table 3.4 presents results from multinomial logistic regression to predict body weight status. MNLR extends binary logistic regression and uses maximum likelihood estimation to generate comparative logits (Hosmer and Lemeshow 2000, Long and Freese 2014). This technique is advantageous because it includes the whole sample in the estimation process and eliminates the need to split the sample into underweight, normal weight, and overweight groups. According to Long and Freese (2014), a basic MNLR model can be written as:

$$\ln \Omega_{m/b} (\mathrm{x}) = \ln \left(\frac{\Pr(y=m/\mathrm{x})}{\Pr(y=b/\mathrm{x})}\right) = \mathrm{x}\beta_{m/b} \text{ for m = 1 to } J \qquad (2)$$

In the equation, b is the contrast or reference outcome, i.e. normal weight in this analysis; *J* is the number of equations for the remaining outcomes. Hence, the MNLR models will estimate two equations simultaneously and generate logits for underweight and overweight relative to normal weight. From these equations, I calculate probabilities for each weight status outcome.

To account for stratified sampling, including two-stage clustering design, I use Stata's *svy* command in bivariate and multivariate estimations.[19] The *svy* specification uses robust standard errors such that the variability at the cluster or community level is adjusted while generating model estimates. I also use sampling weights provided by BDHS in conjunction with the *svy* command to account for variations in probabilities during sampling. I include a note in all tables that present results using the *svy* command.

Model Building Process

The baseline models (Model 1) predict BMI and body weight status as a function of demographic characteristics, including age, marital status, employment status, number of children under 5 years, relation to household head; lifestyle and media exposure variables such as the frequency of watching television, listening to radio, and reading newspaper. The wealth index denotes household's socioeconomic standing. The final set of predictors includes the geographic variables: administrative division, urban or rural residence, and distance from the nearest coastline. The baseline models are additive and test hypotheses H1a and H1b by assessing the impact the geographic variables on BMI and body weight status.

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[19] *Stata Survey Data Reference Manual (Release 13)* provides step-by-step guide to setting up the dataset and specifying survey design characteristics prior to conducting analysis using *svy* command (StataCorp 2013).

Model 2 is the first step to testing hypothesis H1c – whether being a migrant attenuates the size and statistical significance of the effects of geographic variables on health. This model adds migration status. Coefficients for migrant status indicate whether migration significantly predicts nutritional health. Additionally, by comparing coefficients for the geographic variables from these and previous model, I will investigate whether adding migrant status to the equation influences the relationship between rural/urban residence and coastal proximity variables and nutritional health.

Models 3 and 4 fully test hypothesis H1c, which expects migrant status to moderate the nutritional health effects of rural/urban residence and coastal proximity, by including migrant*urban and migrant*distance from coast interaction terms, respectively. Model 3 includes variables from Model 2 and migrant*urban interaction term to formally test whether the associations between nutritional health outcomes and urban or rural location depend on women's migration status (see the coefficient for the interaction migrant*urban). Model 4 includes variables from Model 2 and the final interaction term, migrant*distance from coast. This last model formally tests whether the effect of coastal proximity on nutritional health depends on women's migration status. Together, Models 3 and 4 help answer one of the central questions in this dissertation: does migration protect women's nutritional health against unfavorable geographical characteristics of place of residence?

The second part of the analysis shifts attention to children under the age of five. Following the analytic strategy used in the women's analysis, I examine if the physical environment impacts children in the same manner as their mothers. Using three binary indicators of nutritional health, i.e. stunting, wasting, and underweight, I begin by presenting descriptive statistics for the variables I include in the models in Table 3.5. I start by reporting percentages of children who are stunted, wasted, and underweight, and then provide means and standard deviations or proportions of maternal and household-level attributes followed by focal physical environment variables.

In multivariate analysis, I run three sets of models and present them in three separate panels. The first panel presents results for stunting, the second for underweight, and third for wasting. Because the outcome variables are binary, I proceed with binary logistic regression estimation predicting the likelihood of being undernourished as a function of child and maternal characteristics, household standard of living, and the geographical attributes. The equation for the binary logistic regression is as follows:

$$\ln \Omega (\mathrm{X}) = \ln \left(\frac{\Pr(y=1/\mathrm{x})}{\Pr(y=0/\mathrm{x})}\right) \qquad (3)$$

As shown in the equation above, the logits are estimated from the odds of having poor nutritional status. The first set of models – 1a, 2a, and 3a in Table 3.6 – are additive and predict the likelihood of stunting, underweight, and wasting, respectively. These baseline models test hypotheses H2a, that children living in rural areas are more likely to be undernourished than those living in urban areas, and H2b which states that children living closer to the coast are more likely to be undernourished than children living away from the coast. I also examine the effect of mother's migration status on children's health. As such, I partially test hypothesis H2c, e.g. whether mother's migration status protects the children from unfavorable environmental conditions.

The second set of analysis in Table 3.6 (Models 1b, 2b, and 3b) includes interaction terms and tests hypothesis H2c. Interaction terms indicate whether and how mother's migration status moderates the association between the physical environment and children's nutritional health. I will compare coefficients of the focal geographic variables and interaction terms in the children's models with those in the women's models to assess if the physical environment and migration similarly affect nutritional health of adult women and children.

Results: Women's Analysis

Descriptive Results

Table 3.1 presents weighted statistics for all variables in the women's models. The first panel focuses on BMI and weight status. The average BMI of the sample is 20.7, which falls within the World Health Organization's range of normal or healthy (18.5 - 22.9). Women's BMI ranges from 12 to 44 (not shown in Table 3.1), with a standard deviation of 3.5 indicating some variation across this national sample. Body weight status, derived from BMI, has a similar distribution. Although approximately half (49%) of the women in the sample have a normal body weight, slightly more than one-quarter (29%) are underweight and about 22 percent are overweight. This distribution is consistent with recent national statistics and demonstrates the double burden of malnutrition in Bangladesh, where significant proportions of women are underweight and overweight/obese.

Women in this sample average 30 years of age and the vast majority (93%) are married, which is expected given the BDHS sample is ever-married women of reproductive age. Approximately one-third was working at the time of the survey. On average, they have completed 4 years of education. Almost two-thirds (65%) are spouses of household head, eight percent are household heads, and the rest are related to heads in other ways. Approximately half of the respondents (46%) do not watch television at all, and other half (47%) report watching television once a week or more. A majority (75%) does not listen to the radio, but 19 percent report listening once a week or more. In addition, a large majority (86%) do not read newspapers or magazines.

Respondents reside across six administrative divisions. Approximately 6 percent live in Barisal, 18 percent in Chittagong, 31 percent in Dhaka, 13 percent in Khulna, 25 percent in Rajshahi, and 6 percent in Sylhet. Overall, only 23 percent of the women in this sample live in households located in an urban area. The average distance between a respondent's home and the nearest coastline is 110 km (68 miles), although in results not shown distance ranges from 0 (i.e. living at the coastline) to 402 km (250 miles). More than 20 percent of households are located within 10 km (6 miles) of the coast and about half live only about 80 km (50 miles) from the coast.

Table 3.1 Descriptive Statistics of Variables Used in Women's Analysis, Ever-married Women Aged 15-49, 2007 BDHS

Dependent variables	**Mean (SD)/Percent**
Body mass index	20.7 (3.5)
Body weight status	
Underweight	28.6
Normal weight	49.4
Overweight	22.0
Demographic characteristics	
Age	30.4 (9.4)
Currently married	92.7
Currently working	32.2
Education (years)	4.2 (4.2)
No. of children under 5 years	0.7 (0.8)
Relation to household head	
Head	8.4
Spouse	64.7
Other	26.8
Watch TV	
Not at all	46.2
<Once a week	7.0
>=Once a week	46.9
Listen to radio	
Not at all	75.3
<Once a week	5.7
>=Once a week	19.0
Read newspaper	
Not at all	86.1
<Once a week	7.3
>=Once a week	6.6
Household wealth index	
Poorest	19.2
Poorer	19.6
Middle	19.9
Richer	20.6
Richest	20.7
Geographic Predictors	
Administrative Division	
Barisal	6.0
Chittagong	18.4
Dhaka	31.2
Khulna	12.7
Rajshahi	25.3
Sylhet	6.4
Urban residence	22.6
Distance from the nearest coastline (km)	109.9
Moderator	
Migrant	76.1
Rural migrant	57.8
Urban migrant	18.3
N	10,788

Source: Bangladesh Demographic and Health Survey (2007). Note: Percent and means are weighted using weights provided by the 2007 BDHS data file; Sample size is unweighted.

Migration is embedded in Bangladeshi life.[20] Approximately three-quarters (76%) of respondents moved to the current residence from another administrative district. More than half of migrants (58%) moved to a rural destination from either another rural or urban origin. The rest (18%) currently live in an urban setting as migrants. The rest are nonmigrants.

Bivariate Results

In this section, I report results derived from OLS and multinomial logistic regression models that estimate the determinants of women's BMI and body weight status. Bivariate regression coefficients appear in Table 3.2 and offer a first look at how geography and migration are associated with BMI and body weight status. The table includes three sets of results. The first set includes OLS bivariate coefficients for a continuous measure of BMI. The second set presents results from sub-sample analysis predicting BMI for each weight group. The final set of results includes coefficients from multinomial logistic regression models that estimate the likelihood of being under- or over- weight relative to being normal weight.

The first set of results show that urban/rural residence, distance to the coast, and migration variables are significantly associated with BMI. Urban residence is positively associated with BMI such that the average BMI for urban residents is 2 points higher than their rural counterparts. Distance to coast is negatively and significantly associated with BMI; a one kilometer increase in the distance between community of residence and the coastline decreases the average BMI by .003 units. Compared to nonmigrants, migrants have significantly higher BMI. Results for administrative divisions also show regional variation – compared to Khulna, Barisal, Rajshahi and Sylhet have lower BMI on average.

[20] Many moves are related to marriage because, in Bangladeshi tradition, women move to their spouse's family residence after marriage. Unfortunately, BDHS does not include information on motivation for migration.

Table 3.2 Estimates from Bivariate Regression Models Predicting BMI and Body Weight Status, Ever-married Women aged 15-49, 2007 BDHS

	BMI (1)		BMI (2)						Body Weight status (3) (Contrast = Normal weight)			
			Underweight		Normal weight		Overweight		Underweight		Overweight	
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Geographic variables												
Urban residence (ref=rural)	2.033***	.182	.057	.050	.251***	.053	.984***	.128	-.286***	.075	1.038***	.082
Distance from the nearest coastline	-.003***	.001	.000	.000	.000	.000	-.001	.001	.001**	.000	-.002***	.000
Division (ref=Khulna)												
Barisal	-.813***	.189	-.107	.078	-.148^	.076	.064	.193	.233**	.080	-.489**	.148
Chittagong	-.266	.203	-.100	.085	-.147^	.089	.411*	.174	.097	.082	-.148	.135
Dhaka	-.019	.205	-.097	.075	-.059	.072	.790***	.169	.102	.091	-.049	.121
Rajshahi	-.430*	.180	-.121^	.070	-.056	.076	.373*	.182	.206*	.080	-.225^	.117
Sylhet	-1.005***	.235	-.226*	.075	-.192*	.081	.137	.227	.536***	.093	-.295*	.134
Migration variable												
Migrant status (ref=nonmigrant)	.356***	.099	-.044	.051	-.032	.046	.412**	.124	-.165**	.061	.116	.074
N	10788		2998		5150		2640		10788			

Source: Bangladesh Demographic and Health Survey (2007)
^p<0.1; *p< 0.05; ** p<0.01; *** p<0.001
(1) (2) OLS estimates predicting BMI.
(3) Multinomial logistic regression estimates predicting body weight status.
Note: Robust standard errors are generated using *svy* command in Stata to account for stratified sampling design.

In the second set of bivariate analysis, I predict BMI for each weight group. To evaluate whether the associations vary by different levels of BMI, I split the sample into three groups, i.e. underweight, normal weight, and overweight, and estimate bivariate OLS regression coefficients for each group. Results show that urban residence matters for women who have normal weight and who are overweight. In both categories, urban women have higher average BMI than rural women. For underweight women, the BMI of urban and rural residents are not significantly different. Distance from the coast is not significantly associated with BMI in all three weight groups. Migration status is significantly associated with BMI for only overweight group – compared to nonmigrants, migrants have higher BMI by 0.412 points. These results are interesting because they suggest the association between BMI and key independent variables varies by weight groups.

The third section in Table 3.2 shows bivariate results from multinomial logistic regression model predicting body weight status. Like the earlier analysis, I focus on geographic and migration predictors. First, urban residence is both protective and harmful for nutritional health. Contrasting with normal weight, urban women are less likely to be underweight but they are more likely to be overweight than rural women. Living in urban area protects against undernutrition but increases risks of overweight and obesity. This observation is consistent with the findings from the BMI analysis.

Distance from coast is also significantly associated with body weight status. Moving inland away from the coast increases the likelihood of being underweight. Likewise, an increase in the distance between residence and the coast decreases the likelihood of being overweight. Hence, the results suggest that living farther from the coast may be beneficial from the viewpoint of overweight and obesity but detrimental from the perspective of underweight. Migration status is important for the odds of being underweight. Migrants have lower odds of being underweight than nonmigrants, suggesting that migration status may be protective against undernutrition. However, the odds of being normal weight or overweight are not statistically different for migrants and nonmigrants.

Findings from OLS Regressions Predicting Women's BMI

Table 3.3 presents OLS models predicting BMI. These models test the study hypotheses outlined earlier in the chapter. With respect to hypotheses H1a, i.e. women living in urban areas have higher BMI than their rural counterparts, Model 1 results show that urban/rural residence is an important determinant of women's BMI. On average, urban women have BMI of .438 higher than rural women, net of demographic controls. Urban lifestyle and infrastructure offer access to a variety of food products and contribute to higher BMI. However, urban residence also comes with environmental disamenities such as overcrowding, pollution, and stress but it appears that the effects of these factors on BMI cannot be clearly distinguished in the results. In addition, urban markets offer non-traditional imported food items that have high sugar and fat contents that contribute to unhealthy weight gain (Bodor et al. 2010; Dake et al. 2016; Kim, Shon, and Yi 2017). Overall, the results support hypothesis H1a that urban residence is associated with higher BMI.

