IMPACTS OF CLIMATE VARIABILITY AND CHANGE ON FISHERIES OF THE PADMA RIVER AND ADAPTATION STRATEGIES

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Fisheries

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Dedicated to my beloved

Father & Mother

Whose affection, inspiration and encouragement,
love and prays make me able to get such success

CERTIFICATE

This is to certify that this thesis entitled **"Impacts of climate variability and change on fisheries of the Padma river and adaptation strategies"** submitted by **Makidul Islam Khan**, has been carried out under my supervision. This is further to certify that it is an original work and suitable for partial fulfillment for the degree of MS in Fisheries, University of Dhaka.

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ABSTRACT

According to Global Climate Risk Index 2015, Bangladesh is one of the top ten vulnerable countries to the impacts of climate change. The Padma is the second longest and one of the trans-boundary rivers of Bangladesh that contributes significantly to the fisheries and supports the fishers livelihoods. It is assumed that the Padma river is already affected by the climate variability and change, but there is a lack of evidence on it and the adaptation strategies are unknown. This study assesses the livelihood characteristics, fishing activities, and impacts and adaptation strategies of climate variability and change on the livelihoods of the migratory and non-migratory fishers of the Padma river in Manikganj district, Bangladesh. Data were collected using household interviews, focus group discussions (FGDs), and key informant interviews during July to October, 2015. Climatic shocks and stresses and the impacts faced by the fishers were ranked based on household interviews and verified using FGDs. The results showed a better livelihood conditions of the migratory fishers than those of the non-migratory fishers. Although the non-migratory fishers useda diverse types of fishing boats and gear including nets, traps, hook.The rank order of climatic shocks and stresses (higher to lower impacts) were, storm>low rainfall>high temperature>low temperature>fog. On the other hand, the rank order of climatic impacts (higher to lower impacts) were, reduced availability of fish catch>destruction of fishing equipment's>riverbank erosion>physical injury>drought. Storm damaged fishing equipment and caused increased frequency of physical injury to the fishers which affected their fishing activities and, coping and adaptation strategies. Low rainfall in the rainy season and higher temperature in summer reduced the fish catch in the river. Riverbank erosion displaced the fishers and forced to change their livelihood strategies. The duration and intensity of low temperature and dense fog in winter had increased over the years hindering the fishing activities. This study also found that maladaptation due to unplanned construction of embankment for controlling riverbank erosionhas blockedthe migration of fish between river and floodplains resulting reduced fish catch. The common coping strategies of fishers were selling physical productive assets or livestock, reducing current consumption, employing their school going children in fishery related activities, temporary migration, taking loans, making sheds on their boats and in case of storms, taking shelter in the nearby canal (*ghop*). Adaptation strategies include embankment construction, permanent migration, livelihoodsdiversification, increasing fishing duration, use ofmore efficient fishing gears, using mechanized boat for fishing and tree plantation. This study found thatclimate variability and change hassignificant impact on the fisheries of the Padma river and the dependent livelihoods. The fishers' households are responding to these impacts. However, these are not sufficient to fully address the impacts.Thus, proper measures need to be taken at different levels to respond to these impacts.

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LIST OF ACRONYMS AND ABBREVIATION

As	:	Arsenic
BBS	:	Bangladesh Bureau of Statistics
BOD	:	Biological Oxygen Demand
BWDB	:	Bangladesh Water Development Board
CEGIS	:	Center for Environmental and Geographic Information Service
cm	:	Centimetre
DO	:	Dissolved Oxygen
DoF	:	Department of Fisheries
ed.	:	Edition
e.g.	:	Example
FAO	:	Food and Agriculture Organization
Fe	:	Iron
FGD	:	Focus Group Discussion
FRSS	:	Fisheries Resources Survey System
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
GOB	:	Government of the People's Republic of Bangladesh
ha	:	Hectare
Hg	:	Mercury
HP	:	Horse power
Hrs/day	:	Hours per day
i.e.	:	That is
iMACC	:	International Initiative on Maladaptation to Climate Change
IPCC	:	Intergovernmental Panel on Climate Change
kg	:	Kilogram
KII	:	Key Informant Interview
km	:	Kilometre
LGED	:	Local Government Engineering Department
m	:	Metre
mg/l	:	Milligram per litre

mm	:	Millimetre
NGO(s)	:	Non-governmental organization(s)
ppm	:	Parts per million
sq.km	:	Square kilometre
SIS	:	Small Indigenous Species
SPSS	:	Scientific Package for Social Sciences
SRS	:	Simple random sampling
Tk.	:	Taka
UNDP	:	United Nations Development Programme
UNFCCC	:	United Nations Framework Convention on Climate Change
US$	:	United States Dollar
WMO	:	World Meteorological Organization
%	:	Percentage
°C	:	Degree Celsius

CHAPTER 1 – INTRODUCTION

In Bangladesh with a total 3,548,115 metric tons (MT) fish production, inland capture and culture production is 2,952,730 MT (FRSS, 2015). The market value of 77,328 MT export fish and fishery products are 48.98 billion taka (DoF, 2015). It fisheries sector contributes 22.60% in agricultural sectors, 3.69% to Gross Domestic Product (GDP) and 2.01% to total export earnings (DoF, 2015).

Fisheries and aquaculture play important roles for food supply, food security and income generation all over the world from local to global levels. This sector was a source of income and livelihood to about 58.3 millions of people around the world in 2012 (FAO, 2014). Besides direct dependency, fisheries provides other economic activities generated by the supply of fish (processing, packaging, manufacturing, transport, distributions etc.) and supporting activities (boat building, net and gear making, engine manufacture and repair, ice production and supply, supply of services to fishers and fuel to fishing boats etc.) (FAO, 2005). World per capita apparent fish consumption increased from an average of 9.9 kilogram (kg) in the 1960s to 19.2 kg in 2012 (FAO, 2014). In the last five decades global fish production has grown steadily. In 2012 total 158 million MT world fisheries production, inland capture and culture productions are 11.6 and 41.9 million MT respectively (FAO, 2014) (Appendix 7- Supplementary tables1).

Bangladesh is world's 4th largest inland waters capture fisheries producing country (FAO, 2014) and one of the top ten in total aquaculture production (FAO, 2013). Rivers are considered as common pool resources (CPR) for the livelihoods of millions of fishers and non-fishers households across the country and includes a number of economic sectors i.e. agriculture, fisheries, industry and commerce (DoF, 2015). The major/principal rivers of Bangladesh are the Meghna, the Padma, the Jamuna, the Brahmaputra etc. In 2013-14 river fishery contributed about 167,373 MT fish which were 5.67% of the total inland water fish production of the country (FRSS, 2015). Besides that 2,695 kg carp hatchling (4-5 days old) were collected from all the rivers (natural sources) of Bangladesh in 2014 (FRSS, 2015). Additionally, these rivers provide spawning and nursery areas for different types of fish, amphibians, reptiles and a home for many wildlife species (Latifa *et al*., 2014). See Appendix 1 for details of river fisheries.

In the year of 2012-13, a total of 6,999 MT fish (Figure 1) were harvested from the Padma river which was 4.76% of the total fish captured from all the rivers of Bangladesh (FRSS, 2014). As well as from the Padma river in 2014, total 613 kg carp hatchling were collected which was 22.75% of the total natural hatchling production in all the rivers of Bangladesh (FRSS, 2015). In 2012-13 about 809 MT fish were caught in Manikganj district among the total fish catch in the Padma river. But in 2013-14, it decreased to 431 MT (FRSS, 2015).

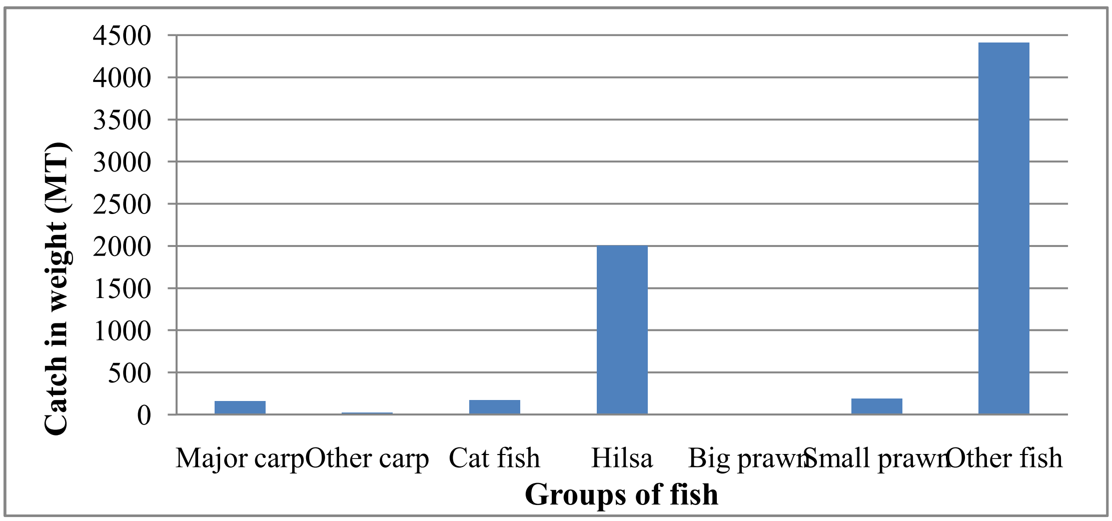


Figure 1: Group-wise annual fish catch of the Padma river (2012-13)

The groups include major carp (*Labeo rohita, Catla catla, Cirrhinus, cirrhosus*), other carp (*Labeo calbasu, Labeo bata, Labeo boggut*), catfishes (*Wallago attu, Mystus aor, Pangasius pangasius, Rita rita),* Hilsa *(Tenualosa ilisha)*, large prawn (Galda), small prawn (other small Chingri) and others (includes all other fishes except snake head (*Channa striata, Channa marulius, Channa punctata*), live fish (*Clarias batrachus*, *Heteropneustes fossilis*, *Anabas testudineus*), exotic carp and those mention above) (FRSS, 2014).

In Bangladesh, fisheries supports the livelihoods of about 17.8 million people (more than 11% of the total population) directly and indirectly (DoF, 2015). Fisheries are often available in remote and rural areas where other economic activities are limited and can thus be important sources for economic growth and livelihoods in rural areas with few other economic activities (FAO, 2005). Fisheries oriented activities (also termed as ancillary activities) provide numerous jobs to the fishers and fish farmers, such as processing, packaging, marketing and distribution, manufacturing of fish processing equipment, net and gear making, ice production and supply, boat construction and maintenance, research, development and administration (FAO, 2012).

1.1 Fishing activities

Fishing is the act of catching fish and shellfish in a variety of ways. The term "fishing activity" means any activity directly related to the catching or processing of fish or shellfish for initial commercial sale or as a principal means of personal subsistence (Heiderson and Edgar, 1996). Here the termfishing clearly refers to catching activities, which means all activities aiming at extracting wild fish from open waters (natural waters), as opposed to rearing of aquatic animals in controlled environments and with human intervention (stocking, feeding etc.). Fishing for commercial purposes means to sell fish in domestic and export markets but not for recreational purposes. Fishing is not just a livelihood activity but a way of life which determines social identity and relationships (Coulthard *et al*., 2011).

Fishing can be three types based on the motivation of fishing such as commercial (fishing for money), subsistence (fishing for food) and recreational (fishing for fun) (Craig *et al*., 1993). Since the fishers mainly depended on fishing for their income and nutrition, so their income varied with their capability and quantity of the capturing fish. The fishers can be classified into three groups depending on time involvement in fishing, such as full-time (9-12 months per annum), part-time (3-9 months per annum) and occasional (less than 3 months per annum) (Welcomme, 1983). While for the full-time group, fisheries are the sole source of their livelihoods, for part-time and occasional groups, fisheries form part of their diversified livelihood strategy (Allison and Ellis, 2001; Coulthard, 2008).

1.2 Migratory and non-migratory fishers

According to Chambers and Conway (1992), a livelihood can be defined as the capabilities, assets and activities required for means of living and it is only sustainable when it can cope with and recover from shocks and stresses maintain or enhance its capabilities and assets, while not undermining the natural resource base. DFID (1999) observed that people's livelihoods are fundamentally affected by seasonality, over which they have limited or no control. But in fisheries, climatic variability and changes as well as human activities for the past three decades have adversely affected the ecosystem, which are critical for breeding, nursery, feeding, growth and migration to both inland and marine finfish and shellfish species (Fregene, 2007). In some water bodies the economic impact of excessive fishing effort exploiting fish stocks, leave fishers and their dependents potentially with an ever-declining source of income. A bleak future faces the rural fisherfolk as they face the likelihood of losing their livelihood over time. Due to the constant reduction in fish stocks, the last options for the improvement of their livelihood conditions entails to migrate to other areas within or outside the country (Fregene, 2007).