Model 1 also tests the second hypothesis (H1b) that women who live closer to the coast have lower BMI than those who live farther from the coast. The coefficient indicates that coastal proximity is adversely related to women's BMI. One kilometer increase in the distance from the coast decreases the average BMI by 0.003. Coastal resources such as seaports and access to marine protein appear to outweigh the risks of storms, cyclones, and flooding which are associated with food and drinking water insecurity in coastal environment. In fact, living in a coastal area seems to protect women against undernutrition by providing them access to marine and mangrove food sources. Hence, the evidence does not support the hypothesis that living in or near the coastal environment is associated with low BMI.

Table 3.3 Estimates from OLS Models Predicting BMI, Ever-married Women Aged 15-49, 2007 BDHS (N=10,788)

	Model 1		Model 2		Model 3		Model 4	
	B	SE	B	SE	B	SE	B	SE
Age (years)	.042***	.005	.042***	.005	.042***	.005	.042***	.005
Marital status								
Widowed	-.638**	.223	-.661**	.224	-.665**	.225	-.665**	.224
Divorced	-.592*	.263	-.578*	.264	-.585*	.264	-.570*	.265
Separated	-.745**	.237	-.744**	.238	-.756**	.238	-.747**	.237
Currently working (ref = No)	-.263**	.084	-.266**	.084	-.265**	.084	-.269**	.084
Education (years)	.089***	.012	.088***	.012	.088***	.012	.088***	.012
No. of children under 5 yrs	-.156**	.052	-.163**	.053	-.163**	.053	-.164**	.053
Relation to head (ref = Self)								
Spouse	-.279^	.159	-.297^	.159	-.299^	.159	-.300^	.159
Other	-.494**	.165	-.463**	.166	-.459**	.166	-.467**	.166
Watch TV (ref = Not at all)								
<Once a week	-.132	.132	-.131	.132	-.132	.132	-.130	.131
>=Once a week	.306**	.100	.312**	.100	.310**	.100	.310**	.100
Listen to radio (ref = Not at all)								
<Once a week	-.061	.134	-.061	.134	-.058	.134	-.059	.134
>=Once a week	-.001	.101	.006	.101	.006	.100	.007	.101
Read newspaper (ref = Not at all)								
<Once a week	.166	.147	.165	.146	.164	.147	.166	.146
>=Once a week	.806***	.186	.808***	.186	.801***	.186	.807***	.186
Wealth index (ref= Poorest)								
Poorer	.231*	.110	.231*	.110	.231*	.110	.230*	.109
Middle	.520***	.117	.516***	.118	.515***	.118	.516***	.117
Richer	.959***	.138	.952***	.138	.953***	.138	.951***	.138
Richest	2.508***	.183	2.495***	.184	2.490***	.184	2.496***	.184
Division (ref= Khulna)								
Barisal	-.652***	.154	-.649***	.154	-.652***	.154	-.651***	.154
Chittagong	-.448**	.157	-.446**	.158	-.452**	.158	-.449**	.157
Dhaka	-.097	.166	-.097	.167	-.102	.166	-.101	.166
Rajshahi	.372	.249	.369	.249	.368	.249	.364	.248
Sylhet	-.444^	.233	-.450^	.231	-.449^	.231	-.458*	.229
Urban residence (ref= rural)	.438**	.141	.435**	.141	.181	.196	.440**	.140
Distance from coast (km)	-.003**	.001	-.003*	.001	-.003*	.001	-.004**	.001
Migrant (ref= nonmigrant)			.149	.095	.087	.106	-.018	.135
Migrant*Urban					.324^	.191		
Migrant*Distance from coast							.001^	.001
Constant	18.877***	.258	18.776***	.265	18.824***	.269	18.902***	.277
R-squared	.1855		.1858		.1860		.1860	

Source: Bangladesh Demographic and Health Survey (2007)
^p<0.1; * p<0.05; ** p<0.01; *** p<0.001
Note: Robust standard errors are generated using *svy* command in Stata to account for stratified sampling design.

In Model 1, the control variables, including individual and household attributes, are also revealing. Age is strongly and positively associated with BMI. Compared to married women, widowed, divorced, and separated have significantly lower BMI, controlling for other variables. Those who are currently working are thinner than those who are not working, net of other factors. Higher education translates to higher BMI. One year increase in education adds 0.09 units of BMI. Having young children is also consequential to women's nutritional status; having more young children in the household is associated with lower BMI. Women who are household head have higher BMI on average than those who are either spouse or other relative of the household head.

Exposure to the media is significantly associated with BMI. Those who watch TV at least once a week have higher BMI than those who do not watch TV at all, net of other factors. Ownership and viewing of television may signify a sedentary lifestyle. Similarly, reading newspapers and magazines more often is associated with higher BMI, but listening to the radio does not have a significant impact. Results for the wealth index are not surprising. Those who are socioeconomically better off have higher BMI on average than those who are poorer after controlling for other demographic attributes. Specifically, Table 3.3 shows a distinct gradient across the wealth quintiles. Compared to the poorest, those in "poorer" quintile have higher BMIs. Likewise, those in the middle, richer, and richest have BMIs that are also greater than the poorest. The difference in the average BMI for the poorest and the richest is 2.51, which indicates a considerable nutritional disparity.

Model 2 in Table 3.3 examines the effects of migration on women's BMI, and offers preliminary evidence to assess hypothesis 1c – that migration will mitigate the negative nutritional health outcomes associated with urban/rural residence and coastal proximity. In this additive model, the migration coefficient is not significant. Moreover, the coefficients for the urban/rural and coastal variables remain unchanged (when compared to Model 1) and significant. Hence, Model 2 does not offer any evidence to support the hypothesis that migrant status protects against poor nutritional health.

To fully test the moderating role of migrant status, I estimate two additional models. Model 3 and Model 4 in Table 3.3 are interaction models that fully test hypothesis H1c. First, Model 3 includes migrant*urban interaction term to examine whether the association between urban/rural residence and BMI depends on migrant status. However, the interaction term is only marginally significant ($p<1.0$). Next, I estimate Model 4, which includes migrant*coastal proximity interaction. Again, the interaction term is only marginally significant. Therefore, Models 3 and 4 results do offer adequate evidence to support hypothesis H1c.

Findings from Multinomial Logistic Regression Predicting Women's Body Weight Status

In the second part of women's analysis, I examine whether and how the physical environment affects women's likelihood of being underweight and overweight versus normal weight. Specifically, I investigate if the type of residence affects the odds of being heavier and thinner. Additionally, is living close to the coast consequential to being overweight, underweight, or both? Finally, does migrant status lowers the odds of poor nutritional health? To answer these questions in relation to the research hypotheses – H1a, H1b, and H1c –I estimate a series of multinomial logistic regression models and compare the odds of being underweight and overweight in contrast to being normal weight as a function of the physical environment and migration covariates. In addition to testing the hypotheses, results from these analyses offer important insights into the double burden of malnutrition.

Table 3.4 presents estimates from four multinomial logistic regression models. The model building strategy is comparable to the BMI analysis discussed earlier. Model 1 focuses on the geographic variables- urban/rural residence and coastal proximity – and their roles in the distribution of body weight status. Model 2 adds migrant status. Models 3 and 4 are interaction models and test the moderating role of migration.

Table 3.4 Estimates from Multinomial Regression Models Predicting Body Weight Status, Ever-married Women Aged 15-49, 2007 BDHS (N= 10,788)

	Model 1 (Contrast=Normal weight)				Model 2 (Contrast=Normal weight)			
	Underweight		Overweight		Underweight		Overweight	
	B	SE	B	SE	B	SE	B	SE
Age (years)	.004	.004	.043***	.004	.004	.004	.043***	.004
Marital status								
Widowed	.589***	.146	.095	.177	.624***	.146	.103	.176
Divorced	.265	.240	-.312	.314	.245	.241	-.316	.314
Separated	.276	.184	-.281	.238	.271	.184	-.282	.238
Currently working (ref = No)	-.047	.063	-.258***	.072	-.042	.063	-.257***	.072
Education (years)	-.035***	.009	.051***	.010	-.034***	.009	.052***	.010
No. of children under 5 yrs	.115**	.033	-.042	.045	.124***	.034	-.039	.046
Relation to head (ref = Self)								
Spouse	-.051	.116	-.200	.126	-.025	.114	-.195	.125
Other	-.003	.124	-.291*	.129	-.047	.127	-.301*	.131
Watch TV (ref = Not at all)								
<Once a week	.056	.116	-.007	.129	.055	.116	-.007	.130
>=Once a week	-.130*	.065	.157*	.077	-.140*	.065	.155*	.077
Listen to radio (ref = Not at all)								
<Once a week	.122	.116	.046	.120	.122	.115	.045	.120
>=Once a week	-.055	.078	-.043	.080	-.065	.079	-.045	.080
Read newspaper (ref = Not at all)								
<Once a week	-.001	.114	.005	.111	.000	.114	.005	.111
>=Once a week	-.114	.163	.221*	.105	-.120	.162	.220*	.105
Household wealth index (ref= Poorest)								
Poorer	-.227*	.095	.112	.120	-.227*	.095	.113	.120
Middle	-.261**	.089	.263*	.122	-.256**	.090	.265*	.122
Richer	-.302**	.097	.723***	.121	-.291**	.098	.726***	.120
Richest	-.588***	.129	1.354***	.144	-.570***	.130	1.358***	.143
Administrative Division (ref= Khulna)								
Barisal	.151	.094	-.529***	.132	.145	.094	-.531***	.132
Chittagong	.066	.089	-.365**	.124	.061	.090	-.367**	.124
Dhaka	.085	.095	-.119	.114	.085	.094	-.119	.114
Rajshahi	.172	.170	.529**	.154	.178	.169	.531**	.154
Sylhet	.422**	.140	.127	.150	.431**	.139	.129	.150
Urban residence (ref= Rural)	-.008	.074	.254**	.082	-.002	.075	.255**	.082
Distance from coast (km)	.000	.001	-.003***	.001	.000	.001	-.003***	.001
Migrant (ref= Nonmigrant)					-.212**	.067	-.049	.086
Migrant*Urban								
Migrant*Distance from coast								
Constant	-.413*	.204	-2.499***	.225	-.267	.218	-2.465***	.234

Source: Bangladesh Demographic and Health Survey (2007)

^p<0.1; * p<0.05; ** p<0.01; *** p<0.001

Note: Robust standard errors are generated using svy command in Stata to account for stratified sampling design.

Table 3.4 Estimates from Multinomial Regression Models Predicting Body Weight Status, Ever-married Women Aged 15-49, 2007 BDHS (N= 10,788) (Contd.)

	Model 3 (Contrast=Normal weight)				Model 4 (Contrast=Normal weight)			
	Underweight		Overweight		Underweight		Overweight	
	B	SE	B	SE	B	SE	B	SE
Age	.004	.004	.043***	.004	.004	.004	.043***	.004
Marital status								
Widowed	.623***	.146	.100	.176	.627***	.147	.102	.175
Divorced	.243	.241	-.318	.313	.239	.241	-.315	.315
Living together	.269	.185	-.291	.237	.275	.184	-.281	.238
Currently working	-.042	.063	-.257***	.072	-.039	.063	-.256***	.072
Education (years)	-.034***	.009	.052***	.010	-.034***	.009	.052***	.010
No. of children under 5 yrs	.124***	.034	-.039	.045	.125***	.034	-.039	.045
Relation to head (ref = Self)								
Spouse	-.026	.114	-.197	.125	-.023	.114	-.195	.125
Other	-.046	.127	-.299*	.131	-.044	.127	-.301*	.131
Watch TV (ref = Not at all)								
<Once a week	.055	.116	-.008	.130	.054	.116	-.007	.130
>=Once a week	-.140*	.065	.153*	.077	-.138*	.065	.155*	.077
Listen to radio (ref = Not at all)								
<Once a week	.123	.115	.048	.120	.119	.116	.044	.120
>=Once a week	-.065	.079	-.045	.080	-.066	.079	-.045	.080
Read newspaper (ref = Not at all)								
<Once a week	.000	.114	.004	.111	.000	.114	.005	.111
>=Once a week	-.121	.162	.216*	.105	-.117	.162	.220*	.105
Household wealth index								
Poorer	-.227*	.095	.113	.120	-.227*	.095	.112	.120
Middle	-.257**	.090	.264*	.122	-.257**	.089	.265*	.122
Richer	-.291**	.098	.725***	.121	-.291**	.098	.725***	.120
Richest	-.571***	.130	1.356***	.143	-.571***	.130	1.358***	.143
Administrative Division								
Barisal	.144	.094	-.532***	.132	.146	.094	-.530***	.132
Chittagong	.059	.090	-0.371**	.124	.064	.089	-.366**	.124
Dhaka	.084	.094	-.122	.113	.089	.094	-.119	.113
Rajshahi	.178	.169	.530**	.153	.182	.170	.530**	.153
Sylhet	.432**	.139	.131	.150	.439**	.139	.128	.150
Urban residence (ref= Rural)	-.061	.127	.111	.140	-.008	.075	.255**	.081
Distance from coast (km)	.000	.001	-.003***	.001	.001	.001	-.003***	.001
Migrant (ref= Nonmigrant)	-.224**	.074	-.096	.105	-.069	.098	-.061	.118
Migrant*Urban	.075	.129	.183	.145				
Migrant*Distance from coast					-.001*	.001	.000	.001
Constant	-.257	.220	-2.427***	.239	-.372^	.221	-2.455***	.246

Source: Bangladesh Demographic and Health Survey (2007)
^p<0.1; * p<0.05; ** p<0.01; *** p<0.001
Note: Robust standard errors are generated using svy command in Stata to account for stratified sampling design.

First, with regard to hypothesis H1a, which states that urban women have higher odds of being overweight and rural women have higher odds of being underweight, I find that place of residence impacts nutritional status in diverse ways. As shown in Table 3.4, Model 1, living in urban area increases the odds of being overweight. However, urban residence is not associated with the likelihood of being underweight. This finding is important to note because a considerable proportion of urban Bangladeshis reside in slums and shantytowns where the health and nutritional amenities of urban living seldom reach. Hence, this result adds a caveat to the earlier BMI finding that indicates a strong positive association between urban living and higher BMI.

Coastal proximity is consequential for the likelihood of being overweight. The coefficient suggests that living farther from the coast decreases the odds of being overweight. From the perspective of health, moving away from the coast seems to protect against overweight and obesity. However, coastal environment does not appear to bear on the odds of being underweight. Hence, the results do not fully support hypothesis H1b that women living closer to the coast have higher odds of being underweight than women living farther from the coast.

In addition, results from Model 1 show that demographic attributes influence the odds of being under- and over- weight differently. For instance, age significantly increases the odds of being overweight but not underweight. Being employed matters but only to overweight category; and employment significantly decreases the likelihood of being overweight. Likewise, education is negatively associated with undernutrition; an increase in the number of years of education decreases the odds of being underweight. However, education level also increases the likelihood of being overweight. Being widowed (compared to married) and having more young children increase the chances of being underweight. With regard to media consumption, the frequency of watching television has significant effects; those who watch television more frequently are less likely to be underweight but it also increases the likelihood of being overweight. Reading newspaper and magazines also increase the odds of being overweight but not underweight.

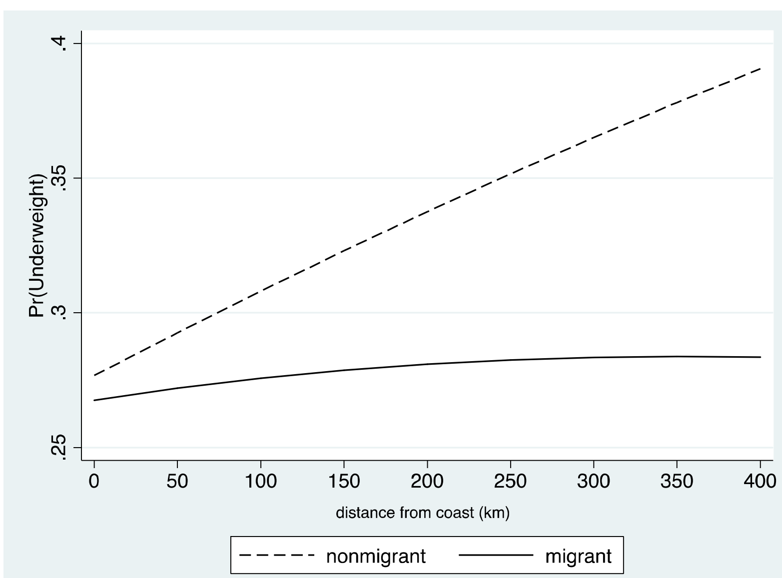
Household wealth index is a strong and highly significant predictor of both categories of malnourishment. As expected, higher wealth quintiles are associated with lower odds of being underweight and at the same time higher odds of being overweight. For instance, compared to the poorest group, groups with more wealth have progressively lower odds of being underweight. Similarly, the likelihood of being overweight is higher for those in the middle, richer, and richest wealth groups. Astoundingly, the likelihood of those being overweight in the richest quintile is 1.4 times higher than the likelihood for those in the poorest group.

The odds of being under- and over- weight also vary by administrative division. Compared to women in Khulna division, those living in Sylhet have higher likelihood of being underweight. Additionally, women in Barisal and Chittagong have lower odds of being overweight or obese when compared to women in Khulna, but women in Dhaka are no different from those in Khulna.

The next model on Table 3.4, Model 2, highlights the role of migration. The migrant status variable is negative and statistically significant suggesting that the likelihood of being underweight is lower for migrant women than their nonmigrant counterparts. This finding offers preliminary support to hypothesis H1c, that migration protects women against undernutrition. Models 3 and 4 include environment-migration interaction terms. Estimates from these models show mixed results. First in Model 3, which contains urban-migrant interaction, neither the urban variable nor the interaction term is significant. Urban residence no longer appears to matter.

Model 4, which includes the coastal proximity-migrant interaction, offers a different story. In support of hypotheses H1c, the interaction term in the model predicting the likelihood of being underweight is significant; the effect of coastal distance on the odds of being underweight varies by migrant status. Figure 3.1, which is estimated from Model 4 in Table 3.4, illustrates the interaction effect and plots the predicted probabilities of being underweight for migrant and nonmigrant women against coastal proximity ($b=-.001$, $p<.05$). The solid line represents migrant women and the dotted line represents their nonmigrant counterparts. For nonmigrant women, as they move further from the coast the probability of being underweight increases. In contrast, migrant women's likelihood of being underweight does not depend on the distance of their residence from the coast. This finding offers evidence that migration protects women's nutritional health against the effects of coastal distance. Note, however, that the protective effect of migration is not significant predicting the likelihood of being overweight.

Figure 3.1 Predicted Probabilities from Multinomial Logistic Regression Model Predicting Body Weight Status as a Function of Distance to Coast, Migration Status, and Other Variables (Table 3.4, Model 4)



Results: Children's Analysis

Descriptive Results

In this section I focus on children's nutritional health. Table 3.5 presents summary statistics on the outcome variables and their key predictors. The first section presents the percent of children who are stunted, underweight, and wasted. These estimates reveal a high burden of malnourishment among young Bangladeshi children. Approximately 43 percent of children are stunted or too short for their age, and approximately 41 percent of the children are underweight, a statistic that reflects a substantial burden of chronic malnutrition. Finally, 17 percent of children are wasted or have acute malnutrition.

In the table, I divide the predictor variables into child-level factors, maternal and household characteristics, and geographic attributes. Approximately half of the children are girls; their average age is 30 months or 2.5 years. Average birth order is 2 which indicates that the average child is second-born. Half of mothers (52%) have normal body weight, one-third (32%) is underweight, and the rest (16%) are overweight or obese. Average age of mothers is 26 years old; almost all are married and over a quarter (27%) are economically active. On average, mothers have completed five years of education (equivalent to primary schooling). About two-thirds of mothers (65%) are spouses of household heads and only five percent reported being the household head. A vast majority does not listen to the radio (75%) or read the newspaper (87%). However, almost half (48%) watch television once a week or more.

The wealth index divides the children's households into quintiles and hence, each category from poorest to the richest contain approximately one-fifth of the households. The geographic variables include urban/rural residence and coastal proximity. I also include administrative division in this section. About one-third (32%) of the children live in Dhaka and one-fifth each in Chittagong and Rajshahi. The rest resides in Khulna (10%), Sylhet (9%), and

Barisal (6%). Approximately one-fifth (21%) of children live in urban areas. The average distance of households from the coast is 111 km. Finally, a large majority of children have mothers who are migrants (76%). Among the migrants, 59 percent migrated to rural whereas the remaining 17 percent moved to urban areas.

Table 3.5 Descriptive Statistics of Variables Used in Children's Analysis, Children 0-5 Years, 2007 BDHS

Dependent variables	**Mean (SD)/Percent**
Stunted	42.9
Underweight	40.8
Wasted	17.4
Independent Variables	
Child-level factors	
Female	50.1
Age (months)	29.8 (17.1)
Birth order	2.1 (0.9)
Maternal and household factors	
Underweight	32.3
Normal weight	51.9
Overweight	15.8
Age	25.5 (6.1)
Currently married	98.0
Currently working	26.5
Education (years)	4.9 (6.4)
Relation to household head	
Head	4.9
Spouse	65.4
Other	29.7
Watch TV	
Not at all	47.9
<Once a week	7.0
>=Once a week	45.2
Listen to radio	
Not at all	75.2
<Once a week	5.9
>=Once a week	18.9
Read newspaper	
Not at all	86.6
<Once a week	7.8
>=Once a week	5.6
Household wealth index	
Poorest	22.6
Poorer	21.7
Middle	19.4
Richer	19.0
Richest	17.4
N	5271

Source: Bangladesh Demographic and Health Survey (2007)

Note: Percent and means are weighted using weights provided by the 2007 BDHS data file; sample size is unweighted

Table: 3.5: Descriptive Statistics of Variables Used in Children's Analysis, Children 0-5 Years, 2007 BDHS (Contd.)

Dependent variables	**Mean (SD)/Percent**
Geographic Factors	
Urban residence	20.6
Distance from the nearest coastline (km)	110.7 (98.9)
Administrative Division	
Barisal	6.3
Chittagong	22.0
Dhaka	31.5
Khulna	9.6
Rajshahi	21.6
Sylhet	9.0
Moderator	
Migrant	75.8
Rural migrant	59.0
Urban migrant	16.8
N	5271

Source: Bangladesh Demographic and Health Survey (2007)
Note: Percent and means are weighted using weights provided by the 2007 BDHS data file; sample size is unweighted

Results from Logistic Regressions Predicting Children's Odds of being Stunted, Underweight, and Wasted

Table 3.6 presents estimates from logistic regression analyses for each of the three health outcomes for children under five. Models 1a and 1b present coefficient from models predicting the likelihood of stunting. Model 1a presents the main effects whereas Model 1b includes the environment-migration interactions. Similarly, the table displays coefficients from models predicting the likelihood of being underweight (Models 2a and 2b) and wasted (Models 3a and 3b).

First, Model 1a describes coefficients from model predicting the likelihood of being stunted as a function of children's characteristics, maternal and household factors, mother's migration status, and environment variables. Recall this model tests hypotheses H2a and H2b, which predict that rural/urban residence and coastal proximity, respectively, will be related to the three nutritional health outcomes, net of other factors. To my surprise, none of the physical environment and migration status variables are significantly associated with child stunting. Hence, migration, urban/rural residence, and coastal proximity do not appear to be consequential to children's likelihood of being stunted.

To examine if migration status interacts with the physical environment to protect children against stunting, I add interaction terms – migrant*urban and migrant*distance to coast, and present these coefficients under Model 1b. The analysis reveals that the interaction terms are not significant. Hence, the results do not support the moderating hypothesis (H2c) that the negative health effects of rural residence and coastal proximity are smaller for children of migrant mothers than those of nonmigrant mothers.

Table 3.6 Estimates from Logistic Regression Models Predicting Nutritional Status of Children Aged 0-5 years, 2007 BDHS (N=5,271)

	Stunted				Underweight				Wasted			
	Model 1a		Model 1b		Model 2a		Model 2b		Model 3a		Model 3b	
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Age (months)	.023***	.002	.023***	.002	.017***	.002	.017***	.002	-.008*	.003	-.008*	.003
Female (ref= Male)	-.074	.073	-.075	.073	.079	.068	.079	.068	-.138	.086	-.138	.086
Birth order	.096	.069	.094	.069	.073	.064	.074	.064	.109	.074	.110	.074
Mother's weight status (ref= Normal)												
Underweight	.167*	.070	.166*	.070	.444***	.078	.444***	.078	.489***	.091	.490***	.091
Overweight	-.387***	.107	-.391***	.107	-.569***	.122	-.568***	.122	-.450**	.151	-.448**	.151
Mother's age (years)	-.008	.008	-.008	.008	-.005	.008	-.005	.008	.000	.010	.000	.010
Marital status												
Widowed	-.536	.427	-.552	.425	.294	.442	.305	.443	.151	.456	.167	.457
Divorced	.376	.676	.369	.678	-.131	.534	-.137	.536	.744	.631	.737	.627
Separated	.635^	.355	.625	.355	.402	.314	.403	.316	.076	.354	.079	.355
Currently working (ref = No)	-.032	.077	-.033	.077	-.040	.085	-.039	.085	.167^	.100	.169^	.099
Mother's education (years)	-.010^	.005	-.010^	.005	-.005	.005	-.005	.005	-.002	.008	-.002	.008
Relation to head (ref = Self)												
Spouse	.109	.162	.102	.163	.066	.166	.070	.167	.127	.183	.130	.183
Other	.004	.177	.002	.178	.171	.175	.174	.175	.242	.202	.244	.202
Watch TV (ref = Not at all)												
<Once a week	-.060	.148	-.060	.148	-.061	.148	-.061	.147	-.076	.175	-.077	.175
>=Once a week	-.099	.094	-.100	.094	.028	.091	.029	.091	.303*	.120	.304*	.120
Listen to radio (ref = Not at all)												
<Once a week	-.087	.143	-.079	.142	-.002	.170	-.004	.170	.074	.200	.070	.200
>=Once a week	.089	.087	.090	.087	.083	.093	.083	.093	.134	.114	.135	.114
Read newspaper (ref = Not at all)												
<Once a week	-.220	.153	-.222	.153	-.357*	.160	-.358*	.160	-.091	.168	-.090	.168
>=Once a week	-.475*	.188	-.482*	.187	-.440*	.180	-.441*	.180	.101	.221	.103	.222
Household wealth index (ref= Poorest)												
Poorer	-.039	.098	-.040	.098	-.091	.104	-.092	.104	-.175	.131	-.176	.131
Middle	-.314**	.115	-.316**	.115	-.242*	.108	-.243*	.108	-.264*	.132	-.265*	.132
Richer	-.366**	.124	-.367**	.124	-.301*	.122	-.300*	.122	-.221	.159	-.221	.159
Richest	-.781***	.146	-.788***	.146	-.619***	.159	-.619***	.160	-.389*	.183	-.388*	.183
Administrative Division (ref= Khulna)												
Barisal	.417**	.148	.410**	.149	.308*	.142	.312*	.142	-.135	.183	-.131	.183
Chittagong	.540***	.129	.529***	.128	.345*	.105	.350**	.104	-.062	.136	-.054	.136
Dhaka	.284*	.141	.274^	.142	.186	.123	.189	.123	-.312^	.173	-.306^	.174
Rajshahi	.004	.187	-.003	.187	.259	.175	.262	.175	-.106	.265	-.102	.265
Sylhet	.152	.184	.146	.183	.185	.170	.189	.169	-.118	.222	-.112	.221
Urban residence (ref= rural)	.131	.100	-.101	.171	.015	.097	.064	.172	-.132	.118	-.041	.221
Distance from coast (km)	.001^	.001	.001	.001	.000	.001	.001	.001	.000	.001	.000	.001
Migrant (ref= nonmigrant)	.094	.082	-.014	.112	.037	.073	.102	.110	.140	.102	.226	.152
Migrant*Urban			.294	.180			-.064	.169			-.117	.250
Migrant*Distance from coast			.001	.001			.000	.001			-.001	.001
Constant	-1.093***	.278	-.998**	.290	-1.107**	.280	-1.162***	.292	-1.701**	.369	-1.774**	.374

Source: Bangladesh Demographic and Health Survey (2007)
^p<0.1; * p<0.05; ** p<0.01; *** p<0.001
Note: Robust standard errors are generated using *svy* command in Stata to account for stratified sampling design.