Migration means the movement of people from one geographical area to another for the purpose of taking permanent or semi-permanent residence, whereas seasonal migration is the periodic movement of a population from one region or climate to another in accordance with the yearly circle of weather and temperature changes (Usman *et al*., 2011). Seasonal migration is often undertaken to improve the socio-economic status of the households. In the 1970s, Nelson (1976) first articulated the idea of seasonal migrations. The main reason why fishers migrate is because of the seasonal migration of fish catch (Usman *et al*., 2011). So based on the migration to other area fishers can be two types such as migratory (see Appendix 2 for details of migratory fishers) and non-migratory/local fisher.

1.3 Climate variability and change

Climate change has been recognized as one of the foremost environmental problems of 21st century. Climate change is the variation in the earth's global climate or in regional climates over time and it involves changes in the variability or average state of the atmosphere over durations ranging from decades to millions of years (Mohanty *et al*., 2010). The United Nations Framework Convention on Climate Change (UNFCCC) uses the term 'climate change' for human-caused change and 'climate variability' for other changes (Mohanty *et al*., 2010). Climate change will affect ecosystems and human systems like agricultural, transportation and health infrastructure and increasing pressure on all livelihoods and food supplies (Mohanty *et al*., 2010). World's 250 million fishers, fish workers and their dependents are living in areas that are highly exposed to human-induced climate change, and their livelihood dependent resources whose distribution and productivity are influenced by climate variation (Allison *et al*., 2005).

1.3.1 Definition of climate variability and change

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes etc.) of the climate on all temporal and spatial scales beyond that of individual weather events (IPCC, 2007). Variability in climate had been regarded as natural internal processes within the climate system (internal variability) but over the past few decades anthropogenic external forcing (external variability) has compounded this variability in climate (IPCC, 2007).

Climate change refers to any change in climate over time as a result of natural variability or human activity (IPCC, 2007). The UNFCCC makes a distinction between climate change attributable to human activities altering the atmospheric composition where climate variability attributable to natural causes (IPCC, 2007). Climate change differs from climate variability in the sense that the former is a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period, typically decades or longer (IPCC, 2012). According to World Meteorological Organization (WMO) climatic averaging period is 30 years.

Climatic issues such as increase in temperature, changes in precipitation, increase in flooding, changes in storms and cyclones, increase in drought, changing in seasonal variability and rise in sea level have impacts on natural and human systems in various ways (IPCC, 2007). Global mean precipitation is predicted to increase, with an increase in tropical regions but a decrease in the subtropics (IPCC, 2007). More precipitation will cause more flooding but in areas where mean precipitation will decrease can cause greater risk of drought in those regions (IPCC, 2007).

Climate variability and change not only created unprecedented impacts on natural and human systems, but also predicted that in future it will do more (Islam *et al*., 2014). These impacts are classified as potential impacts (without considering adaptation, all the impacts that might occur within a projected change climate) and residual impacts (the impacts of climate change that would occur after adaptation) (IPCC, 2007). These impacts can range from changes in ecosystems and fish stocks (IPCC, 2007; Cheung *et al*., 2009; Brander, 2010; Drinkwater *et al*., 2010) to damage in fishery methods, and land-based property and infrastructure (Westlund *et al*., 2007; FAO, 2008). These have the potential to make fishers and their livelihoods more vulnerable (Islam, 2013).

1.3.2 Climate variability and change in Bangladesh

Bangladesh is regarded as one of the most vulnerable countries to the impacts of climate change where vulnerability is the degree to which a system is susceptible to, and unable to cope with against the adverse effects of climate change, including climate variability and extremes (IPCC, 2012). As well as Bangladesh also experiences various disasters such as storms, tropical cyclones, storm surges, coastal erosion, floods and droughts that causing heavy loss of life and property and jeopardizing the development activities (Dastagir, 2015). In the Global Climate Risk Index (CRI), Bangladesh ranked 6th position among 170 countries (Table 1), that are most vulnerable to climate change from 1994 to 2013 (Kreft *et al*., 2014).

Table 1: The Long-Term Climate Risk Index (CRI) ranking(Adapted from Kreft *et al*., 2014)

CRI 1994–2013	Country	CRI score	Deaths per 100,000 inhabitants	Losses per unit GDP in %	Number of Events (total 1994–2013)
1	Honduras	10.33	4.60	3.30	69
2	Myanmar	14.00	14.80	0.87	41
3	Haiti	16.17	3.41	1.86	61
4	Nicaragua	16.67	2.98	1.71	49
5	Philippines	19.50	1.13	0.74	328
6	Bangladesh	20.83	0.54	1.20	228
7	Vietnam	23.50	0.48	1.01	216
8	Dominican Republic	31.00	2.38	0.37	54
9	Guatemala	31.17	0.68	0.62	80
10	Pakistan	31.50	0.31	0.77	141

An increase in temperature of about 1°C in May and 0.5°C in November (from 1985 to 1998) has found in Bangladesh (Mirza, 2002). In Bangladesh projected temperature would rise 1.3°C by 2030 (over mid-20th century levels) and 2.6°C by 2070 (Agrawala *et al*., 2003). In coming decades, Bangladesh will experience a mixture of climate variability and change (some data are shown inTable 2). Greater variation in temperature and rainfall has been predicted compared to the past. In contrast, rainfall is predicted to decrease in winter (Dastagir, 2015; Anik and Khan, 2011) and may increase in summer (Agrawala *et al*., 2003).

The Met Office (2011) projects 3 to 3.5°C increase in temperature in Bangladesh and 20% increase in precipitation in the north of the country with increases of 5-10% more typical through the rest of the country by 2100 under A1B (higher) emissions scenario of IPCC. With a global temperature rise of 2°C, the flooded area in Bangladesh will rise by at least 23-29% more than today (Mirza, 2003).

Table 2: Future climate change scenarios for Bangladesh(Adapted from Agrawala *et al*., 2003; Mirza, 2003; Islam *et al*., 2014)

Year	Mean temperature change (°C)			Annual Rainfall change (%)	Cyclone (% increase of wind speed)	Sea level rise (cm)
	Annual	December, January, February	June, July, August			
Baseline average				2278 mm		
2030	+1.0	+1.1	+0.8	+3.8		14
2050	+1.4	+1.6	+1.1	+5.6		32
2100	+2.4	+2.7	+1.9	+9.7	10-25	88

Both Ganges and Brahmaputra rivers rise in the Himalaya-Tibetan Plateau region where glaciers are melting rapidly and for that Bangladesh faces an additional hydrological challenge. Though Bangladesh occupies only 7% of the combined catchment area (Appendix 1- River fisheries of Bangladesh) of the Ganges-Brahmaputra-Meghna river basin, the country has to drain out 92% of the flow into the Bay of Bengal. Two-thirds of

Bangladesh is less than 5 m above sea level, making it one of the most flood prone countries in the world which causes significant damage to crops and property as well as severe adverse impacts on rural livelihoods (Dastagir, 2015).

Analysis of past flood records indicates that about 21% of the country is subject to annual flooding and an additional 42% is at risk of floods with varied intensity (Ahmed and Mirza, 1998). Every four or five years, a severe flood occurs during the monsoon season that submerging more than three fifths of the land (GOB, 2009). The most recent exceptional flood which occurred in 2007, inundated 62,300 sq. km or 42% of total land area, causing 1,110 deaths and affecting 14 million people; 2.1 million ha of standing crop land were submerged, 85,000 houses completely destroyed and 31,533 km of roads damaged (BWDB, 2007).

Bangladesh is also a global hot spot for tropical cyclones (UNDP, 2004). Nearly every year, cyclones hit the country's coastal regions in the early summer (April-May) or late rainy season (September-October) (Dastagir, 2015). There is some evidence that regional frequencies of tropical cyclones (storms) peak intensity may increase (Goodess, 2013)/may increase by 5% to 10% (IPCC, 2001) but there is still uncertainty whether the frequency of cyclones will change (IPCC, 2007).

The dangerous features of the storms may injure or kill peopleand animals, start fires in buildings or vegetation, flood fields and communities, damagebuildings, destroy crops, blow down trees, and disrupt communications(Schmidlin, 2009).Based on intensity, storms can be as moderate storms (tropical storms) winds speed of 34-47 knots, severe storms (48-63 knots) and very severe storms (64-119 knots) while minor storms have less than 34 knots winds speed (adapted from WMO, 2012). Storms can also include lightning, large hail, heavy rains and thunder storms (Schmidlin, 2009). Thunder storms are known as nor'westers (Kalbaisakhi) in Bngladesh (Schmidlin, 2009) that usually hit in May-April.

The south-western coastal region of Bangladesh is highly prone to cyclones, coastal flooding and salinity, which causes huge losses to agriculture production and rural livelihoods (Ullah and Rahman, 2014). In the north-eastern region of Bangladesh, the major climatic events were temperature change, drought, heavy rainfall, cyclone and storm surges and the main livelihood problems arising from those events were lack of fish availability, scarcity of water in drought seasons and frequent flood in the rainy seasons (Anik and Khan, 2012).

Land erosion is a regular and recurring phenomenon in Bangladesh. The invariable threat of riverbank erosion was contributed to a substantial disaster subculture in the riverine zones of Bangladesh (Mtton and Haque, 2004). More riverbank erosion occurred in winter seasons when water level became lower in the river (Anik and Khan, 2012). As a result of riverbank erosion about one million people become affected directly or indirectly every year (Islam and Rashid, 2011).

There is evidence that droughts will intensify in the 21st century in some seasons and areas, due to reduced precipitation and increased evapotranspiration (Seneviratne *et al*., 2012). Drought prone areas in Bangladesh under climate change scenario projections already affected by low rainfall in the dry season that reduce available flows in rivers (Dastagir, 2015).

1.3.3 Impacts of climate variability and change on fisheries of Bangladesh

The fisheries sector of Bangladesh is one of the most vulnerable to climate change in the world (Figure 2) and the projected climate change may directly impact on the fish stocks and on the livelihoods of the fishery-dependent people. (Allison *et al*., 2009a). The fishers of Nijhum Dwip in Noakhali district of Bangladesh had lived in an extremely dynamic environment facing tropical cyclones, tidal surges, embankment erosion and salinity intrusion that affected their life and livelihood options (Hossain *et al*., 2013).

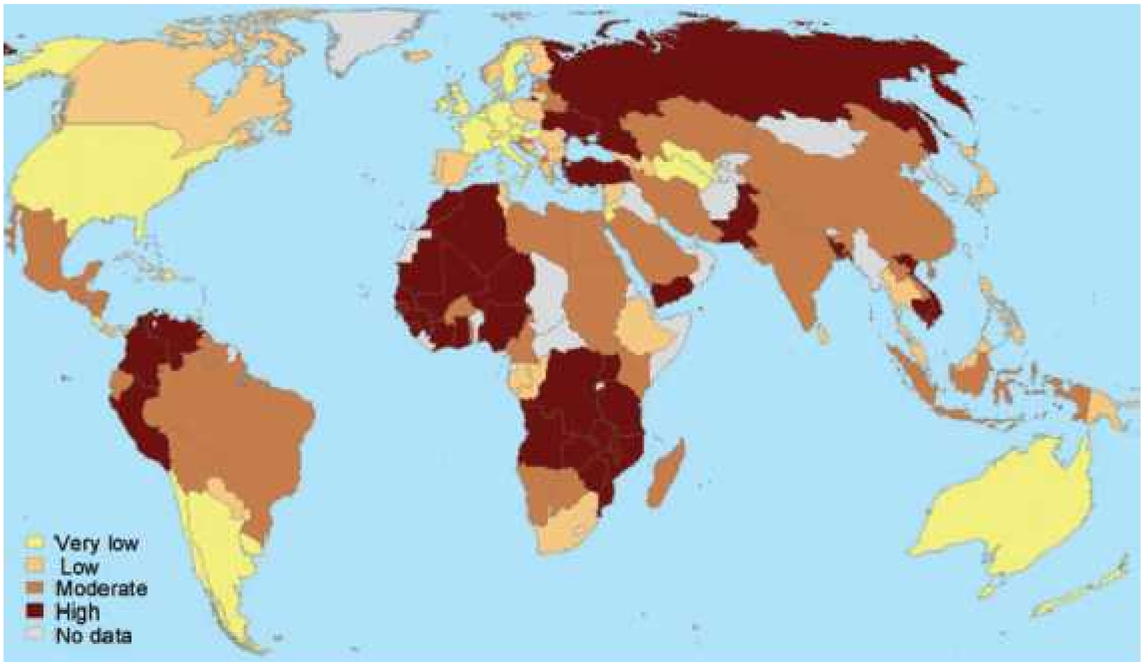


Figure 2: Vulnerability of national economies of potential climate change impacts on fisheries (Allison *et al.,* 2009a).