However, the roles of demographic and maternal characteristics merit some discussion. With respect to children's demographic characteristics, only age is statistically significant. As age (in months) increases, so does the likelihood of being stunted. Mother's weight status is another important factor. Compared to women who are of normal weight, underweight women are more likely to have stunted children. Mother's age, marital status, and employment do not matter, but mother's education has a borderline significant effect. With more years of education, children have a lower likelihood of being stunted. Watching television and listening to the radio are not associated with children being stunted. However, women who read newspapers more than once a week are less likely to have stunted children than those who do not read newspapers. Not surprisingly, household wealth index is significantly associated with stunted children. Compared to those in the poorest households, children in households with higher socioeconomic status are less likely to be stunted.

The next set of columns in Table 3.5 present coefficients for the likelihood that children are underweight. I examine whether living in urban areas and away from the coast protect children from being underweight. My results for the main effects model (Model 2a) are not substantially different from the findings for stunting. That is, children's age, mother's weight status, newspaper reading, and household wealth are significant factors associated with the likelihood of being underweight. However, coefficients for urban/rural residence and coastal proximity are not statistically significant. After adding the environment-migration interaction terms (see Model 2b), I see no evidence that mother's migration status moderates the nutritional health effects of living in rural area and in coastal proximity.

The final analysis examines the likelihood of wasting among children. Once again, the key environmental variables – urban/rural residence and coastal proximity, and migrant status do not predict the odds of wasting. From similar models to those for stunting and underweight, I see that child's age is an important predictor. Its effect is opposite of that observed in the stunting and underweight models. An increase in children's age decreases the odds of wasting. Mother's weight status matters in expected ways. Children of mothers who are underweight are more likely to be wasted and those of overweight mothers are less likely to be wasted. Interestingly, household wealth is not significantly associated with child being wasted.

Together these findings do not provide evidence to support my expectations. The lack of significant effects may be related to the presence of very young children in the sample. Table 3.5 shows that children's average age is just 30 months; it is likely that effects of migration and the environment may take years to cumulate and exhibit among children. It may also be that the nutritional health outcomes are not sensitive to the set of physical environment variables used this analysis. Future studies should build on these findings by using longitudinal data that include a diverse set of health outcomes and observe children throughout childhood and adolescence.

Summary and Conclusion

Findings show that physical environment and migration are important determinants of women's BMI in Bangladesh. Urban living correlates with higher BMI whereas rural living is associated with lower BMI. It is important to note that the observed rural-urban nutritional disparity is a double-edged sword; urban residence may protect against low BMI but it also increases the risk of overnutrition and obesity. On the other hand, rural residents are less likely to be overweight but more likely to be undernourished. Hence, the rural-urban nutritional disparity is a contributing factor in the double burden of malnutrition.

The relationship between coastal proximity and malnutrition is not straightforward. The results show that women's BMI decreases as the distance from the coast increases. Although

Bangladesh's coastal region is fraught with natural calamities and environmental degradation that adversely influence agricultural outputs and water quality, coastal proximity may offer better access to marine and mangrove food sources. Moreover, analysis of body weight status revealed that living further from the coast decreases the odds of overweight.

Although migration is not significantly associated with BMI, i.e. migrant status does not moderate the relationship between urban-rural residence or coastal distance and BMI, it significantly lowers the odds of being underweight relative to normal weight. The significant interaction between migrant status and coastal proximity for underweight category indicates that the effect of coastal distance on the odds of being underweight depends on migrant status. Hence, migrant women do not experience the negative health impact of coastal distance. For nonmigrant women, as they move farther from the coast, their odds of being underweight gradually increases.

The children's analysis produced limited findings in support of my hypotheses about the relationship between environmental factors and malnutrition. The lack of significance may be due to two main reasons. Effects of an unfavorable environment may take years to appear, accumulating over the life course, and given the sample is so young, I am unable to detect such impacts whether in the form of a health advantage (or disadvantage). Future work must examine these effects using longitudinal panel data. The second reason is that the outcome variables under study may not be sensitive to the particular set of physical environment variables used in the analysis. Future studies could also include extreme environmental conditions such as thermal stress due to heat waves and climate sensitive infectious diseases such as cholera and malaria (McMichael and Haines 1997). Nonetheless, findings from the children's analysis remain important because they reveal that the environment affects adults and children differently.

Among women, there are health effects related to environmental conditions, but among children few appeared significant.

CHAPTER IV

ARSENIC, HEALTH, AND MIGRATION: FINDINGS FROM BANGLADESH ENVIRONMENT AND MIGRATION SURVEY

This chapter shifts focus to southwest Bangladesh, a coastal, low-lying region with gradual and rapid onset environmental degradation. Using Bangladesh Environment and Migration Survey (BEMS) and water chemistry data from BEMS sites, I investigate whether and how objective measures of drinking water quality and perceived environmental degradation influence health outcomes. I also assess whether migration – as measured by the number of migration trips made by household members and receipt of remittances – protects against the negative health impacts of the environmental conditions.

Briefly below I reiterate the research hypotheses that guide the analytic framework and organization of this chapter. I then lay out the analytic strategy and describe the data and key variables. I follow with my bivariate and multivariate findings and conclude the chapter by discussing the main findings.

Hypotheses

The objective of this chapter is to improve our understanding of how different aspects of the environment, both perceived and actual, impact multiple dimensions of adult health. I also examine whether and how household-based adaptation in the form of migration protects those living in unfavorable environmental conditions with limited access to institutional resources. Below are two sets of hypotheses that I test in this chapter: H1 focuses on the environment-health association whereas H2 describes the moderating or protective role of migration in the environment-health relationship.

H1: Environmental stress adversely impacts physical health outcomes of men and women in southwest Bangladesh.

H1a: Arsenic contamination and salinity in tube well water and perceived environmental degradation increase the odds of being underweight and reporting poor quality of health.

H2: Household migration moderates the relationship between environmental stress and health by mitigating negative health impacts.

H2a: Number of household migration trips and remittances are positively associated with body weight status such that they decrease the odds of being underweight.

H2b: Number of migration trips and receiving remittances (money) attenuates negative environmental impacts on body weight status and self-reported health.

Analytic Plan

To assess evidence for these hypotheses, I used BEMS household data and water chemistry data. First, I integrated the household and water chemistry data sets by matching BEMS household data with water chemistry data at the *mouza* level. After creating a master data file, I generated the analytic sample. Because the study collected data from household heads and spouses, my analysis includes married adults. After removing respondents with missing data on the key health and moderator variables, the total analytic sample size is 2513 respondents; 1202 men and 1311 women.[21] Overall, the BEMS data set includes information from 1364 households in 8 communities across five districts in the Khulna division.

Chapter II provides detailed descriptions of the dependent and independent variables I use in this chapter. Appendix 4.1 also includes description of these variables. Hence, here I briefly discuss the focal variables. My analysis centers on three outcome variables that measure health and well-being: body mass index (BMI), body weight status, and self-reported quality of health. Environmental predictors include objective measures of water quality and subjective perceptions about environmental degradation. I use two variables to denote community water quality: salinity level and arsenic contamination of tube well water. As mentioned earlier, salinity level of 2000 μS/cm or greater is considered unsafe; for arsenic the cut-off for safe level is 10 μg/L. An important caveat related to water quality data is that the observations are at the *mouza* level. Hence, I do not include *mouza* dummies or other *mouza*-level institutional variables in the analysis. Finally, to capture perceived environmental stress, I created a summary index from household heads' responses to 10 questions about environmental conditions.

Because one key objective is to investigate whether migration protects against the negative health impacts of the environment, I use two migration variables as moderators. First, household migration trips refers to the number of trips, both internal and international, that household members have taken in years prior to the survey. The second migration variable is whether the household received remittances from within Bangladesh, India, or other countries in the previous year.

[21] As mentioned in Chapter II, I excluded data from Narail Sadar *mauza* (n=394) altogether in the analysis because we do not have water chemistry data from this site. Height and weight data are missing for 241 respondents (175 men and 66 women). Self-reported health at marriage has 91 missing cases. Finally, remittances information is missing for 8 respondents.

Model Building Process

The analysis broadly follows the same approach as Chapter III but it includes different measures of environment, health, and migration. First, Table 4.1 presents descriptive statistics of variables under study. Second, I present two sets of bivariate regression models. The first tests the relationship between the environment and health variables and the second set centers on migration and health. I use OLS regression to predict BMI (continuous variable), multinomial logistic regression to predict body weight status (categorical variable), and logistic regression to predict self-reported health (binary variable).

In Table 4.2, Panel A reports bivariate associations between the three outcome variables and three environment variables. Panel B displays coefficients for the three outcome variables and two migration variables. Coefficients from these panels reveal the nature and strength of bivariate associations among focal variables in absence of other predictors and demographic controls. As a preliminary analysis, this step provides direction for multivariate analysis by parsing out statistically significant associations that warrant further investigation.

The bivariate results indicate a strong and statistically significant relationship between body weight status and arsenic in tube well water. Higher arsenic is associated with a higher chance that adults will be underweight. Interestingly, neither salinity nor perceived environmental stress is correlated with the three adult health outcomes.

Panel B shows that of the two migration variables, only the number of household member trips is significantly associated with BMI and body weight status. In households with more migration trips, the members are less likely to be underweight. Given these results, the key analysis that follows in this chapter focuses on the distinct ways in which arsenic levels in tube well water and household migration trips are associated with the weight status of adult men and women net of other characteristics. I describe these bivariate results in more detail in the results section below.

Table 4.3 presents coefficients from multinomial logistic regression models that estimate the likelihood of being underweight and overweight in contrast to being normal weight (the reference category). Coefficients in the baseline model, Model 1, describe body weight status as a function of arsenic in tube well water, controlling for age, sex, religion, health at marriage, human capital index, and home materials index. Model 1 tests hypothesis H1, that is, arsenic increases the odds of being underweight relative to being normal weight. Model 2 adds migration variable to test hypothesis H2a, which states that household migration trips decrease the odds of underweight. Comparing the size and significance of the coefficients for arsenic in Model 1 and Model 2 also permits me to test whether presence of migration in the equation modifies the effect of arsenic on body weight status in any way. To fully test the moderating role of migration, I enter an interaction term, arsenic*migration trips, to Model 2. Hence, the resulting Model 3 tests hypothesis H2b, i.e. migration trips made by household members attenuate the health effects of arsenic. I also generate and graph predicted probabilities of being underweight, normal weight and overweight as a function of migration trips for high arsenic and low arsenic communities. Together Model 2 and Model 3 test the protective role of migration in the context of high arsenic water.

The last analysis, Model 4, considers whether and how gender differentiates in the environment, health and migration nexus. Because gender variable is highly significant in all models and past research indicates that the environmental conditions impact men and women differently (Denton 2002; Kovats and Hajat 2008; WHO 2014), I investigate whether the effect of arsenic on body weight status depends on gender. To that end, I add arsenic*female interaction term to Model 2. Hence, Model 4 nuances the environment-health relationship by considering whether and how gender is important in BEMS communities.

Results

Descriptive Results

I present descriptive results for the full sample and by gender in Table 4.1. To test for gender differences, I use two-tailed t-tests for continuous and chi-squared tests for categorical variables. The average BMI for the full sample is 22.1, falling within the BMI range that is considered healthy or normal. However, there are important gender differences. Women are significantly heavier than men (BMI for women is 22.5 and for men, 21.7). Women's BMI is very close to the overweight borderline by Asian population standards (BMI >= 23).[22] With respect to body weight status, approximately one-third (35%) of the sample is overweight. This is consistent with ongoing nutritional trends in Bangladesh whereby a significant proportion of the population is shifting toward being overweight and obese (Shafique et al. 2007; Shrimpton and Rokx 2012; Khan and Talukder 2013; Hoque et al. 2017). Moreover, the gender difference in the body weight status is noteworthy and significant. Approximately 40 percent of women are overweight, compared to 30 percent of men. As for being underweight, about 14 percent of women and 15 percent of men are underweight. Self-reported health displays little variation. The majority of men (83%) and women (82%) report that they consider themselves as healthy or fairly healthy, and the rest report being unhealthy.

[22]As mentioned in Chapter II, the World Health Organization's recommended cut-off for overweight category among Asian populations is BMI>=23.