In the short term, climate change is anticipated to affect freshwater fisheries through incremental changes in water temperature, storm frequency and intensity, high evaporation and lower rainfall (Allison *et al*., 2009a). Low rainfall can reduce the level of water body and water flow in river, which can increase droughts and can reduce river productivity. As well as higher water temperatures can change in sex ratios, alter time of spawning and migrations which has possible impacts on timing and levels of productivity on fresh-water systems (Allison *et al*., 2009a). Figure 3 shows the climate-induced changes in inland fisheries systems.

Decreased rainfall in rainy season and high temperature in summer also result in low level of water body that finally can reduce opportunities for fishing and aquaculture as part of rural livelihood systems and reduce diversity of rural livelihoods (Allison *et al*., 2009a). Increased frequency of storms and cyclones can increase risks for fishing and inland fish farming and make it less viable livelihood options for the poor (Allison *et al*., 2009a). Their important livelihood assets such as boats and gears are more exposed to storms and cyclones which can easily lost than land-based property (Westlund *et al*., 2007).

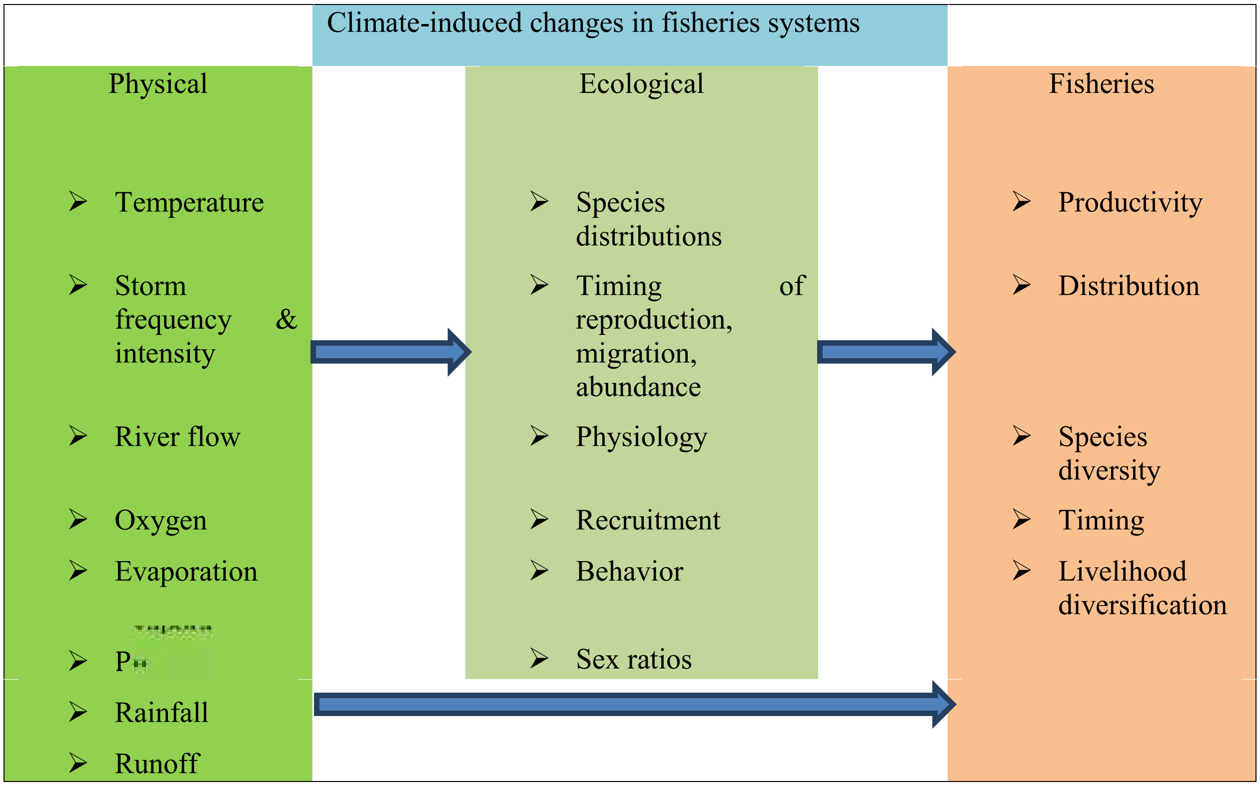


Figure 3: Climate-induced changes in inland fisheries systems (Adapted from Allison *et al*., 2009a)

Climate change can reduce the amount of fish production in Bangladesh (Ali, 1999; Ahmed *et al*., 2002). Tremendous impacts on fishing assets, infrastructure and ultimately on the livelihoods of fishing communities may be exerted from cyclones and associated floods (Islam *et al*., 2014).

Climate change poses new challenges to the sustainability of fisheries and aquaculture systems. The productivity, distribution and seasonality of fisheries and the quality and availability of the habitats that support them, are sensitive to these climate change effects (World Fish Center, 2009). In addition, many fishery-dependent communities and aquaculture operations are in regions highly exposed to climate change. Climate change stresses will compound existing pressure on fisheries and aquaculture and threaten their capacity to provide food and livelihoods.

1.3.4 Impacts of climate variability and change on the Padma river fisheries

In winter season, the rate of water flows decreases and during summer the flow is very less as well as a result of continuous siltation permanent sand bars (island or chars) are formed (Islam, 2004). Similarly Bhuiyan *et al*. (2008) also reported that as a consequence of climate change the water temperature of the Padma river has increased that caused reduction of water flow and as a result spawning and nursing grounds of fishes have been drastically affected in recent years. But in dry season (October-April), the Padma flows at less than a quarter of its capacity and water flows in the downstream network of rivers, which often stops altogether and it is insufficient to wash tidal water back out to sea (Vineis *et al*., 2011).

Abundance and biodiversity of fish and other aquatic species in the Padma river has declined over time (Rahman *et al*., 2012; Mohsin *et al*., 2013). Use of illegal fishing nets (such as current jal) is a major problem which badly affects the overall fish production. One of the most important reasons for declining fish abundance and diversity is anthropogenic impacts especially destruction of natural habitat (Mohsin *et al*., 2013).

1.4 Coping and adaptation strategies

To cope with the climatic impacts fishers have taken both coping and adaptive strategies. Coping means the use of existing resources to achieve various desired goals during and immediately after unusual, abnormal and adverse conditions of a hazardous event or process (Agrawal, 2010). The term coping strategies focuses on the micro level. The important notion of the definition of a coping strategy is that the strategy should not only function during extreme or adverse conditions, it should also function during normal times. Consequently, a coping strategy should be in place and function also prior to the occurrence of any weather hazards (UNISDR, 2009).

Adaptation is the actions and adjustments undertaken to maintain the capacity to deal with stress induced as a result of current and future external changes (Agrawal, 2010). By adjustment is meant a system's ability not only to moderate potential damages and consequences, but also to work with potential opportunities that may arise from climate change. Primarily a system's means of adjustment are linked to adjusting national behavior, use of resources and technologies (IPCC, 2007).

Adaptation strategies (see Appendix 2 for details) by its nature is not a single response, but action taken over time, whereas coping strategy clearly is a collection of short-term responses. However, it is important to note that a short-term response (coping) can overlap and develop into long-term strategies (adaptation) over time (Berkes and Jolly, 2002).

The main difference between the coping and adaptation strategies is that coping is the short term, flexible strategies which fishers often adopt to survive in a unpredictable livelihoods, whereas adaptation is the long term strategies, more permanent livelihood change and adaptation occurs when coping strategies become permanently incorporated into the normal cycle of activities (Coulthard, 2009).

To cope with the climatic impacts on fishery-based livelihoods adaptation strategies is important. Adaptation strategies can reduce vulnerabilities of fishing and fish farming and diversify inland fishery-based livelihoods (Cochrane, 2009).

1.5 Maladaptation

Adaptation is classified as maladaptation or successful/effective/sustainable adaptation based on its failure or success. Maladaptation can be defined as the "action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups" (Barnett and O'Neill, 2010). iMACC defined maladaptation as "an adaptation process that results in increased vulnerability to climate change and/or undermines capacity for future adaptation."

Adaptation can also be unsuccessful, which does not necessarily mean that harm is done. It could mean that something 'just didn't work'. But there are instances of unsuccessful adaptation that result in people being worse off than before. This is what would be called as maladaptation.

Tompkins *et al*. (2005) argue that maladaptation occurs as the result of miscalculating climate impacts. The authors present maladaptation scenarios caused by various estimation errors on impacts, using coastal infrastructure projects as example. Although telling examples, it does take a rather narrow/technical view of maladaptation.

In other reports, authors see maladaptation as the failure to account for the myriad of systems and feedbacks between sectors and groups, which in turn can lead to poor decisions on adaptive responses (Scheraga *et al*., 2003; Satterthwaite *et al*., 2007; Pittock, 2011). This extends to interactions with ecological systems, i.e. short term agricultural solutions resulting in the decrease of farmers' adaptive capacity in the long run (World Bank, 2010).

Davis (2014) takes a 'do no harm' approach to maladaptation, processes to define strategies and programs to build climate resilience should always incorporate an assessment of their potential negative impacts. In cases where potential harm is identified, measures to substantially reduce or remove it should be built into the strategy and program design. To avoid creating a false sense of security, or promoting maladaptation, programs should always be based on a multi-hazard, multi-effect assessment.

What becomes clear is that there isn't one definition of maladaptation, though authors agree there to be an increase in vulnerability and a decrease in adaptive capacity or willingness to adapt when maladaptation is discussed.

For example, the increasing flooding level due to climate change may be tackled by the agriculture sector taking adaptive strategies such as construction of more flood control, drainage and irrigation schemes. However, these structures may create negative consequences for fisheries. Studies of such schemes in Bangladesh found that fish production can be 50% lower inside flood control schemes compared to outside mainly because of diminished recruitment of migratory fish (Halls *et al*., 1998; Halls *et al*., 2008). Osbahr *et al*. (2010) found that adaptation by individuals may have negative spill-over effects at the community level. Therefore, an action that is successful for one may be classed as unsuccessful by another. Successful or sustainable adaptations are those measures that reduce vulnerability and promote long-term resilience in a changing climate (O'Brien and Leichenko, 2007). The success of an adaptation strategy depends on how that action meets the objectives of adaptation, the scale of implementation and the criteria used to evaluate it

(Adger *et al*., 2005a). Climate change-induced displacements and migration may result in negative outcomes or maladaptation (Reuveny, 2007).

Policies and practices that are unrelated to climate but which do increase a system's vulnerability to climate change are termed "maladaptation" (Burton, 1996; Burton, 1997). Examples of maladaptation in coastal zones include investments in hazardous zones, inappropriate coastal-defence schemes, sand or coral mining and coastal-habitat conversions. A common cause of maladaptation is a lack of information on the potential external effects of proposed developments on other sectors, or a lack of consideration thereof. More proactive and integrated planning and management is widely suggested as an effective mechanism for strengthening sustainable development (e.g., Cicin-Sain, 1993; Ehler *et al*., 1997; Cicin-Sain and Knecht, 1998) and can be both environmentally sound and economically efficient (Tol *et al*., 1996).

1.6 Research gaps

In this chapter the key terms of the thesis' objectives are explained. After reviewing literature that identifies impacts of climatic variability and change on fishers and their adaptation strategies to climate variability and change are found important research areas, especially at the local scale of small-scale fishery systems in the Padma river, Bangladesh.

Most studies on climate variability and change, and fisheries, have focused on documenting trends and fluctuations in fish abundance and distribution, and its impact on the marine ecosystem that are mainly focused on large-scale industrial fisheries (Cushing, 1982; Kliashtorin, 2001; Yanez *et al*., 2001; Glantz, 2005; Kell *et al*., 2005; Lehodey *et al*., 2006; Cheung *et al*., 2009; Brander, 2010; Drinkwater *et al*., 2010).

Some of the studies have investigated the impact of climate change on the vulnerability and adaptive capacity of the fisheries sector and dependent communities at the macro scale (e.g., national) (Sadovy, 2005; McClanahan *et al*., 2008; Allison *et al*., 2009b). But macro scale study cannot provide specific findings applicable to the local or community level (Hahn *et al*., 2009; Allison *et al*., 2009b). The problem is particularly acute for small scale and subsistence fishers, who tend to be overlooked in national censuses or aggregated into and hidden within the agricultural sector (Sadovy, 2005; Andrew *et al*., 2007).

There are agriculture-based vulnerability and adaptation assessments to climate change at the global and regional level (Fischer *et al*., 2005; Parry *et al*., 2005; Howden*et al*., 2007; Schmidhuber and Tubiello, 2007; Vincent, 2007; Eakin and Bojórquez-Tapia, 2008; Paavola, 2008; Sallu *et al*., 2010; Antwi-Agyei *et al*., 2013), which are different from fishery-based ones.

Risks are apparent in agriculture, fisheries and many other components that constitute the livelihood of rural populations in developing countries (Adger *et al*., 2003).With mounting evidence of the impacts of climate variability and change on aquatic ecosystems, the resulting impacts on fisheries livelihoods are likely to be significant, but remain a neglected area in climate adaptation policy (Badjeck *et al*., 2010). Nevertheless, until recently there has been little directed analysis at the local scale of how climate variability and change is affecting the lives and livelihoods of the fishers (Coulthard, 2008; Badjeck *et al*., 2010).

In Bangladesh climate variability and change have the potential to make fishers livelihood more vulnerable, but they are only occasionally investigated in the context of agricultural sector (Anik and Khan, 2012; Ullah and Rahman, 2014) and in respect of coastal regions of Bangladesh (Hossain *et al*., 2013; Islam *et al*., 2014) but the impacts on inland fishery-based livelihoods and adaptation strategies have not been evaluated.

A detailed study on how fishers are vulnerable to past and current climate impacts can provide important insights to address the enhanced level of future impacts or reduce vulnerability for them. Fishers' adaptation strategies are also very important to assess. So a study has to be conducted to assess the impacts of climatic variability and change on the Padma river fishers and their adaptation strategies to overcome the impacts. With these understanding about the impacts and adaptation of the Padma river fisheries dependent communities, it will be possible to develop appropriate policies and strategies to reduce the impacts and enhance sustainable adaptation for them. This will ultimately play a significant role in poverty reduction of the dependent people and sustainable development of the country, more broadly.

1.7Research aim and objectives

The aim of this study was to investigate the livelihood characteristics, fishing activities, and impacts and adaptation strategies of climatic variability and changes on the livelihoods of the fishers of the Padma river in Manikganj district, Bangladesh.

The objectives of the study were:

i. to compare the livelihood characteristics and fishing activities of migratory and non-migratory fishers of the Padma river;
ii. to assess the impacts of climate variability and changes (especially storms) on the fishing activities of the fishers of the Padma river; and
iii. to assess the adaptation strategies to overcome the impacts of climate variability and changes of the fishers of the Padma river.

CHAPTER 2 – STUDYSITES, MATERIALS AND METHODS

This chapter contains the research methodology of the study including study area selection, sample size determination, researchdesign, methods for data collection, and data processing and analysis.

2.1 Selection of the study sites

Two villages (Andharmanik and Dhulsura) (Figure 4) under Harirampur upazila in Manikganj district were selected as study sites based on the criteria of the vulnerability due to climate variability and changes and fisheries dependency on the Padma river.

Manikganj is one of the highly vulnerable districts in Bangladesh (Islam *et al*., 2013a). Both the study sites are located on the bank of the Padma river and they experience various climatic events (such as riverbank erosion, storm, riverine floods, drought, dense fog etc.) every year. About 2.77% people of Harirampur upazila depend on fishing for their livelihoods (BBS, 2001) and the Padma is the main source of fishing. But the Padma river is already affected by climate variability and changes (Islam, 2004; Bhuiyan *et al*., 2008; Vineis *et al*., 2011). All this impacts affected the Padma river fishers' lives and livelihoods. The study sites are located about 70 km far from Dhaka city and it takes about 4 hours to reach the study sites from Dhaka by bus.

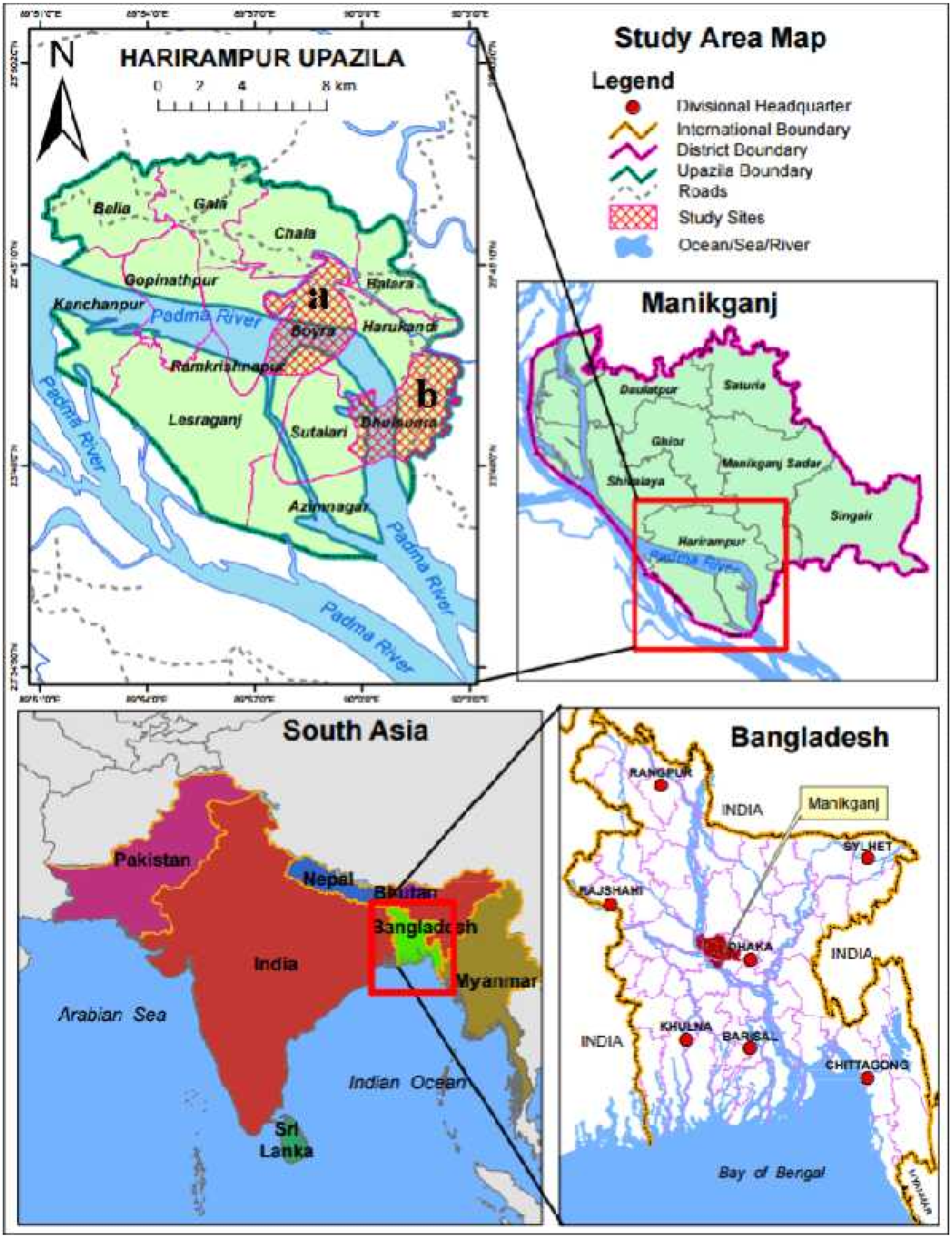


Figure 4: Map of the study sites under harirampur upazila: a) Andharmanik within Boyra union and b) Dhulsura within Dhulsura union

2.2 The study sites

2.2.1 Descriptions of the two study sites

Harirampur upazila is the largest upazila of Manikganj district. It is located in between 23°38' and 23°48' north latitudes and in between 89°50' and 90°03' east longitudes. It is bounded by Shivalaya, Ghior and Manikganj sadar upazilas on the north, Char Bhadrasan and Faridpur sadar on the south, Manikganj Sadar, Nawabganj (Dhaka) and Dohar upazilas on the east, Shivalaya, Goalandaghat and Faridpur Sadar upazilas on the west. Main rivers are the Padma and Ichamati and main depressions are Bhatsala and Gharilpur beels.

The area of Harirampur upazila is 245.42 sq. km with 171,274 population and literacy rate 48.4% (BBS, 2011). Main sources of income from agriculture 54.54%, commerce 13.73%, service 13.18%, fishing 2.77%, non-agricultural labourer 2.68%, rent and remittance 2.56%, transport and communication 2.43%, construction 1.80%, industry 1.23%, religious service 0.27% and others 4.81% (BBS, 2001). The two study sites are separately described below:-

Andharmanik

Andharmanik is situated on the northern part of the Padma river in Boyra union. It is a home of 4.161 people with 982 households. The physical infrastructure of Andharmanik is poor. In Andharmanik 89.8% households are earthen (BBS, 2011). According to local government engineering department (LGED), there is 9.69 km paved road in total 18.42 km road and the rest is earthen (data were collected from Harirampur upazila LGED) that become muddy during rainy season and are dusty when there is no rain. Both roads and waterway transportation used as the mode of communication.

In Andhamanik the literacy rate was 68.6% (BBS, 2011). The households are involved in various livelihood strategies such as fishing, agriculture, driving vehicles, fish trading, boat making, farm labouring, household working, firewood selling, grocery shop keeping, cattle rearing, investing money in informal loan systems and fish culturing (from reconnaissance study).

There has two primary school (1 governmental and 1 non-governmental), one high school (non-governmental), one madrasa. Harirampur upazila which is about 2 km away from Andharmanik, most of the government offices are located there. In Andharmanik, 200 years old Andharmanik bazar which is located about 200-300 m away from the Padma river. Harirampur upazila rest house (governmental), Harirampur police station and two NGOs are also located there.

One public and one private hospital are located in Horirampur upazila which is 1.30-2 km away from Andharmanik. In Andharmanik bazar three local pharmacies are found where some common medicines are available.

In the study site, there has no access to piped water supply. Most of the people used tube-well water for drinking (BBS, 2011) that contains harmful arsenic (As) (from reconnaissance study). Tube-well water also contains iron (Fe). So people use locally filtered river water of uncertain quality for household works. There is a good source of As free deep tube-well water available in Andharmanik bazar. In Andharmanik 53.3% households have electricity access (BBS, 2011).

The households are affected by various climatic variability and changes. This study area with other villages of Manikganj district were severely affected by the 1988 (Islam and Sado, 2000)and 2004 floods (Shoji, 2010) that caused a great loss to the households.After the heavy flood of 2004, most of the flood-hit people in this study area were in acute crisis of food and many of them were suffering from water-borne diseases (from reconnaissance study).

Every year few storms (including very severe storms) hit the study area (from reconnaissance study). The nor'westers (*Kalbaisakhi*) usually hit in the study area in May-April (from reconnaissance study). The most devastating tornado that hit the Manikganj district, killing 800 people (Karim, 1995; Paul and Bhuiyan, 2004). This study area is also located in the drought-prone district of Manikganj (Islam *et al*., 2013a) that severely affect livelihoods opportunities of the people in this area.

River bank erosion is a regular phenomenon in the Padma river. As a result Harirampur upazila is a victim of it. In 2007 and 2008, Bangladesh Water Development Board (BWDB) built 1800 m long embankment in Andharmanik for Tk.200 million in two phase to protect the upazila town from the Padma riverbank erosion. But recently it is already affected by the Padma riverbank erosion which threatening the upazila complex compound, upazila health complex, police station, rest house and 200 years old Andharmanik bazar.

Dhulsura

Dhulsura is situated on the eastern part of the Padma river in Dhulsura union. Dhulsura is a home of 992 people with 254 households. The physical infrastructure is very poor comparing to Andharmanik as 98.0% households are earthen (BBS, 2011). According to LGED, it has only 1.05 km paved road in total 15.34 km and the rest of larger portion (14.29 km) is earthen (data were collected from Harirampur upzila LGED)that become muddy during rainy season and are dusty when there is no rain. In Dhulsura due to the bad conditions of the roads throughout the year, transportation facility cannot develop. From Ghoshayl bazar, it takes about 40 to 45 minutes to reach Dhulsura by walking. Waterway transportation is the main mode of communication in Dhulsura (from reconnaissance study).

In Dhulsura the literacy rate was 57.9% (BBS, 2011). There has two primary school (non-governmental) which are the only formal educational institutions. There has no governmental office, public or private hospital. People with medical needs visit the nearby town Bandura which is about 25 km away from Dhulsura. Some common medicines are available in local pharmacies in Ghoshayl bazar which is about 1.30 km away from Dhulsura. Only one small bazar with three tea stalls, five groceries, two tailors, one electronic, one mosque and one temple are there.

In the study site, there has no access to piped water supply. People (92.1%) used tube-well water for drinking (BBS, 2011) that contains harmful arsenic (As) (from reconnaissance study). Tube-well water also contains iron (Fe). So people use locally filtered river water of uncertain quality for household works. In Dhulsura 30.2% households have electricity access (BBS, 2011).