Table 4.1 Descriptive Statistics of Variables Used in the Analysis, Married Adults, 15+ years, BEMS

	Mean (SD)/ Percent		
Dependent Variables	Full sample	Men	Women
Body Mass Index (BMI)	22.1 (3.6)	21.6 (3.1)	22.5 (3.9)***
Body weight status			
Underweight	14.4	14.6	14.1
Normal weight	50.4	55.7	45.5***
Overweight	35.3	29.7	40.4***
Self-reported health			
Healthy (healthy & fairly healthy)	82.4	83.0	81.9
Unhealthy	17.6	17.1	18.2
Key predictors			
Environmental conditions			
Mouza with high arsenic in water (> 10 µg/liter)	60.5	60.7	60.3
Mouza with extremely high arsenic in water (> 50 µg/liter)	42.4	43.7	41.3
Mouza with saline water (>2000 µS/cm)	46.5	45.7	47.3
Environmental stress index (1- 10)	6.7 (1.8)	6.7 (1.8)	6.6 (1.8)
Migration			
Received remittances	13.4	11.1	15.5**
Number of migration trips by household members	2.4 (3.1)	2.3 (3.1)	2.4 (3.1)
Demographic characteristics			
Age (years)	40.9 (12.7)	45.3 (12.8)	36.9 (11.2)***
Female	52.2		
Muslim	81.3	80.5	82.0
Self-reported health at marriage			
Healthy	96.4	96.8	96.0
Human capital index (0-3)	1.4 (1.2)	1.4 (1.2)	1.4 (1.2)
Home material index (0-3)	0.8 (1.0)	0.8 (1.0)	0.8 (1.0)
N	2513	1202	1311

Source: Bangladesh Environment and Migration Survey (BEMS)
^p<0.1; *p< 0.05; ** p<0.01; *** p<0.001
Note: To test for gender differences, I use two-tailed t-test for continuous variables and Chi-squared test for categorical variables.

The mean age of the sample is 41 years. Women are significantly younger than men, with a difference of approximately 8 years. There are more women in the sample than men (52% vs. 48%), and more than 80 percent of the sample is Muslim. As expected, most (96%) respondents reported that they were healthy at the time of their first marriage and there was no gender difference. The average human capital index is 1.4 and average home materials index is below 0.8. Although the indices indicate a low living standard, they do vary. Recall, these SES indices range from 0 to 3. As such, the standard deviation of 1.2 for human capital index and 1 for home materials index show that the study sample includes individuals from a wide spectrum of socioeconomic status.

Over 60 percent of respondents live in communities that have unsafe arsenic levels (>10 μg/L) in tube well water. In addition, more than 42 percent of respondents are exposed to dangerous levels of 50 μg/L or higher. As for salinity level in tube well water, approximately 47 percent of the respondents are exposed to highly saline (>2000 μS/cm) water. In addition, respondents believe that many environmental conditions have degraded over the past ten years. Recall environmental stress index is a summary index based on 10 questions on perceived environmental degradation. The average number of degraded conditions reported was 6.7 (with a range of 0-10). Overall, these statistics paint a grim picture of the environmental conditions faced by people in the BEMS sample.

The data also indicate substantial migration activity in BEMS communities. Approximately 13.4 percent of respondents reported that they received remittances in the year preceding the survey. Almost 16 percent of women reported receiving remittances whereas 11 percent of men did so. The two-tailed t-test also reveals the difference is statistically significant. Remittances come from migrants who have traveled within Bangladesh or to India and other countries. On average, the total number of trips made by household members is 2.4.

Bivariate Results

Table 4.2 presents results from bivariate analysis. Panel A reports bivariate associations between the three outcome variables and three environment variables. Recall, health outcomes include BMI, body weight status, and self-reported health. Environment variables are arsenic contamination, salinity level, and perceived environmental degradation. Results show that only arsenic in water is significantly and positively associated with body weight status. Living in communities with high arsenic in tube well water is associated with higher likelihood of being underweight. Bivariate analyses for the remaining environment variables and health outcomes yield no significant results.

Next, in Panel B, I report bivariate results for migration and health variables. Coefficients for BMI are only significant for the overweight sub-sample. Among overweight individuals, an increase in the number of household trips increases the BMI by 0.79 points. Not accounting for other variables, this suggests that migration worsens the nutritional health of already overweight/obese individuals. There is no evidence of bivariate relationship between migration variables and BMI for underweight and normal weight samples. For these groups, BMI is not associated with receipt of remittances or the total number of migration trips household members have made in the past.

The second health outcome, body weight status, is significantly and negatively associated with the number of household migration trips. Those living in households with higher number of migration trips have lower odds of being underweight. In this case, migration trips appear to protect against undernutrition. However, remittances have no significant bearing on body weight status.

Table 4.2 Estimates from Bivariate Regression Models, Married Adults, 15+ years, BEMS (N=2,513)

Panel A: Environment and health												
	BMI (1)						Body Weight status (2) (Contrast = Normal)				Self-reported health (3)	
Environment variables	Underweight		Normal weight		Overweight		Underweight		Overweight			
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Arsenic	-.016	.102	-.108	.090	-.346	.306	.545**	.137	-.132	.226	.022	.201
Salinity	-.055	.101	-.017	.103	-.333	.266	-.273	.207	-.124	.229	-.285	.165
Perceived environmental stress	.047^	.023	.003	.018	-.016	.035	-.063	.052	-.033	.020	.027	.036
N	361		1266		886		2513				2513	

Panel B: Social support and health												
	BMI (1)						Body Weight status (2) (Contrast = Normal)				Self-reported health (3)	
Migration Variables	Underweight		Normal weight		Overweight		Underweight		Overweight			
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Received remittances	-.440^	.205	-.206^	.091	.431	.279	-.033	.162	.140	.119	-.608*	.190
Number of migration trips by family	-.068	.041	.006	.008	.079*	.031	-.060**	.011	-.015	.027	-.010	.015
N	361		1266		886		2513				2513	

Source: Bangladesh Environment and Migration Survey (BEMS)
^p<0.1; *p< 0.05; ** p<0.01; *** p<0.001
(1) Estimates from OLS predicting BMI, by body weight categories.
(2) Estimates from multinomial logistic regression predicting body weight status.
(3) Estimates from logistic regression predicting self-reported health.
Note: Robust standard errors are generated using *svy* command in Stata to account for stratified sampling design.

Finally, the coefficients for the final health outcome, i.e. self-reported health, also indicate a positive effect of migration on health. Recall that this variable is reverse-coded (0= healthy/fairly healthy and 1= unhealthy). Hence, the negative coefficient estimate for remittances indicates that those who receive remittances are less likely to report their quality of health as poor when compared to those who do not receive any remittances.

As noted earlier, these bivariate results provide the foundation for subsequent multivariate analysis. Hence, I focus on body weight status and arsenic contamination. The number of household trips is also strongly correlated with body weight status. As a result, my further analysis centers on the relationship between arsenic in water and body weight status and whether the number of household migration trips moderates this relationship. Additionally, examining body weight status also offers an opportunity to shed light on the environmental and migration correlates of the dual burden of malnutrition in southwest Bangladesh.

Multinomial Logistic Regression Results

To understand how arsenic in drinking water affects body weight status after controlling for socio-demographic variables, I present coefficients in Table 4.3. I use multinomial logistic regression to predict the odds of being underweight and overweight in relation to normal weight as a function of socio-demographic characteristics, arsenic level in tube well water, and household migration trips

In Model 1, the focal environment variable – arsenic – is significant. It is positively associated with being underweight suggesting that living in communities with high levels of arsenic in water increases the odds of being underweight, after controlling for demographic and socioeconomic characteristics. However, arsenic level does not bear significantly on the odds of being overweight. This finding offers support for the first hypothesis, H1a, that arsenic adversely impacts health by contributing to poor nutritional health. This is an important finding because a significant proportion of the Bangladeshi population, especially those residing in rural areas, relies exclusively on tube well water for drinking. Arsenic may exacerbate malnutrition especially in rural communities, even as Bangladesh continues to work towards improving nutritional health and well-being of its population as part of the UN Sustainable Development Goals.[23]

Model 1 also shows that demographic and socioeconomic attributes play an important role in the distribution of body weight status. Age significantly increases the odds of being overweight and decreases the odds of being underweight (marginally significant). Women have a significantly higher likelihood of being overweight than men, compared to normal weight. Those who report being healthy at first marriage have lower odds of being underweight, but the association is only marginally significant. More human capital translates to higher odds of being overweight, but there are no significant effects for being underweight. On the other hand, coefficients for home materials display a health gradient. Compared to households made of the poorest materials, those with higher scores have lower likelihoods of being underweight but higher likelihoods of being overweight.

[23] Of the 17 sustainable development goals, goals 2,3, and 6 pertain to food and water security and nutritional well-being.

Table 4.3 Estimates from Multinomial Regression Models Predicting Body Weight Status, Married Adults, 15+ years, BEMS (N=2,513)

	Model 1 (Contrast=normal weight)				**Model 2** (Contrast=normal weight)				**Model 3** (Contrast=normal weight)				**Model 4** (Contrast=normal weight)			
	Underweight		Overweight		Underweight		Overweight		Underweight		Overweight		Underweight		Overweight	
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Age	-.058^	.027	.101**	.017	-.058^	.028	.102**	.018	-.058^	.028	.101**	.018	-.057^	.028	.102**	.018
Age squared	.001*	.000	-.001**	.000	.001*	.000	-.001**	.000	.001*	.000	-.001**	.000	.001*	.000	-.001**	.000
Female (ref= male)	.217	.112	.544**	.081	.233	.121	.554***	.078	.234	.122	.559***	.075	.536*	.157	.586***	.052
Religion (ref=Islam)	-.139	.094	-.010	.096	-.186	.096	-.036	.098	-.186	.096	-.032	.100	-.186	.098	-.036	.099
Healthy at marriage (ref= unhealthy)	-.471^	.234	-.364	.356	-.475^	.236	-.366	.349	-.474	.247	-.345	.359	-.469^	.235	-.365	.350
Human capital index (ref=0)																
1	-.356	.273	.137	.177	-.348	.273	.139	.176	-.346	.274	.149	.176	-.348	.274	.139	.175
2	-.256	.158	.457**	.078	-.254	.162	.459**	.082	-.255	.162	.459**	.080	-.254	.161	.459**	.081
3	-.331	.208	.778***	.108	-.310	.205	.790***	.114	-.309	.204	.786***	.112	-.307	.205	.790***	.115
Home materials index (ref=0)																
1	-.067	.175	.161	.112	-.077	.170	.160	.113	-.075	.171	.153	.113	-.080	.172	.159	.112
2	-.425**	.085	.442*	.137	-.424**	.089	.446*	.132	-.424**	.095	.427*	.126	-.427**	.088	.445*	.133
3	-.814*	.309	.907*	.246	-.787*	.303	.930**	.247	-.793*	.310	.901*	.245	-.788*	.303	.929**	.247
High arsenic (ref= low)	.452*	.153	.026	.179	.418*	.154	.002	.168	.407*	.166	.145	.207	.646*	.252	.025	.230
Migration trips					-.058*	.019	-.028	.017	-.067	.023	-.004	.014	-.058*	.019	-.028	.018
High arsenic*migration trips									.007	.038	-.063^	.029				
High arsenic*female													-.429	.249	-.054	.126
Constant	.102	.718	-2.826**	.714	.211	.739	-2.782**	.710	.227	.795	-2.865**	.723	.008	.711	-2.801**	.730

Source: Bangladesh Environment and Migration Survey (BEMS)

^p<0.1; * p<0.05; ** p<0.01; *** p<0.001

Note: Robust standard errors are generated using *svy* command in Stata to account for stratified sampling design.

To assess H2a, which expects that migration protects health in communities with high level of arsenic, Model 2 includes migration trips by household members. The association between body weight status and migration trips observed earlier in the bivariate analysis remains statistically significant after controlling for socio-demographic variables. Here, the coefficient shows that, after holding other variables constant, an increase in migration trips decreases the likelihood of being underweight. In addition, coefficient for arsenic decreases only slightly from Model 1 to Model 2.

To visualize these results, I generate three figures that plot the number of migration trips against predicted probabilities for being underweight, normal weight, and overweight from Model 2. Figure 4.1a includes two lines; the solid red line represents high arsenic communities and the dotted blue line represents low arsenic communities. Hence, the figure shows the probabilities of being underweight for adults who live in high arsenic and low arsenic communities. Respondents in high arsenic communities have higher probabilities of being underweight than those in low arsenic communities. This difference remains as migration trips increase and the chances for both groups decline.

Figure 4.1b shows upward trajectories in the predicted probabilities for both high and low arsenic communities. Those living in low arsenic communities have higher probabilities of having normal or healthy weight than those living in high arsenic communities. This gap between the two groups remain as the number of migration trips increase. Figure 4.1c also illustrates the low arsenic vs. high arsenic gap. Those living in low arsenic communities have higher probabilities of being overweight than their counterparts in high arsenic communities. This disparity and downward trend remain as the number of migration trips increase.

Figure 4.1 Predicted Probabilities from Multinomial Logistic Regression Model Predicting Body Weight Status as a Function of Arsenic Contamination, Migration Trips, and Other Variables, BEMS (Table 4.3, Model 2)

Figure 4.1a: Underweight group

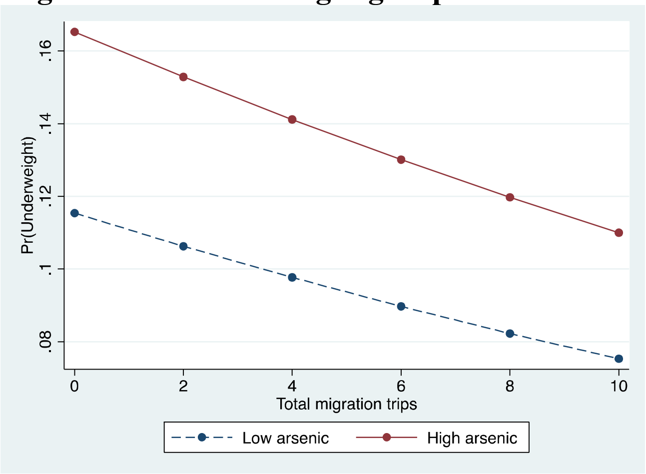


Figure 4.1b: Normal weight group

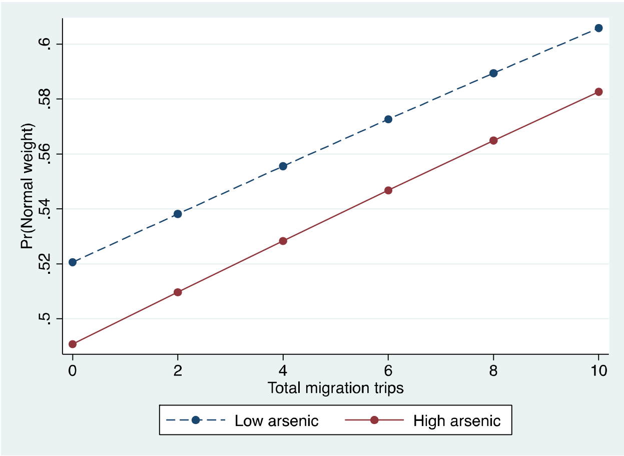
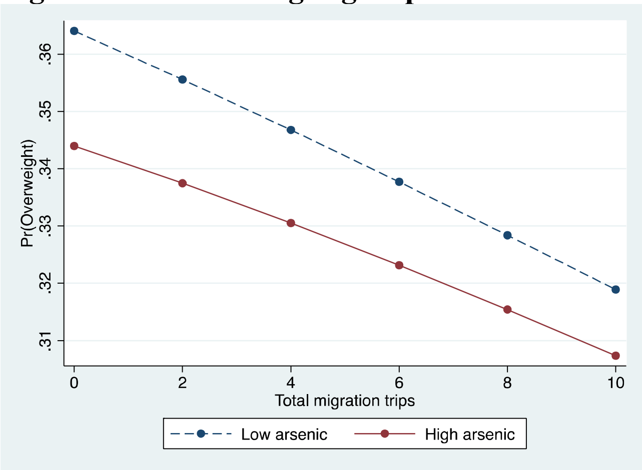


Figure 4.1c: Overweight group



Model 3 includes all the variables from Model 2 and an interaction term between arsenic and household migration trips. This model formally tests the moderating hypothesis. The interaction term is not significant suggesting that the number of migration trips does not attenuate the impact of arsenic on the odds of being malnourished. Hence, these results do not offer evidence to support hypothesis H2b that migration offers protection for those living in communities with poor water quality. In the last set of analysis, I examine whether and how gender is important. Model 4 in Table 4.3 adds an arsenic*female interaction term. The interaction coefficient is not significant. Again, there is no evidence of moderating effects of gender in the arsenic-body weight status relationship.

Summary and Conclusion

Overall, the results offer important insights into environment, health and migration interactions. First, there is unequivocal evidence that arsenic in tube well water is deleterious to health and undermines national efforts to combat poor nutritional health. Results show that arsenic contamination significantly increases the odds of being underweight. Second, although there is inadequate evidence to support the hypothesis that migration moderates the association between arsenic and body weight status, there is some evidence that past migration trips influence health in diverse ways in Bangladesh's southwestern communities. For example, my analysis shows that an increase in migration trips decrease the odds of being underweight.

The results are encouraging and indicative of the important role that migration plays in southwest communities of Bangladesh. In the context of promoting health, family's migration as denoted by the number of trips family members made in the past increase the likelihood of having healthy or normal weight in both high and low arsenic communities, more so in the former than the latter. Migration trips may also work towards decreasing the odds of overweight in high arsenic communities.

These findings offer a glimpse into the complex ways in which adverse environmental conditions, including unsafe and contaminated water sources, contribute to poor health. In limited resource settings like the BEMS villages, drawing on family's personal resources and adaptive strategies such as migration may offer some respite, although alone it may not be enough to overcome environmental adversity. In the next chapter, I consider whether and how social support operates to protect adult health.

CHAPTER V

ARSENIC, HEALTH, AND SOCIAL SUPPORT: FINDINGS FROM BANGLADESH ENVIRONMENT AND MIGRATION SURVEY

This chapter builds on Chapter IV and uses household and water chemistry data from BEMS to investigate whether and how social support protects the health of adults living in communities with high levels of arsenic in tube well water. The analytic strategy and coding schemes of the independent and dependent variables are similar to Chapter IV. However, the moderator variables are different; instead of migration, I use three measures of social support. Specifically, I examine whether one or all three types – practical, emotional, and monetary – attenuate the negative health impacts of arsenic. Below I present the research hypotheses, followed by the analytic strategy, and bivariate and multivariate findings. In the final section, I summarize the main results.

Hypotheses

The main objective of this chapter is to assess whether social support is a valuable resource for adults in environmentally vulnerable communities. Specifically, does social support protect the health of men and women who live with high levels of arsenic in their tube well water? I further examine what type of support- practical help, emotional support, and monetary/material assistance – is more (or less) salient in the environment-health relationship. To guide the analysis, I formulate the following hypotheses about the relationship among arsenic, health, and social support.

H3: Social support moderates the relationship between adverse environmental condition (i.e. high arsenic in tube well water) and body weight status.

H3a: Social support is positively associated with body weight status such that it decreases the odds of being underweight and overweight.

H3b: Social support moderates the influence of arsenic contamination on body weight status. I expect monetary support will have the largest moderating effect, followed by practical support and emotional support.

Analytic Plan

I use BEMS household and water chemistry data to test these hypotheses. As in Chapter IV, my preliminary analysis focuses on three outcome variables that capture adult health and well-being – body mass index (BMI), body weight status, and self-reported health. Recall, BMI is a continuous variable that reflects nutritional health and disease risks. Body weight status, a categorical variable derived from BMI, consists of three levels: underweight, normal or healthy weight, and overweight. The third outcome represents self-reported health, which is a dichotomous variable that categorizes adults as healthy or unhealthy. Combined, these three variables capture perceived and objective adult health status in BEMS study sites. As described in Chapter IV, I use three measures of environmental conditions; arsenic and salinity levels in tube well water denote drinking water quality and environmental stress index represents perceived environmental deterioration.

The three types of social support are hypothesized as moderators and are the focus of this chapter. Practical support refers to routine help such as assistance with household chores and help during the harvest season. Emotional support includes receiving advice and comfort.

Finally, monetary or material support consists of receiving cash and tangible help such as food items and transport.

The analytic sample size is 2,507 respondents after I remove observations with missing data on the dependent and social support variables.[24] The sample includes 1198 men and 1309 women. The sample size for the analysis in this chapter is slightly different from that in Chapter IV because I removed 6 observations that were missing social support data.

As in previous chapters, I begin the analysis by generating descriptive statistics of the variables under study. I then examine bivariate associations between environmental predictors and health outcomes. In this preliminary assessment of the relationships between my key variables and health outcomes, I identify statistically significant associations that warrant further analysis. I use OLS regressions to predict BMI; multinomial logistic regression (MNLR) to predict body weight status; and logistic regression for self-reported health. Similar to Chapter IV, results from the bivariate analysis inform the subsequent multivariate analyses.

Model Building Process

The goal of this chapter is to assess whether and how social support moderates the health impacts of environmental stressors, net of other demographic and socioeconomic factors. Following the data driven approach, the multivariate analysis focuses only on the association between body weight status and arsenic and whether practical support buffers this relationship because, similar to the earlier chapter, arsenic is the only environmental variable that has a statistically significant association with body weight status at the bivariate level. Likewise, only

[24] I excluded respondents from the Narail Sadar *mauza* (n=394) in this analysis because we do not have water chemistry data for this site. In addition, I also removed respondents for which height and weight data are missing (N=241), those who did not self-report health at marriage (N=91), and those for whom practical social support is missing (N=6).

practical support is associated with body weight status, albeit marginally. Hence, I focus on only one aspect of social support – practical support – and do not present results for emotional and monetary support in the dissertation.[25]

Since body weight status is a polytomous variable with three categories, I estimate multinomial logistic regression (MNLR) models. As in the previous two chapters, I use normal weight as the reference category. Following the analytic strategy outlined in Chapter IV, I generate four MNLR models to test the research hypotheses. Model 1 predicts the odds of being underweight and overweight as a function of arsenic level in tube well water and socio-demographic controls. Model 2 adds practical support to Model 1, and tests H3a, i.e. social support decreases the odds of being underweight and overweight. By comparing the coefficient for arsenic from Models 1 and 2, I can check whether adding practical support to the equation changes the size and statistical significance of arsenic. To formally test H3b, I enter arsenic*practical support to Model 3. Coefficients from this model, Model 4, indicate whether the effect of arsenic on body weight status depends on whether one receives practical support. Finally, I investigate the role of gender by adding arsenic*female interaction term to Model 2.

Results

Descriptive Results

Table 5.1 presents descriptive statistics for the total sample and by gender. I used two-tailed t-tests for continuous and chi-squared tests for categorical variables to test for gender differences. The average BMI for the full sample is 22.1, which falls in the normal weight range

[25] Further multivariate tests of emotional and monetary support as predictors and moderators did not yield significant results.

(18.5-22.9). Women, on average, have higher BMI (22.5) than men (21.6), and the difference is statistically significant. BMI for the full sample ranged from 11.1 to 45.5, for women it ranged from 12.2 to 45.5, and for men 11.1 to 38.6 (not shown).

Table 5.1 Descriptive Statistics of Variables Used in the Analysis, Married Adults, 15+ years

	Mean (SD)/ Percent		
Dependent Variables	Full sample	Men	Women
Body Mass Index (BMI)	22.1 (3.5)	21.6 (3.1)	22.5 (3.9)***
Body weight status			
Underweight	14.4	14.6	14.1
Normal weight	50.3	55.7	45.5***
Overweight	35.3	29.7	40.4***
Self-reported health			
Healthy (healthy & fairly healthy)	82.3	82.8	81.9
Unhealthy	17.7	17.2	18.1
Key predictors			
Environmental conditions			
Mouza with high arsenic in water (> 10 µg/liter)	60.4	60.6	60.2
Mouza with extremely high arsenic in water (> 50 µg/liter)	42.3	43.5	41.2
Mouza with saline water (>2000 µS/cm)	46.5	45.6	47.3
Environmental stress index (1-10)	6.7 (1.8)	6.8 (1.8)	6.7 (1.7)
Social support			
Received practical support	63.8	67	60.8**
Received emotional support	77.5	79.1	76.0 ^
Received monetary support	61.9	70.0	54.5***
Demographic characteristics			
Age (years)	40.9 (12.7)	45.3 (12.8)	36.9 (11.3)***
Female	52.2		
Muslim	81.3	80.6	82.0
Self-reported health at marriage			
Healthy	96.4	96.8	96.0
Human capital index (0-3)	1.4 (1.2)	1.4 (1.2)	1.4 (1.2)
Home material index (0-3)	0.8 (1.0)	0.8 (1.0)	0.8 (1.0)
N	2507	1198	1309

Source: Bangladesh Environment and Migration Survey (BEMS)

^p<0.1; *p< 0.05; ** p<0.01; *** p<0.001

Note: To test for gender differences, I use two-tailed t-test for continuous variables and Chi-squared test for categorical variables.

About half of the respondents in the total sample (50.3%) fall within the normal weight range, slightly more than one-third (35.3%) is overweight, and approximately 14 percent are underweight. However, there are notable gender differences in these distributions. Although the shares of men and women who are underweight are comparable (14.6 and 14.1, respectively), there are significant gender differences among those with in the healthy and overweight categories. Among men, approximately 56 percent falls in normal weight category whereas less than half of women (46 %) fall in this category. This difference of 10 percent points is statistically significant at 0.001 level. Approximately 40 percent of women and 30 percent of men are overweight, a difference that is also highly significant. Thus, these results indicate that a substantial proportion of the BEMS sample is overweight. In fact, the proportion of overweight or obese is more than twice as large as the share of underweight group. Among women, this difference is more conspicuous – there are almost three times as many overweight women as underweight. Women also have higher average BMI than men.

Findings for self-reported health show that most respondents (82.3%) rate their current health as healthy or fairly healthy, and there was little difference among men and women. Approximately 83 percent of men and 82 percent of women reported themselves as healthy.

Women comprised slightly more than half of the sample (52%). The average age of respondents in the total sample is 41 years. Men are significantly older than women; the average man is 45 years old whereas the average woman is 37 years old. Given that Bangladesh is a largely Muslim country, it was not surprising to find that more than 80 percent of the total sample is Muslim and there is no gender difference. The remainder of respondents are Hindus (18.3%), Christians (0.3%), and Buddhists (0.1%). Self-reported health at first marriage reveals that an overwhelming majority (96%) reported being healthy at the time of their first marriage.

The human capital index and home material index, which together characterize the socioeconomic conditions of the household, reveal that the respondents are mostly poor.[26] Recall that I added literacy, education, and occupation variables to create a summary index of human capital, and hence, higher values indicate higher levels of human capital in households. For home material index, I summarized responses to whether home has finished or cement floor; whether home has cement roof, and whether home has brick and/or cement walls. Because these indices are each constructed from 3 items, they range between 0-3. The average human capital index of the sample is 1.4. Likewise, home materials index also revealed poor living conditions. The average index score is less than 1.

From the descriptive statistics for environmental predictors, I present arsenic contamination in two ways. First, using the contamination cut-off set by the World Health Organization (2011), we see that that 60 percent of respondents live in communities where the average arsenic content in the water bodies exceeds 10 µg/L. Second, using a more conservative cut-off set by the Bangladesh Government, i.e. 50 µg/L, we see that 42 percent of respondents live in communities that have extremely high concentration of arsenic in tube well water (BGS and DHPE 2001). Thus, large shares of respondents in the sample are exposed to unsafe levels of arsenic through tube-well water, which is used extensively for drinking and other household purposes.

In addition, a substantial proportion of the study sample lives in communities with highly saline water. Approximately half of respondents (47%) live in communities that have tube well water with salinity measuring over 2000 µS/cm, which is the cut-off for unhealthy level of salts in water (Ravenscroft 2003; Uddin and Kaudstaal 2003; Ravenscroft et al. 2009).