All the impacts of climatic variability and changes are somewhat similar with the study site of Andharamnik as they are located in the same geographical area. But the main differences is that the riverbank erosion is very devastating in Dhulsura than Andhamanik and there has no embankment for controlling river bank erosion (reconnaissance study).

2.2.2 Description of the Padma river

The Padma (Figure 5) is the second longest river in Bangladesh (Hossain *et al*., 2005). It is the main distributary of the Ganges which originates in the Gangotri Glacier of the Himalayan. The part of the Ganga in Bangladesh is known as the Padma which enters Bangladesh from India (Murshidabad district) at Shibganj Upazila (Manakosha and Durlavpur unions) of Chapai Nawabganj district. Its length in Bangladesh is 366 km (Hossain *et al*., 2005). The Padma is joined by the mighty Jamuna (lower Brahmaputra) and the resulting combination flows with the name Padma further east, to Chadpur. Here the widest river in Bangladesh, the Meghna, joins the Padma, continuing as the Meghna almost in a straight line to the south, ending in the Bay of Bengal. Main stream goes through Chapai Nawabganj, Rajshahi, Pabna, Kushtia, Faridpur, Rajbari and Chadpur districts of Bangladesh. But the river from Goalanda to Chadpur is named Padma which is 120 km long and 4-8 km width and the river flows from Chapai Nawabganj to Goalanda, is the Ganga (Banglapedia, 2004).

According to Islam and Hossain (1983), there were 110 species of fishes under 59 genera, 28 families, 12 orders and 2 classes. But recent studies have revealed that the diversity of fishes has decreased in the river. Bhuiyan *et al*. (2008) recorded only 73 species of fishes (under 44 genera, 22 families, 10 orders and 2 classes) and 11 non-fish species (under 4 classes). In another research, Samad *et al*. (2010) recorded 57 small indigenous species (SIS) of fishes under 23 families and 11 orders.

Figure 5: Map of the Padma river in Bangladesh (Highlighted in the rectangular box)

2.2.3 Fisheries in the study sites

In this study the household who directly depends on the Padma river fishing to support their family are considered as fishers and depending on their standard fishing practice, they are categorized into three groups such as professional (who depended on fishing almost year round for their livelihood), occasional (who used to fish during a part of the year as income earning) and subsistence (who used to catch fish for their own consumption only).

Both the study sites are located at the bank of the Padma river in Harirampur upazila. So the fishers who are directly depend on the Padma river for their livelihoods, are living nearby the river bank. The fishers are live in together and the place where they live is known as "*Majhi Para*" or "*Jele Para*" or "*Halder Para*" or "*Rajbongshi Para*". All the fishers primary occupation is fishing in the Padma river. Some of the fishers have alternative livelihood options besides fishing such as fish trading, agriculture, daily labour, auto driving and firewood selling.

There are two main fishing seasons: rainy (May to September) and winter (November to February). In this seasons, the fishers fishing about 10 to 16 hours per day, although there are a few days (during rough weather, physical weakness etc.) within which fishing does not take place. But usual fishing duration is 6 to 12 hours per day. When the fishers get more fish, their fishing duration is extended. During the other three months of the year (March, April and October), the fishers does not fishing or reduce their fishing duration per day due to the occurrence of the local severe storms. The frequency of devastating nor'westers (*Kalbaishakhi*) usually reaches the maximum in April. So in that time the local fishers repair their fishing boats, nets and traps and migratory fishers go back their home.

Both study sites have *"Arat"* (fish auction centre) at the bank of the Padma river. To keep fresh or avoid spoilage, all the fishers of the Padma river brought their catches to the nearby *arat* to sell. But the fishers who have taken "*Dadon*" (advance money) from "*Aratdars*" (commission agents) or "*Mohajons*" (money lenders) through informal loan system, are bound to brought their catches to the respective *aratdar*/*mohajon*. In the arat a small portion of fish (known as "*Khoraki*" fish) are kept by the *aratdar*/*mohajons* as commission. In both the study sites 5% commission are kept from the fishers on their catches.

2.2.4 Migratory fishers in the study sites

In this study migration means seasonal or periodic movement of the fishers from one region or climate to another in accordance with the movement of fisheries or for better fishing activities. Fishers seasonal migration is often undertaken to improve the socio-economic status of the household or fulfillment of their occupation. So based on the migration to other area fishers are known as migrants/migratory fishers and those who do not migrate, they are known as non-migratory/local fishers.

The migratory fishers are come from different districts of Bangladesh mainly Sirajgani, Pabna, Barisal, Jamalpur, etc. for fishing in the Padma river in Manikganj district. A group of 8-12 members in a large mechanized boat (HP 8.5) with fishing equipment's migrate from one area to another for fishing. Each group of migratory fishers has a leader who is known as "*Mohajon*" and usually he takes most of the decisions on the boat during fishing.

The migratory fishers generally use large seine and gill net for fishing except any fishing traps, spears, lines and hooks. Depending on their fish catch, they usually stay one area for one to two months or more, otherwise migrate to another area. Similarly their fishing duration per day varies 12-16 hours depending on their catches. In Dhulsura,this study found about 8-9 migratory fishing boats who were come from different districts.

The migratoty fishers usually set their nets in the river in early morning after selling their catches in the nearby *arat*. The money gets after selling fish is equally distributed to all members but if one has more share (owner of the boat/nets), then he gets money in proportionate to his share. Generally they stay on the boat throughout day-night.

2.3 Data Collection

Both primary and secondary data were collected through mixed method approaches for the study. Quantitative methods (e.g., semi-structured interview) were used for collecting data on context, whereas qualitative methods (e.g., FGDs and Key Informants Interviews) were used to get rich, detailed and contextually grounded data (Nightingale, 2003).A flowchart (Figure 6) was given below to understand the methodology of this study.

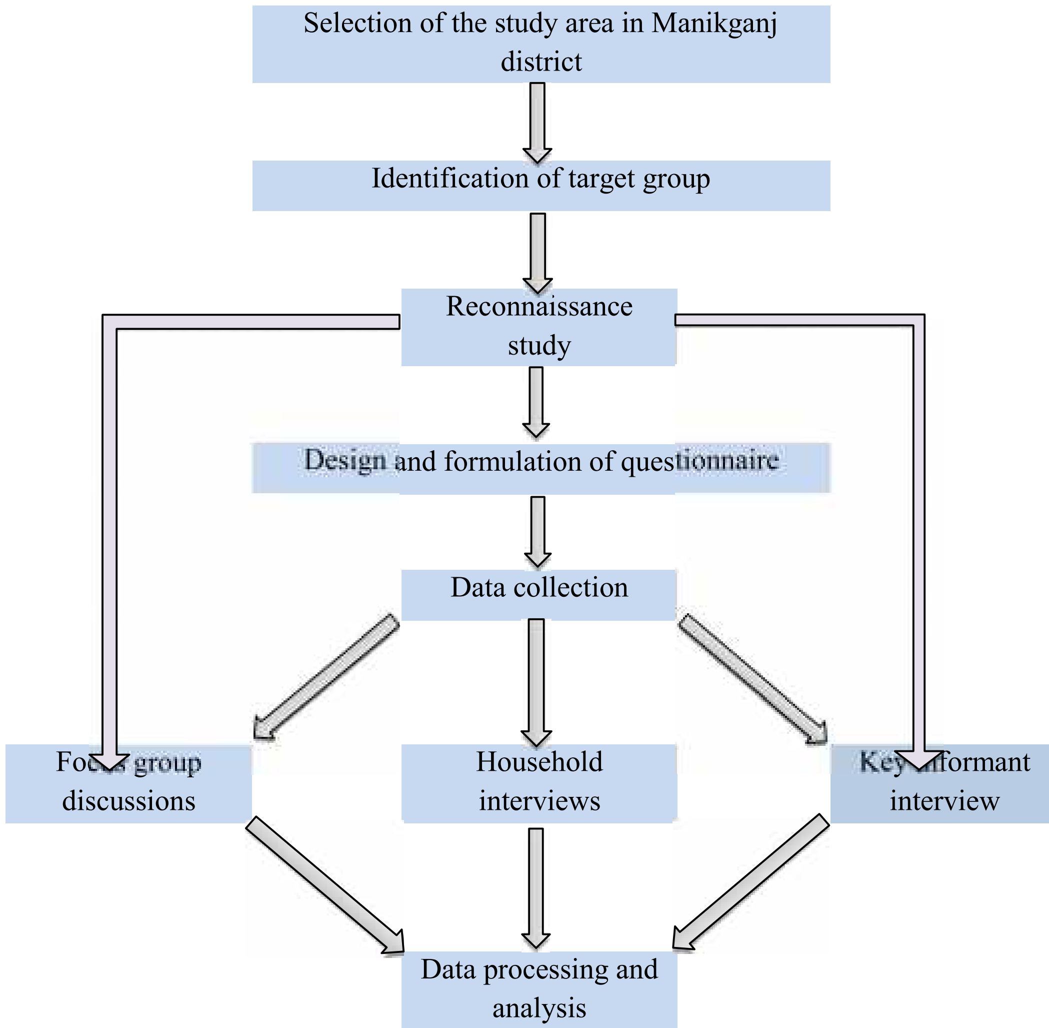


Figure 6: Flow chart of the methodology followed for this study

2.3.1 Primary data collection

Primary data were collected usinghousehold interviews, focus group discussions (FGDs) and key informants interviews.

2.3.1.1 Household interviews

Household interviews were employed to collect data on household characteristics including fishing activities, factors affecting fishing activities, impacts of climate variability and change on fishing activities and the adaptation strategies to the impacts of climate variability and change. It also served as a means of selecting participants for other data collection methods mainly FGD.

Determination of sample size for household interviews

The fishers (target group) were identified through reconnaissance study and their numbers were collected from Harirampur upazila fisheries office, Manikganj.

The sample size (number of respondents for household interviews) was determined according to Kortlik *et al*. (2001) and Henderson *et al*. (1982) as below-

$$n_0 = \frac{Z^2pq}{2}$$

Here, n_0= Desired sample size

Z = Standard normal deviate usually set at 1.96 which correspond to the 95% confidence level

p = Assumed proportion in the target population estimated to have a particular characteristic

q = Assumed proportion in the target population estimated to not have a particular characteristic. Where p+q = 1

d = Allowable maximum error in estimating population proportion

In this study Z = 1.96 at 95% confidence level, the 'p' value for sample size determinations can be obtained from the previous sampling of the same or similar population or from the results of pilot survey (Cochran, 2007). Unfortunately in the study sites no previous research was found from where the value of 'p' can be obtained. So through pilot survey, the value of 'p' calculated and it was found that p = 95% responses = 0.95, so the value of q = 1-p = 0.05 and d = level of significance = 5% = 0.05

So the sample size for this study was

$$n_0 = \frac{Z^2pq}{2} = \frac{1.96^2 \times 0.95 \times 0.05}{0.05^2} = 72.99 = 73\text{(approximately)}$$

The final sample size for household interviews of this study was 73.

Development of questionnaire

A semi-structured questionnaire was designed (Figure 7) following De Vaus (2002) and adapted to achieve the study objectives.

The questionnaire was designed to collect both quantitative and qualitative data from both migratory and non-migratory fishers for comparison. The responses from closed questions allowed statistical analysis, whereas the open-ended questions gathered qualitative data eliciting more detail and personal opinions on specific issues.

Two important issues were considered before conducting the interview so that responses were not influenced and the success of the research not jeopardized. Firstly, care was taken when designing the questionnaire as the design and wording of the questions can have a significant effect on the answers obtained as recommended by Linden and Sheehy (2004).