[26] Since HCI and HMI are household level measures, testing for gender differences is not possible.

I also measure perceived environmental stress over degrading environmental conditions in communities in the last 10 years before the survey. As in the earlier chapter, I created a summary index from respondent's perceptions about 10 environmental issues and whether they have experienced/witnessed worsening conditions for those conditions. On average, the respondents reported between 6 to 7 degraded conditions. In fact, more than three-quarters (78%) of respondents reported five or more degraded environmental conditions (not shown).

With regard to social support, many respondents have received one or more types of social support. For instance, about 64 percent of respondents reported receiving practical help. Men report practical support more than women (67 vs. 61 percent) over the last 12 months, and the difference is significant at .01 level. Approximately 78 percent of the total sample reported receiving emotional support, and more men reported receiving it than women (79 vs. 76 percent), although the difference is only marginally significant. Fewer respondents received monetary support, however. Approximately 62 percent of respondents reported receiving tangible help, including money and other goods. As expected, men had significantly higher access to monetary support than women (70 vs. 55 percent, respective). Overall, these results suggest that more men than women received the three kinds of social support.

Bivariate Results

I present results from the bivariate analysis in Table 5.2. Findings help guide the independent, dependent, and moderator variables to include in multivariate analysis. Table 5.2 includes two panels. Panel A focuses on the association between environmental predictors and health outcomes, and Panel B displays bivariate results for social support and health outcomes.

Table 5.2 Estimates from Bivariate Regression Models, Married Adults, 15+ years, BEMS (N=2,507)

Panel A: Environment and health												
	BMI (1)						Body Weight status (2) (Contrast = healthy weight)				Self-reported health (3)	
Environment variables	Underweight		Healthy weight		Overweight		Underweight		Overweight			
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Arsenic	-.020	.102	-.110	.090	-.343	.305	.547**	.137	-.129	.227	.027	.203
Salinity	-.050	.103	-.019	.103	-.329	.264	-.265	.206	-.123	.229	-.288	.168
Perceived environmental stress	.046	.024	.001	.018	-.012	.038	-.063	.050	-.037	.022	.021	.040
N	360		1262		885		2507				2507	

Panel B: Social support and Health												
	BMI (1)						Body Weight status (2) (Contrast = healthy weight)				Self-reported health (3)	
Social support variables	Underweight		Healthy weight		Overweight		Underweight		Overweight			
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Practical support	.089	.167	.054	.069	-.257^	.132	-.133^	.068	-.229^	.096	-.228^	.113
Emotional support	.003	.118	.001	.086	.019	.233	.212	.119	-.109	.090	-.436^	.220
Monetary support	.185^	.094	.0746^	.038	-.043	.256	-.114	.165	-.179	.117	-.130	.144
N	360		1262		885		2507				2507	

Source: Bangladesh Environment and Migration Survey (BEMS)
^p<0.1; *p< 0.05; ** p<0.01; *** p<0.001
(1) Estimates from OLS predicting BMI, by body weight categories
(2) Estimates from multinomial logistic regression predicting body weight status.
(3) Estimates from logistic regression predicting self-reported quality of health.
Note: Robust standard errors are generated using *svy* command in Stata to account for stratified sampling design.

Panel A shows few significant relationships between arsenic, salinity, and perceived stress, on the one hand, and health on the other. The exception is for arsenic and body weight status. These two variables are significantly and positively associated. Living in high arsenic communities results in higher odds of being underweight when compared to living in low arsenic communities. Neither of the remaining two environmental predictors appears to be consequential to BMI, body weigh status, or self-rated health.

Panel B shows marginally significant effects of different kinds of social support on health. Although significant at .1 level, these findings merit some discussion. From the BMI sub-group analysis, practical support and BMI are negatively associated for the overweight sample; among overweight respondents, those who have practical support have lower BMI than those who do not have access to such support. Emotional support does not influence the BMI in any of the weight groups, but monetary/material support is consequential those who are underweight or have normal weights. Those who receive this kind of support have higher average BMI than their counterparts who do not receive support. Practical support is marginally significant when predicting the odds of being underweight and overweight. Practical support decreases the odds of being underweight and overweight. Finally, receipt of practical and emotional support decreases the likelihood of being unhealthy (marginally significant).

Because arsenic level and body weight status is the only statistically significant association, I only include these two variables in the multivariate models and, as a moderator variable, practical support.[27] Hence, in the next section, I examine how arsenic influences body weight status of men and women and whether practical support moderates this relationship.

[27] Emotional and monetary support are not significant predictors of body weight status at the bivariate and multivariate levels (results not shown).

Multinomial Logistic Regression Results

Table 5.3 presents coefficients from multinomial regression models 1-4. The base model (Model 1) focuses on the effect of arsenic, net of control variables, on body weight status. In Model 1, the coefficient for arsenic is significant – those living in high arsenic communities have higher likelihood of being underweight (after controlling for demographic characteristics). Age matters for both underweight and overweight groups. As age increases, the likelihood of being underweight decreases (marginally significant) but the likelihood of being overweight increases. Women have higher odds of being underweight (marginally significant) and overweight than men.

The human capital index is a significant predictor of being overweight; when compared to those without human capital, those who have some level of human capital have higher odds of being overweight. Note, however, that the effect of human capital on being underweight is not significant. Coefficients for the home materials index are highly significant. Higher scores on the index, i.e. higher socioeconomic status, correlate with lower odds of being underweight and higher odds of being overweight. These results show a strong and consistent role that SES plays in nutritional health in BEMS communities.

Model 2 adds the moderator – practical support – to the equation to partially test hypothesis H3a, which states that practical support contributes to better nutritional health by decreasing the odds of being underweight and overweight. Coefficients for the arsenic and other control variables do not change substantially after including the practical support variable. For instance, arsenic level remains significant for underweight category. More notably, the coefficients for this moderator variable show that compared to those who do not receive practical support, those receiving practical support have lower odds of being underweight and overweight.

The former is significant at the .1 level and the latter is significant at the .05 level. Hence, the results offer evidence to support H3a and that practical support contributes towards improving nutritional health by lowering chances of having unhealthy weight status.

Table 5.3 Estimates from Multinomial Regression Models Predicting Body Weight Status, Married Adults, 15+ years, BEMS (N=2,507)

	Model 1 (Contrast=healthy weight)				Model 2 (Contrast=healthy weight)				Model 3 (Contrast=healthy weight)				Model 4 (Contrast=healthy weight)			
	Underweight		Overweight		Underweight		Overweight		Underweight		Overweight		Underweight		Overweight	
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Age	-.059^	.027	.101**	.017	-.058^	.027	.101**	.016	-.059^	.027	.101**	.017	-.057^	.027	.101**	.017
Age squared	.001*	.000	-.001**	.000	.001*	.000	-.001**	.000	.001*	.000	-.001**	.000	.001*	.000	-.001**	.000
Female (ref= male)	.224^	.113	.547**	.081	.215	.112	.533**	.079	.207	.109	.531**	.081	.502*	.160	.551***	.046
Religion (ref=Islam)	-.136	.094	-.007	.096	-.131	.095	.000	.100	-.115	.097	.006	.101	-.132	.097	.000	.100
Healthy at marriage (ref= unhealthy)	-.471^	.234	-.362	.356	-.481^	.237	-.372	.361	-.471^	.233	-.369	.360	-.476^	.236	-.372	.362
Human capital index (ref=0)																
1	-.351	.272	.132	.178	-.358	.269	.125	.175	-.358	.267	.125	.175	-.358	.270	.125	.175
2	-.245	.153	.453**	.078	-.240	.155	.460**	.076	-.230	.159	.464**	.078	-.240	.154	.460**	.076
3	-.319	.207	.775***	.109	-.315	.205	.778***	.108	-.307	.206	.781***	.111	-.311	.204	.778***	.109
Home materials index (ref=0)																
1	-.069	.175	.161	.111	-.061	.178	.168	.105	-.075	.178	.162	.111	-.065	.180	.167	.104
2	-.440**	.085	.459*	.140	-.434**	.081	.464*	.136	-.456**	.085	.455*	.145	-.437**	.080	.464*	.136
3	-.820*	.314	.909*	.248	-.821*	.316	.910*	.258	-.820*	.308	.910*	.258	-.822*	.315	.910*	.257
High arsenic (ref= low)	.452*	.153	.032	.181	.470*	.143	.060	.183	.237	.238	-.035	.172	.685*	.243	.070	.245
Practical support (ref= none)					-.169^	.072	-.224*	.080	-.432*	.153	-.309^	.142	-.158^	.073	-.223*	.080
High arsenic*practical support									.400	.214	.151	.160				
High arsenic*female													-.406	.246	-.030	.123
Constant	.104	.721	-2.819**	.706	.194	.743	-2.693**	.700	.340	.702	-2.639*	.712	-.003	.720	-2.701*	.721

Source: Bangladesh Environment and Migration Survey (BEMS)
^p<0.1; *p< 0.05; ** p<0.01; *** p<0.001
Note: Robust standard errors are generated using *svy* command in Stata to account for stratified sampling design.

To visualize the above results, I estimate predicted probabilities of being underweight, normal weight, and overweight from Model 2 in Table 5.3 and generate graphs to depict the relationship between arsenic contamination and body weight status and how it varies by practical support. Figure 5.1 includes three sets of graphs representing the probabilities of being underweight (Fig 5.1a), normal weight (Fig 5.1b), and overweight (Fig 5.1c). The red solid line represents high arsenic communities and the dotted blue line represents low arsenic communities.

Figure 5.1a shows that compared to those living in low arsenic communities, adults living in high arsenic communities have greater probabilities of being underweight. This difference remains regardless of whether one receives practical support or not. However, access to practical support modestly decreases the probabilities of being underweight for both low and high arsenic communities.

Figure 5.1b shows that those living in high arsenic communities have lower probability of having normal weight than their counterparts in low arsenic communities. This holds true for those with or without practical support. However, those with practical support have higher probability of having normal weight than those without such support.

Finally, Figure 5.1c indicates that the probability of being overweight is higher among low arsenic community residents than those in high arsenic communities. However, practical support decreases the probabilities of being overweight among those living in both low and high arsenic communities. Overall, living in high arsenic communities translates to higher odds of being underweight and lower odds of overweight when compared to living in low arsenic communities. In both low arsenic and high arsenic communities, practical support decreases the likelihood of being underweight and overweight and increases the odds of having normal weight.

Figure 5.1 Predicted Probabilities from Multinomial Logistic Regression Predicting Body Weight Status as a Function of Arsenic Contamination, Practical Support, and Other Variables (Table 5.3, Model 2)

Figure 5.1a: Underweight group

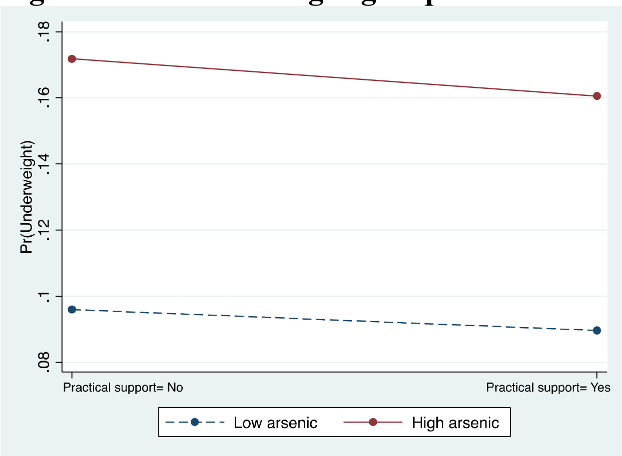


Figure 5.1b: Normal weight group

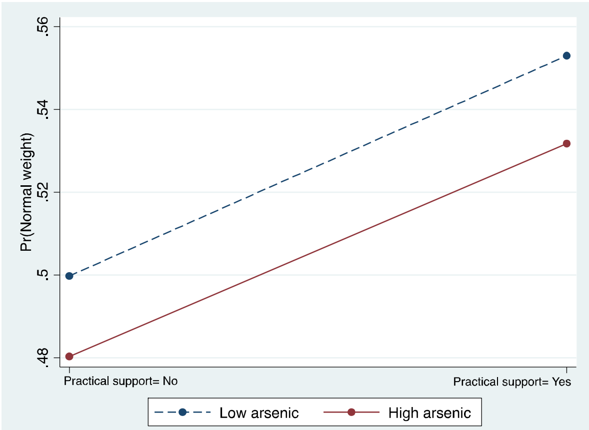
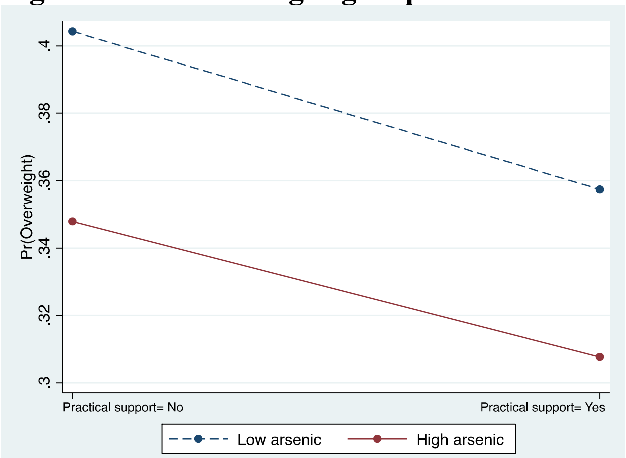


Figure 5.1c: Overweight group



Next, to test the moderating effect of practical support (H3b), I introduce the interaction of arsenic*practical support to Model 2 and present estimates in Model 3. Coefficients for the interaction term are not significant suggesting that receiving practical support does not protect against the odds of being underweight or overweight in high arsenic communities. Hence, these results do not support hypothesis H3b that practical support buffers the negative health impacts of arsenic in tube well water.