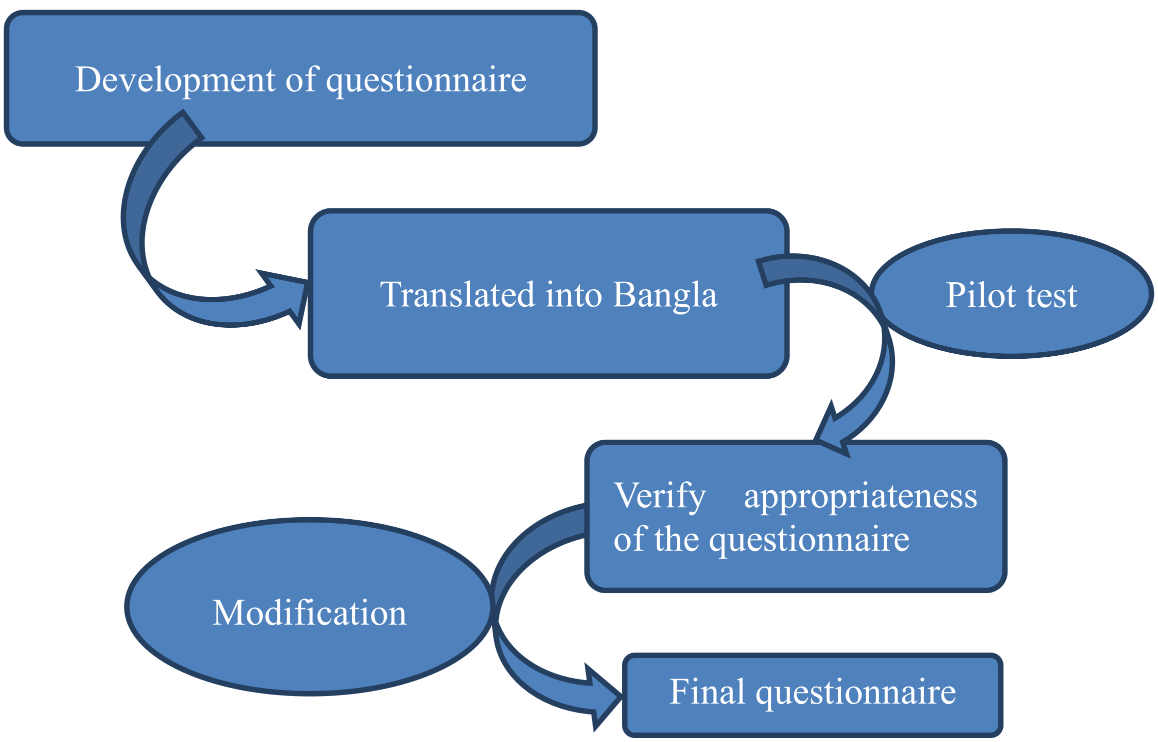


Figure 7: Process of questionnaire developmentfor household interviews of this study

The questionnaire was first developed in English then translated into Bangla (native language) carefully maintaining the meaning. Secondly, the questionnaires were pilot-tested with a small sample of respondents to verify the appropriateness of the questions asked and the wording used. The questionnaire was given in appendix 4.

Selection of respondent

Stratified random sampling was used to select the respondents as the population characteristics of the study sites were heterogeneous. To gain a higher degree of precision, this sampling technique had given a better cross-section of population. Respondents were selected based on their primary occupation, dependency of the Padma river fisheries, years of involvement in fishing, age, years of education and family compositions.

Simple random sampling (SRS)

The total number and list of the fisher households were taken from the Harirampur upazila fisheries office which was used as a sampling frame in this study. Out of total 130 fisher households, 73 were selected by using simple random sampling (SRS) method for household interviews in the study.

In this study, SRS was done by first assigning serial numbers 001 to 130 for the total 130 fishers household. Since 130 was a three digit number, so in this study merely read three-digit random numbers from the table of random numbers (Appendix 9). In the random numbers table, each random number consisted of 5 digits but in this study the leftmost first three digits of first row were used discarding the last two and proceeded downwards. After completing 1st column, the researcher proceeded to 1st row 2nd column and did so on until achieved the sample of 73. The researcher only used those numbers from the random numbers table that were laid in the range of 001 to 130. Any number lying outside that range was omitted, since they did not correspond to any serial number of the fishers household. If a random number occurred twice, the second occurrence was omitted and another number was selected as its replacement. In this study, the process was stopped after achieving desired sample.

Conducting the household interviews

These questionnaires were used in interviewer administered manner to conduct the face-to-face interviews. All the questions were asked in the same way and in the same order, which enabled collection of a set of comparable answers on which statistical analysis could be performed.

Interviews were voice recorded with the consent of the respondents (53 were recorded for this study) and then transcribed.Where recording not permitted, the responses of the open ended questions were hand written on the questionnaires. The length of surveys was not restricted but generally lasted between forty-five minutes to one-and-half hours (Antwi-Agyei *et al*., 2013). Questions referring to climate change were deliberately deferred to the end of the questionnaire surveys to avoid biases and prejudice in answers.

During household interviews a list (appendix 4) of climatic shocks and stresses regarding climate change impacts that was prepared based on the reconnaissance study, was provided to each respondent to rank the climate related shocks and stresses. Then they were asked to sort all climatic shocks and stresses separately into 5 categories that affected them mostly throughout their lives including fishing activities and overall livelihoods namely, very high, high, moderate, low and very low or no risk. The rank order of climatic shocks and stresses (higher to lower) was based on the respondent opinions. A list (appendix 4) of climatic impacts that was prepared based on the reconnaissance study, was also provided to each respondent and then they were asked to follow the same procedures (that was followed for ranking of climatic shocks and stresses) to rank the climatic impacts separately into 5 categories.

For this study only household heads were surveyed because they had a good understanding of the fishing activities, factors affecting fishing activities, impacts of climate variability change on fishing activities and the adaptation strategies to the impacts of climate variability and change.

2.3.1.2 Focus group discussions (FGDs)

FGD is a participatory method of data collection. FGDs were conducted to supplement and triangulate information gathered from the household interviews. Due to interaction among participants, focus group discussions would have inherent quality control in them (Robson, 2002).

FGDs were conducted in two stages for this study- during the reconnaissance study and the data collection period. During the reconnaissance study, the goals of FGDs were to develop the research objectives and methodology by exploring the research context and issues as well as getting to know the study area and people. Then during the data collection period, the FGDs were conducted to gather the data on fishing activities, factors affecting fishing activities and adaptation strategies related to climate variability and change.

A list of topics and possible questions (appendix 5) for the participants were developed before the start of the FGDs to ensure some structure and direction in the discussions. More emphasis was given to clarifying issues which seemed unclear from household interviews. Each FGD session would be ran for one to two and a half hours (Antwi-Agyei *et al*., 2013) or about 3 hours and 5-8 issues were discussed (Islam *et al*., 2014). For an FGD, a group of 8-10 (Powell and Single, 1996) or 5-12 (Hopkins, 2007) household heads were selected.This ensured a grouping of relatively homogenous households in each FGD where participants were able to freely express their opinions.

For this study four FGDs were done, each with a group of 6-9 members and each session continued about two hours.The household heads, who had experience of central phenomena or were thought to be able to explore the key concepts, were selected (Creswell and Clark, 2007). In addition, household heads who were found to be cooperative and enthusiastic during household interviews were selected. Overall the FGD sessions were run ensuring that the focus was kept, momentum maintained and that there was real participation and closure on questions (Coldwell and Herbst, 2004). To ensure good representation of fishers careful consideration was given to age and wealth groups in the selection of participants (Hopkins, 2007).

2.3.1.3 Key informant interviews

Like FGD, key informant interviews were also conducted at two stages for this study- during the reconnaissance study and at the later stage of data collection period.

During the reconnaissance study, the goals of key informant interviews were to develop the research objectives and methodology by exploring the research context and issues, becoming acquainted with the study area and people, and researching the sources of secondary information. During the data collection, the goals of key informant interviews were to collect data on the issues in the research objectives or issues raised by respondents during the other data collection methods (e.g., if respondents mentioned any significant role of a local commissioner in the adaptation process, that specific commissioner is interviewed). Key informant interviews were therefore conducted at a later stage of the data collection.

During the FGDs and household interviews, respondents who demonstrated appreciable knowledge on climate change and variability on fishing activities, their impacts and adaptation strategies were selected for key informant interviews. Interviews with key informants were accompanied by visits to points of interest, where appropriate. The key informant interviews allowed in-depth discussions and validation of the main issues that were highlighted in the household interviews and FGDs. Key informant interviews were taken on one-to-one basis to ensure confidentiality of responses and lasted between forty minutes or one and a half hours (Antwi-Agyei *et al*., 2013).

Both individuals from inside and outside the villages were included in the key informants interview data collection. From inside the villages, village leaders (e.g., the local commissioner) and village members who were knowledgeable about the issues for this study were selected. Whereas, from outside the villages, government officials (e.g., the upazila fisheries officer), NGOs officials who were directly associated with the villages' interest were selected. For this study six key informants were selected. Then the key informants were interviewed using a checklist (appendix 6) and each interview has taken about forty five minutes.

2.3.2 Secondary data collection

For this study secondary data (temperature and rainfall) were collected from Bangladesh Meteorological Department (BMD), Agargaon, Dhaka-1207. Furthermore, fisheries related data (such as number of fishers) were also collected from Harirampur upazila fisheries office, Manikganj.

2.3.3 Ethical considerations

The ethical considerations are necessary to safeguard research participants, the research process. Broadly, two main ethical issues were considered-participants consent and confidentiality of the data. Consent was taken from each participant before collecting data. Before taking consents, participants were given information that sufficiently explained the purpose and the nature of this study. They were assured that the information would be used for research purposes only and they had the opportunity to ask questions if they had any query. They were recruited voluntarily, were not compensated and their names were not revealed. They also had the option to withdraw from the research at any time. To comply with confidentiality, the data (both hard and electronic copies) were not shared with anyone. Participants were assured that their names would always be kept anonymous.

Collection of data from the field involved interaction between the researcher and the respondents. The way the respondents treated the researcher was therefore important, as it could affect the quality of the data and therefore the entire research process. Due to this, it was important for the researcher to be aware that his/her own identity and positionality would shape the interaction between the researcher and the respondent(s) (England, 1994; Twyman *et al*., 1999). Class, family status, ethnicity and other social identities shape relationships between the researcher and the participants (Gilbert, 1994). In this study, the author was in an advantageous position as he was from a similar ethnic, cultural and language background to the respondents but not exactly from the same locality. Gender was another factor that can affect the quality of data collection (McNay, 2003). For this study the respondents (household heads) were usually male.

2.4 Results verification

In this study, after analyzing all the data, results were verified by three household interviews and one FGD to entirely different fishers samplein the study area.

2.5 Data Analysis

2.5.1 Qualitative data analysis

Qualitative data collected through a mixture of household interviews, FGDs and key informant interviews. The qualitative data were audio recorded, except 20 household interviews and 3 key informant interviews as recording was not permitted. The responses of the open ended questions of the semi-structured interviews and the key informant interviews were hand written on the questionnaires soon after the interviews. The recorded data were transcribed in the originallanguage (Bengali) that were hand written. The researcher of this study heard all the recorded audios at least once to check any confusion, which increased reliability of data.

The qualitative data were analysed using the modified grounded theory approach (Strauss and Corbin, 1990). Literature review allowed possible predetermined categories (themes) of empirical data before analysing them (Strauss, 1987). During the different steps of analysis, these categories were revised based on the themes that arose from the data (grounded theory approach) (Strauss and Corbin, 1990). Content analysis technique (Miles and Huberman, 1994) was used to analyse the qualitative data before translation. At the later stage of writing, selected quotes were translated into English.

Qualitative data analysis consisted of three steps: i) preparing and organising the data for analysis, ii) reducing the data into themes through a process of coding and condensing the codes, and iii) finally representing the data in tables or as part of a discussion (Creswell, 2007). When all the transcripts were ready, codes were leveled on the text to assign units of meaning (Miles and Huberman, 1994). Pencils and different colours were used for this purpose. Codes were attached to “chunks” of varying size – words, phrases, sentences or whole paragraphs of interest (Miles and Huberman, 1994). In the coding process, it was kept in mind that not the words themselves but their meaning matters (Miles and Huberman, 1994).

These codes were then condensed (development of subthemes and themes) where evidences were grouped and ideas were labeled so that they reflected increasingly broader perspectives in a process of sense-making (Creswell and Clark, 2007). Subthemes and themes were identified by the scrutiny techniques developed by Ryan and Bernard (2003): looking for repetitions, indigenous typologies, metaphors and analogies, transitions, similarities and differences and linguistic connectors. Reducing the data into themes further included sorting themes into a manageable few (i.e., deciding which themes are important to fulfill each objective), building a hierarchy of themes, and linking themes into theory (Ryan and Bernard, 2003).

Increasing the reliability of the data, coding was done by the researcher of this study. Mixing of quantitative and qualitative data were done either by connecting two datasets (building one dataset on the other) or embedding (one dataset within the other where one type of data provides a supportive role for the other) (Creswell and Clark, 2007). After finishing the analysis, the results were checked again with the original transcripts to ensure further reliability.

2.5.2 Quantitative data analysis

Quantitative data (such as fishers type, gender, religion, age, years of education, family composition, years of involvement in fishing, annual income, measurements of fishing equipment) were coded in a way that MS Excel (Version 2010) and Scientific Package for Social Sciences - SPSS (version 20) could understand to enable appropriate statistical analysis. Data were analyzed in SPSS using descriptive statistics and compared means (Kinnear and Gray, 2012). Data were presented in the form of graphs and tables to give graphical representation to the data (MS Excel and SPSS).

Monthly temperature data for the period of 38 years (1977-2014) and monthly rainfall data for the period of 40 years (1975-2014) of Faridpur station (nearby station of the study sites) were obtained from Bangladesh Meteorological Department. The obtained data were thoroughly checked and screened. The trends of temporal and spatial variations of temperature and rainfall were analyzed using linear regression. A time series analysis was done to understand the past rainfall pattern to help future projections and planning using the past and present data. Among many components of time series, secular trend method was used to comprehend the general tendency of the time series data to increase or decrease or stagnate during a long period of time. Least square curve fitting technique was used to fit linear trend in the data.

The linear trend between the time series data (y) and time (t) is given in the equation below-

$y = a + bt$

Where,

y = temperature or rainfall

t = time (year)

"a" and "b" are the constants estimated by the principle of least squares

The annual mean temperature and average annual rainfall was analyzed and their trends were studied (Practical Action, 2009).

CHAPTER 3 – RESULTSAND DISCUSSION

3.1 Livelihood Characteristics of Fishers

3.1.1 Fishers type

Depending on time involvement in fishing, fishers are three types such as full-time, part-time and occasional. But based on migration, they are migratory and non-migratory (Table 3). From household interviews, this study found that 26.03% fishers in Dhulsura were migratory due to the low number of local fishers while there was no migratory fishers in Andharmanik (Figure 8).

Table 3: Frequency and percentage of fishers in the study area

Types of fishers	Migratory fishers			Non-migratory fishers		
Studysites	Andharmanik	Dhulsura	Total	Andharmanik	Dhulsura	Total
Full-time	-	19	19	38	10	48
Part-time	-	-	-	3	2	5
Occasional	-	-	-	-	1	1
Total			19			54
Percentage (%)			26.03			73.97

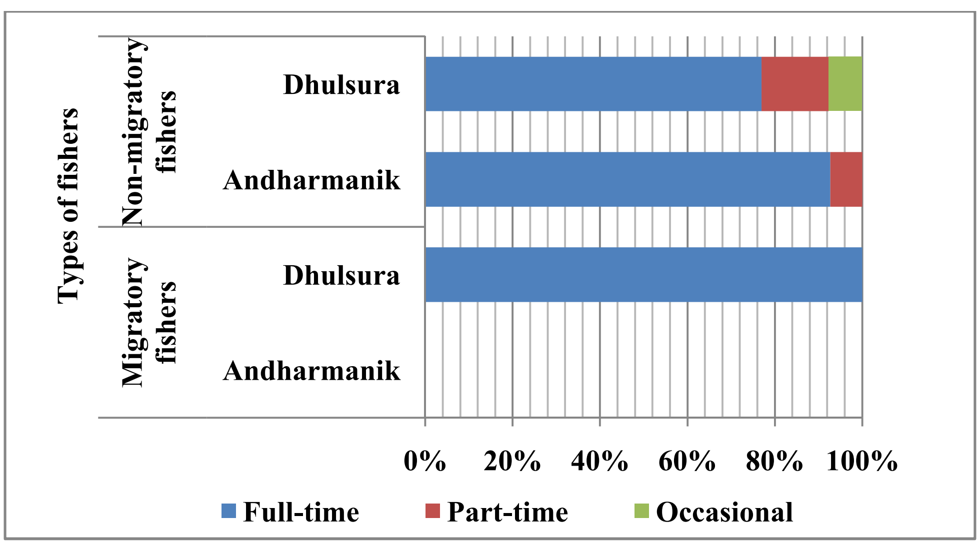


Figure 8: Types of the fishers in the study area

This study also found from household interviews that all migratory (100%) and most of the non-migratory fishers(88.89%) were full-time, but there were also part-time and occasional fishers among the non-migratory. Full-time fishers depend on fishing throughout the year for their livelihood and income (9-12 months per annum). Part-time fishers undertake fishing during part of the year (3-9 months per annum), mainly in the monsoon and post-monsoon seasons, supplementing their fishing income by doing farm works as labourers and driving vehicles, whereas occasional fishers are opportunistic and fish mainly for household consumption (less than 3 months per annum). They rely primarily on petty business, livestock rearing and agriculture for their livelihoods. Islam (2013) categorized the above three types of fishers in coastal area of Bangladesh.

3.1.2 Gender

In this study, no female fisher was found in any of the study area. Faruque and Ahsan (2014) also found no involvement of female in the Padma river fishing in Rajshahi district. Ahmed *et al*. (2009) reported that women have less freedom both socially and economically than men that restrict their activities. But in the fisheries sector women are mainly involved in making and repairing fishing gear and post-harvest activities such as processing and small-scale marketing (Ahmed *et al*., 2012). Sultana and Thompson (2006) also reported that women are often excluded from fishing.

3.1.3 Religion

This study found from household interviews that average 93.15% migratory and non-migratory fishers from both study sites were Hindu followed by 6.85% Muslims (Figure 9). This results indicate that the Padma river fishing in both study area of Manikganj was dominated by Hindu fishers. This study also found that at present the involvement of Muslim in fishing activities increasing continuously in the study area.This study agrees with the finding of Bijoya *et al*. (2013) in Turag river, Dhaka and Islam *et al*. (2013b) in Monirampur upazila, Jossore. But Kabir *et al*. (2012) in old Brahmaputra river and Khan *et al*. (2013) in Tista river reported that most of the fishers were Muslim in that area.

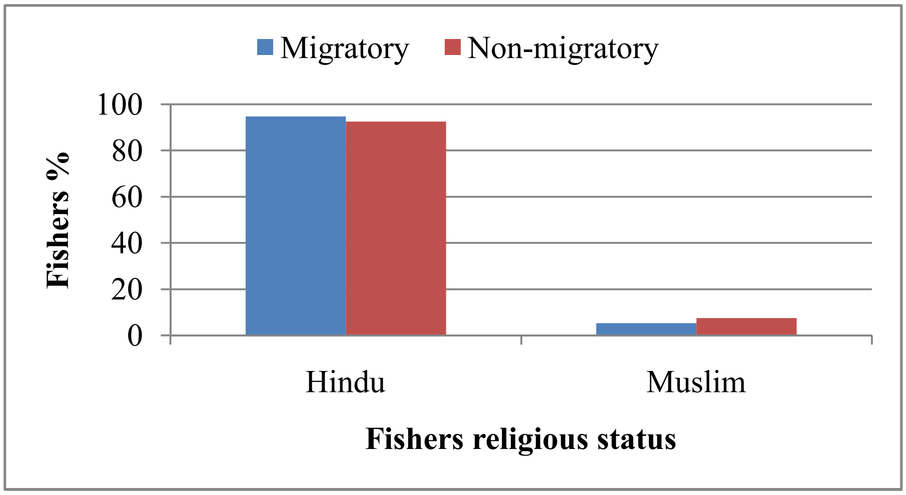


Figure 9: Religious status of the fishers in the study area

3.1.4 Age

The age status of the fishers are important to understand the potential productive human resources. In this study, it was found from household interviews that most of the fishers of the Padma river in the both study sites were to the age group 31 to 40 years (Figure 10). This study also found that the percentage of young fishers less than 30 years were very low.

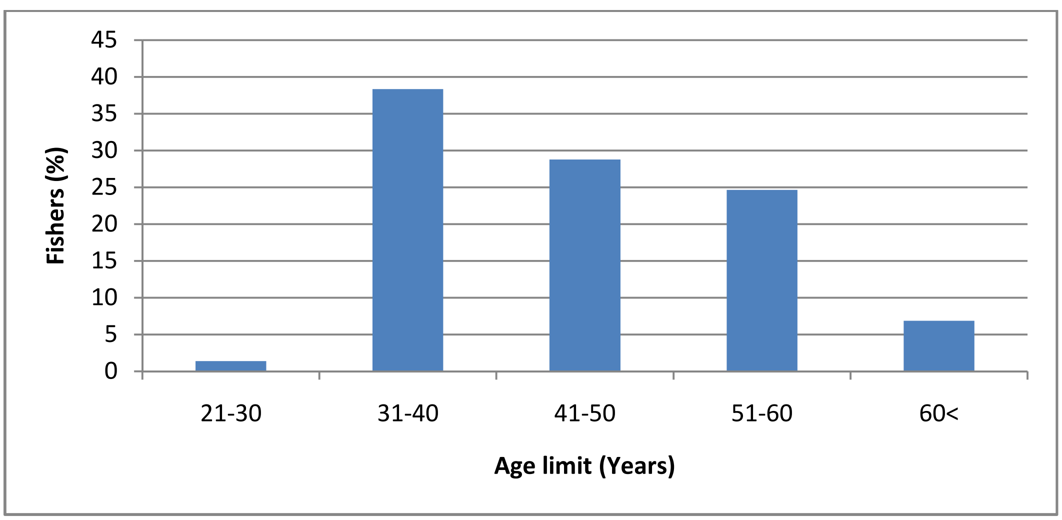


Figure 10: Age structure of the fishers in the both study sites

From FGDs, this study found that young generation (age less than 30 years) of both migratory and non-migratory fishers of both study sites lost their attention towards fishing in the Padma river due to the decreasing catch as well as various negative impacts of climatic variability and changes(Figure 11). Therefore, they seeks other works to support their livelihood. Similarly Hossain *et al*. (2009) in seasonal floodplain beels in Rajshahi, Faruque and Ahsan (2014) in the Padma river, Rajshahi, Islam *et al*. (2013b) in Jossore and Kabir *et al*. (2012) in old Brahmaputra river reported maximum fishers were in the age group of 31-40 years.

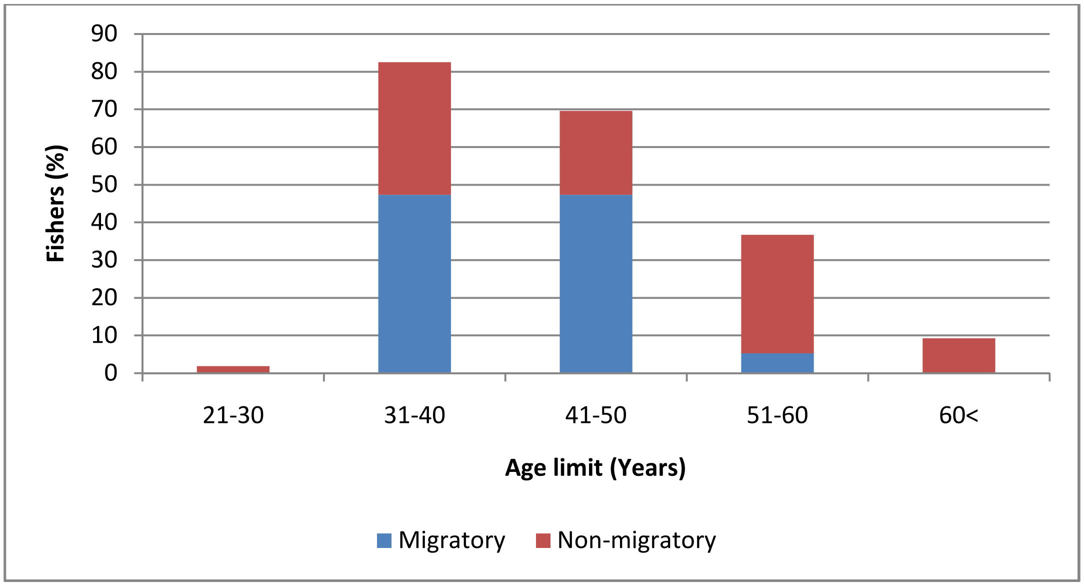


Figure 11: Age structure of migratory and non-migratory fishers in the both study sites

3.1.5 Educational status

This study found from household interviews that more than half (58.90%) of the fishers (Figure 12) in the both study sites had no education. Kabir *et al*. (2012) and Khan *et al*. (2013) reported that 88% in old Brahmaputra river and 68% in Tista river respectively had no education. From reconnaissance study, it was found that due to the fishers poor socio-economic conditions, they could not get the opportunity to take education. Again they led their children involved in fishery related activities to support their family rather than going school. This study also supports the finding of Chowdhury *et al*. (2011) in Naaf river, Bangladesh.