The final model, Model 4, incorporates gender. I add arsenic*female interaction term to Model 2 to test whether there are gender differences in the effects of arsenic contamination on body weight status. Again, the interaction term is not significant suggesting the effect of arsenic on the odds of being underweight and overweight does not vary by gender.

Summary and Conclusion

Findings from this chapter underscore the strong impact of arsenic contamination in tube well water on adult's nutritional health. Social support appears to somewhat benefit the nutritional status of men and women in BEMS communities. Results from the main effects model testing the association between support and body weight status suggest that practical support promotes healthy weight, e.g. those who receive this form of support have lower odds of being underweight and overweight compared to those who do not receive such support. This is an important finding. Findings from predicted probabilities add some nuances to the findings. For instance, those who do not have practical support are more likely to be under- and over-weight and less likely to have normal weight when compared to those without such support in both low and high arsenic communities.

However, results from the moderation analysis, testing the interaction between support and arsenic, are not significant. The interaction model shows the effect of arsenic on body weight status does not depend on whether one receives practical support. Hence, there is no evidence that practical support protects against the negative effects of high arsenic in tube well water. Again, arsenic appears to be a formidable determinant of nutritional health in BEMS communities.

CHAPTER VI

POLICY IMPLICATIONS AND LIMITATIONS

In this dissertation, I examine the diverse ways in which geographic and environmental attributes interact with social factors to influence human health in Bangladesh. My analyses accomplished three substantive goals that have important implications for future research and policy development. First, I shed light on the extent of the dual burden of malnutrition nationally and in the southwest region of the country. Second, by looking at multiple health outcomes as a function of environmental and socioeconomic factors across Bangladesh and in southwest region of the country, I demonstrate the unique ways in which the physical environment is intertwined with adult and child health. Finally, I offer insights about whether and how family- and community-based resources, such as migration and social support, are associated with health in communities where institutional and infrastructural capacities are limited.

In my first empirical chapter, I use BDHS to examine the dual burden of malnutrition in Bangladesh – a phenomenon that threatens to undermine the country's recent public health gains. Historically, developing countries like Bangladesh have grappled with widespread undernourishment but recent trends indicate rising prevalence of overweight and obesity. The 2007 BDHS data show that Bangladesh bears the public health burden of both underweight and overweight/obesity; the proportion of the latter surpassed that of the former in 2011 and this gap continues to expand. BEMS study reveals that the prevalence of overweight and/or obesity is even higher in the southwest region. Compared to BDHS, a much larger proportion of women in BEMS sample is overweight or obese (22% vs. 40%). BEMS data also provide information on men; about 30 percent of men are overweight or obese, an important statistic which is often overlooked or absent from national studies.

In addition to nationwide nutritional health trends, my analysis reveals variation by urban/rural residence and coastal proximity. Women in urban areas have higher BMI after controlling for all relevant factors. Similarly, coastal living is also associated with higher BMI – those who live on or near the coast have higher average BMI than those who live further from the coastline. Further examination by looking at body weight status adds some nuances; coastal living is actually associated with higher chances of being overweight and has no bearing on the odds of being underweight. In addition to geography, socioeconomic status, which is measured by wealth quintiles, is an important predictor of nutritional status. There is a discernible health gradient; compared to the poorest group, the better off groups have incrementally higher BMI. Together, the physical environment and socioeconomic standing play critical role in predicting nutritional health and well-being. Hence, future policy interventions should incorporate social, economic, and geographical considerations in addressing the dual burden of Bangladesh among women.

Shifting focus to southwest Bangladesh further shed light on the severity and extent of environmental challenges in the region. Interdisciplinary data collection efforts permitted the integration of household survey and water chemistry data, which made it possible to examine the association between arsenic contamination in tube well drinking water and body weight status. My analysis of BEMS data focuses on arsenic for two main reasons. First, arsenic level in tube wells is strongly associated with body weight status. Second, arsenic poisoning continues to have wide-ranging health impacts in Bangladesh and across South Asia. Hence, understanding how arsenic affects health contributes to a larger public health debate and calls for concerted research and policy action. For instance, results suggest that arsenic poisoning poses a formidable hurdle in Bangladesh's efforts to accomplish the United Nations' Sustainable Development Goals, especially those pertaining to mortality and nutritional health outcomes. A comprehensive review of arsenic poisoning and its effects on health list wide-ranging impacts, including respiratory, cardiovascular, gastrointestinal, dermal, renal, and neurological diseases (Mandal and Suzuki 2002). Arsenic exposure is also associated with low birth weight (Nordstrom, Beckham and Nordenson 1979) and low body weight among adults (Goebel et al. 1990; Grashow et al. 2014). However, combatting arsenic is not easy because most people across the country rely extensively on tube well water for drinking.

As observed in BEMS sites, arsenic contamination is pervasive and ranges widely – from 1μg/L in Kalia and Mongla to 161μg/L in Tala. Arsenic is consistently associated with higher odds of being underweight after controlling for important factors such as age, sex, religion, past health status and socioeconomic standing. Therefore, these findings suggest an urgent need to address arsenic contamination of tube well water and mitigating its health effects.

Policy responses may include a number of interventions that focus on treating well water and exploring alternative sustainable water sources. For example, a filtration technique called Stevens Technology for Arsenic Removal (STAR), which enables households to purify well water by using inexpensive iron sulfate mixture with calcium hypochlorite, is implemented in a number of villages in Bangladesh (WHO 2002). Future efforts could focus on scaling up and implementing this intervention across the entire country. Another solution is to invest in sustainable water sources such as harvesting rainwater and desalinizing seawater. Together, these and other solutions require substantial funding and partnerships with governmental and nongovernmental stakeholders.

In addition to technological solutions, policy responses must include mitigation efforts to ameliorate adverse health impacts. A recent report by Human Rights Watch (2016) estimates that more than 20 million people in Bangladesh still drink water contaminated with arsenic and an estimated 43,000 people die each year from arsenic-related conditions. Given the scale and persistence of the problem, national-level health interventions are long overdue. Studies suggest that nutritional supplements, including certain vitamins, may alleviate symptoms of arsenicosis (Khandker et al. 2006; Ghose et al. 2014). Bangladesh's health system includes community health centers at the village levels, which could be mobilized to diagnose and treat individuals suffering from arsenic poisoning.

Such interventions are critical in reducing arsenic exposure and poisoning in countries like Bangladesh, but responses from government and other multilateral agencies are often slow and piecemeal. Moreover, in low-resource settings, there is little or no institutional capacity to respond to this public health crisis. Thus, it is important to consider other resources that could promote resilience in households and communities. For instance, migration offers some degree of protection against poor environmental conditions. Informational and monetary capital may buffer the adverse health impacts of poor water quality by enabling households to buy clean water and invest in water filtration system. The BDHS analysis in Chapter III showed that migration offers health benefits and lowers the odds of being underweight among women who live away from the coast. No such effects are seen for non-migrant women. Further research could look at the mechanisms that link migration, health promoting behaviors and actions, and water security.

Results from BEMS data are also encouraging. At the bivariate level, the number of migration trips is positively associated with lower odds of being underweight when compared to the odds of being normal weight. Likewise, receipt of remittances is associated with self-reported health – those who received remittances are less likely to report their quality of health as poor when compared to those who did not receive any remittances. However, migration did not moderate the relationship between environmental conditions and health. Arsenic appears to have such a devastating impact on health that migration-related resources alone may not be enough to protect against such an effect.

In theory, social support may also moderate the negative health impacts of poor environmental conditions. Prior studies document the salubrious qualities of social support in stressful situations, including natural disasters. In Japan, for example, emotional support was associated with fewer sleep difficulties after the Great East Japan Earthquake and tsunami (Sakuma et al. 2015). In southwest Poland, the amount of social support received was associated with positive appraisal of psychological well-being among those recovering from severe flooding (Kaniasty 2012). Using the BEMS, my findings suggest practical support contributes to nutritional health by decreasing the odds of underweight and overweight. However, there is not sufficient statistical evidence to suggest that social support moderates the relationship between high arsenic in drinking water and health. Together, these findings offer a promising starting point for future research to explore other social resources that promote resilience.

Of course, the analyses presented here have limitations. First, the BDHS is a secondary data source with limited information on migration. Second, because the data set is cross-sectional, my analysis cannot ascertain causality between the environmental attributes and health outcomes. In addition, although nationally representative, the BDHS includes comprehensive information only from ever-married women of reproductive ages and their young children. Finally, the BDHS randomly places the GPS waypoints of surveyed communities within 2-5 kilometers (1-3 miles) to maintain confidentiality of survey respondents. Because I use the waypoints to measure distance between surveyed communities and the nearest coastline, my measure of coastal proximity contains some positional errors.

With respect to Chapters IV and V, they too have some important limitations. One obvious limitation is that because the BEMS derive from eight purposively selected mouzas in southwest region, my findings are not generalizable to other areas of Bangladesh. In addition, the BEMS do not permit me to make causal inferences and, despite having information on environmental conditions, some of these also have their limits. For example, because arsenic and salinity contamination are measured at the *mouza* level, my analytic models do not include institutional or contextual controls at the mouza level. Future research would benefit from collecting environmental variables at the household level to assess whether and how variation in environmental health can be differentially explained at household vs. community levels. With household environmental conditions, models would then allow for controls such as local infrastructure and political climate.

Despite the limitations, this study has a number of strengths. First, it utilizes multidisciplinary concepts and methods to investigate a pressing global health problem. By combining household, anthropometric, water chemistry, and geo-spatial data, I offer a holistic examination of the role of social factors in the environment-health relationship in Bangladesh. In addition, I am able to use multiple environmental predictors, moderators, and health outcomes. Third, I demonstrate how to combine different types of data and analyze the integrated data set to yield findings that are valuable to social, physical, and geospatial sciences.

In addition, findings from this dissertation offer a promising avenue to examine social resources that contribute to resilience against environmental adversities. I examine two social dimensions of migration – trips made by household members and whether household receives remittances – but future research may consider other aspects of migration such as social remittances, a valuable resource that encompasses knowledge, norms, and behavior that migrants transfer to their families and communities at the origin (Levitt 1998; Levitt and Lamba-Neives 2011). Social remittances have a diverse impact on health such as improved knowledge about health practices, including use of modern contraceptives, in Guatemala (Lindstrom and Munoz-Franco 2006), greater use of antiparasitic medication in Ecuador (Lopez-Cevallos and Chi 2012), and higher birthweight and lower mortality rates among children in rural Mexico (Hildebrandt and McKenzie 2005). Hence, future studies could examine different migration-related resources and identify mechanisms that underlie the migration-health link.

In conclusion, this research contributes to improving our understanding of the inextricable relationship between natural and human systems. Importantly, by investigating the protective role of migration and social support in environmentally vulnerable settings, my dissertation lays groundwork for future research on social resilience. In doing so, I make a strong case for including social resources derived from family and community in future debates on mitigating health impacts of global environmental change.

APPENDICES

Appendix A: Description of Key variables from BEMS data set Used in Chapter IV Analysis

Key variables	Description	Values	Level
Dependent variables			
Body mass index (BMI)	Body weight (kg) divided by the square of height (meters)	Continuous numeric values	Individual
Body weight status	Three-category variable derived from BMI such that BMI < 18.5 coded as underweight; 18.5<=BMI<23 coded as healthy weight; and BMI >=23 coded as overweight	1= Underweight 2= Normal weight 3= Overweight	Individual
Self-reported health	Self reported quality of current health	0 = Unhealthy 1= Healthy	Individual
Environmental predictors			
Salinity	Average level of salinity in drinking water sources. Conductivity of 2000 µS/cm or lower is coded as fresh; > 2000 µS/cm is coded as saline	0= Fresh 1= Saline	Community
Arsenic	Average level of arsenic in drinking water sources. Arsenic content of 10 µg/liter or lower is coded as fresh; >10 µg/liter is coded as contaminated.	0= Fresh 1= Contaminated	Community
Perceived environmental stress	Index measure created from a series of 10 questions on perceived environmental conditions.	Numeric values between 0-10	Household
Moderators			
Received remittances	Whether household received remittances from migrants in Bangladesh, India, or other countries in the past 12 months	0= No 1= Yes	Household
Total number of migration trips	Number of migration trips that household members have taken in years prior to the survey	Continuous numeric values	Household

Appendix B: Description of Key variables from BEMS data set Used in Chapter V Analysis

Key variables	Description	Values	Level
Dependent variables			
Body mass index (BMI)	Body weight (kg) divided by the square of height (meters)	Continuous positive numeric values	Individual
Body weight status	Three-category variable derived from BMI such that BMI < 18.5 coded as underweight; 18.5<=BMI<23 coded as healthy weight; and BMI >=23 coded as overweight	1= Underweight 2= Healthy weight 3= Overweight	Individual
Self-reported health	Self reported quality of current health	0 = Unhealthy 1= Healthy	Individual
Environmental predictors			
Salinity	Average level of salinity in drinking water sources. Conductivity of 2000 μS/cm or lower is coded as fresh; > 2000 μS/cm is coded as saline	0= Fresh 1= Saline	Community
Arsenic	Average level of arsenic in drinking water sources. Arsenic content of 10 μg/liter or lower is coded as fresh; >10 μg/liter is coded as contaminated.	0= Fresh 1= Contaminated	Community
Perceived environmental stress	Index measure created from a series of 10 questions on perceived environmental conditions.	Numeric values between 0-10	Household
Moderators			
Practical help	Practical support received in the past 12 months. Those who received support at least once every 1-2 months out of 12 months coded as 1; 0 otherwise.	0= None 1= Some or more	Individual
Emotional help	Emotional support received in the past 12 months. Those who received support at least once every 1-2 months out of 12 months coded as 1; 0 otherwise.	0= None 1= Some or more	Individual
Monetary help	Monetary or material support received in the past 12 months. Those who received support at least once every 1-2 months out of 12 months coded as 1; 0 otherwise.	0= None 1= Some or more	Individual

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