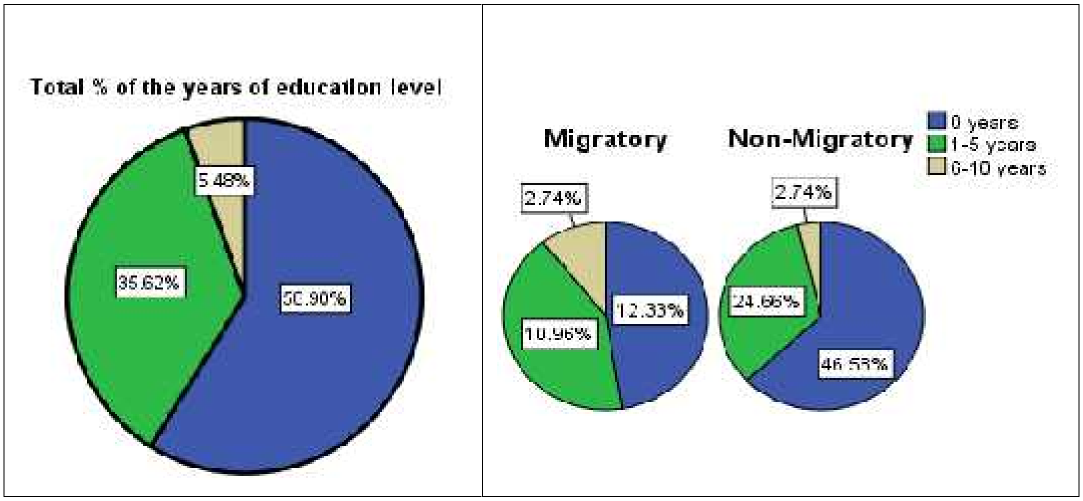


Figure 12: Educational status of the fishers in the study area

Education is a part of human resource development. Though education is not a compulsory subject for fishing in the Padma river, but it is regarded as one of the more important factors in coping and adaptation, both in terms of promoting survival as well as in enhancing quality of life (Blunt *et al*., 1994). Education enhances a person's ability to understand and manipulate critical aspects of the modern world, receive and integrate information and perceive and resolve difficult situations (Caldwell, 1979; Schultz, 1975). So fishers education is important to be aware and familiar with the latest technology for fishing and to become updated with the recent climatic variability and changes.

3.1.6 Family composition

Family size is an important socio-economic indicator as it affects the income, food consumption and socio-economic wellbeing of the households. This study revealed from household interviews that the family composition in the both study sites was 5.23± 2.11 members (mean ± standard deviation). This study divided fishers family into three classes depending on its size such as small, medium & large. This study also showed that 48% fishers (Figure 13) had 5 to 7 family members. Khan *et al*. (2013) reported that 57% fishers family in Tista river had 5-7 members. The family size and its composition are related to occupation and income, and in fishers family it has an important influence on the fishing activities.

From this study, it was also found that the large (joint) family were continuously broken and as a result the number of nuclear family had increased. In the both study sites about 11% family had more than 7 members, whereas only 1% had more than 10 members. This happened because most of the fishers were economically poor, as a result children separated from their families when parents grown.

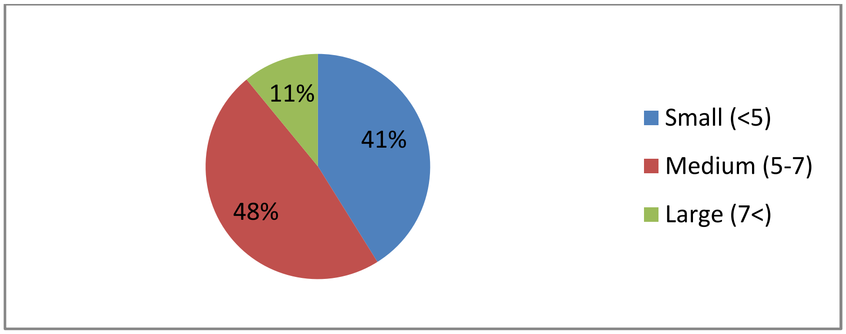


Figure 13: Family size of the fishers in the both study sites

This study also found from household interviews that in case of migratory fishers the tendency to break down joint family to nuclear family was comparatively low than non-migratory fishers (Figure 14). The migratory fishers thought that their large family size support them in fishing activities as they have migrated from one area to another. Faruque and Ahsan (2014) also found that only 7.92% fishers of the Padma river, Rajshahi district had 7 to 9 family members, whereas Alam *et al*. (2009) found 10% fishers had 8-10 family members in Basantapur beel, Natore district, Bangladesh.

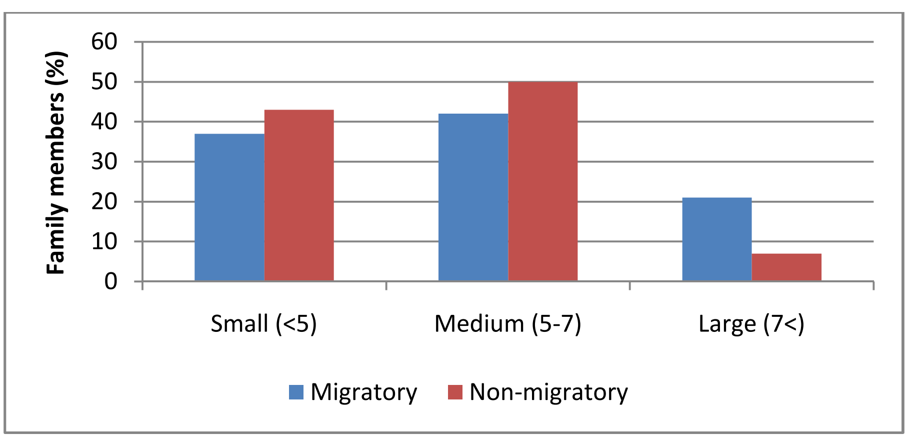


Figure 14: Family size of the migratory and non-migratory fishers in the both study sites

3.1.7 Years of involvement in fishing

Years of involvement in fishing is important for the experienced of more climatic shocks and stresses. From household interviews, this study found that fishers had 31.70± 10.753 years of involvement in the Padma river fishing. This study also found that more than 50.0% of the fishers in both study sites had experienced over 30 years (Table 4). All the non-migratory fishers had mixed experienced about the climatic variability and changes (Figure 15).

Table 4: Fishers years of involvement in fishing in the both study sites

Years of involvement	Frequency	Percentage (%)	Cumulative %
Up to 10	5	6.8	6.8
11 to 20	8	11.0	17.8
21 to 30	23	31.5	49.3
31 to 40	26	35.6	84.9
41 to 50	10	13.7	98.6
50<	1	1.4	100.0
Total	73	100.00	

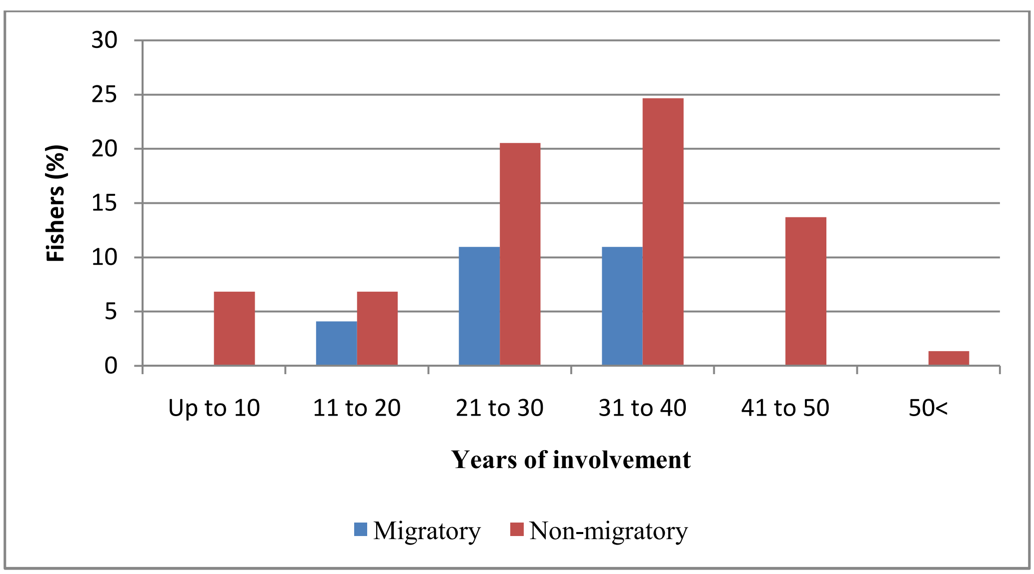


Figure 15: Fishers years of involvement in fishing in the both study sites

3.1.8 Income of fishers

For better understanding of the state of fishers livelihoods, their income is the most important factor. In this study,fishers income were calculated including expenses. This study found from household interviews that 63% fishers (Figure 16) of the Padma river in both study sites had a moderate annual income (Tk.30,000-60,000). Only 11% fishers had a high annual income (above Tk.60,000) but no fisher had annual per-capita income above US$ 1,314 (BDT 102,770) (CPD, 2015). Khan *et al*. (2013) also reported 63% fishers had moderate income in Tista river.

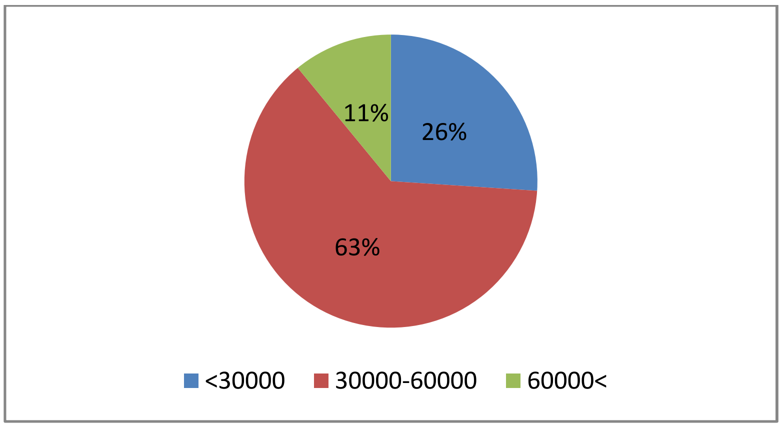


Figure 16: Annual income (Tk.) of the fishers of the study area

Depending on the types of nets and gears used for fishing, the amount of catch varied. Fish selling price also varies depending on fish size, species and quality. For that reason fishers annual income varied. This study founf from household interviews that seine and gill nets (such as ber jal, current jal) users annual income higher than other groups. About 26% migratory fishers had annual income above Tk.60,000 (Figure 17). Since they used large seine and gill nets for fishing. The non-migratory fishers who used only cast net and lift net their annual income was low than other fishers.

But Faruque and Ahsan (2014) reported that most of the Hilsa fishers (on an average 94.17%) in the Padma river of Rajshahi district had average annual income to the range of Tk.30, 000 to Tk.60,000. But Ali *et al*. (2008) also reported that majority of fish farmers in Hamirkutsha and Kamarbari unions of Bagmara upazila under Rajshahi district had an average annual income above Tk.75,000.

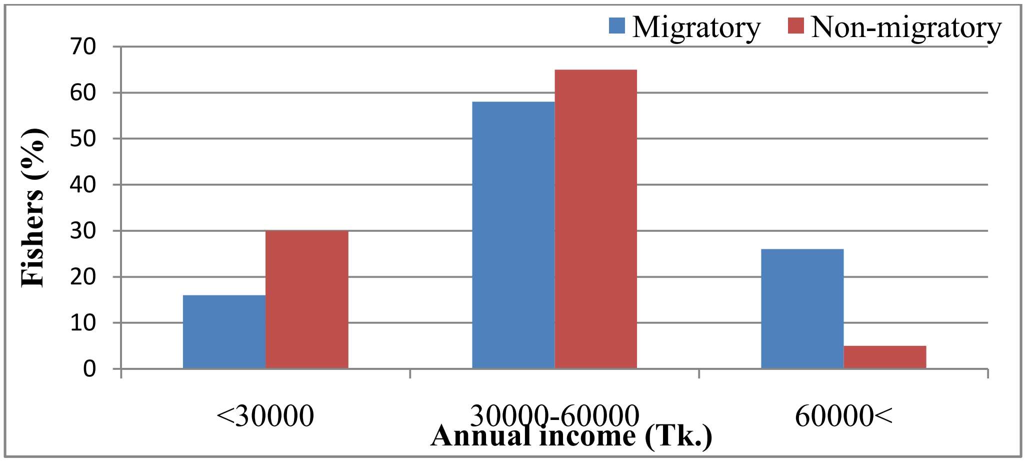


Figure 17: Annual income (Tk.) of the migratory and non-migratory fishers in the study sites

The summary of the general characteristics of the fishers in the study sites are presented below (Table 5):-

Table 5: Summary of the general characteristics of the fishers in the both study sites

General characteristics of the fishers		Migratory	Non-migratory
Types of fishers (%)		26.03	73.97
Family traditional occupation (%)		100.00	90.74
Full-time fishers (%)		100.00	88.89
Religion (%)	Hindu	94.74	92.59
	Muslim	5.26	7.41
Age of the household head (years)	Mean±s.d	42.05±6.704	47.35±11.114
Family composition	Mean±s.d	5.84±2.911	5.02±1.732
Years of involvement in fishing	Mean±s.d	30.42±6.149	32.15±11.977
Mean income from fishing including expenses (taka)	mean	43,684.21	35,277.78

3.2 Fishing Activities of the Fishers of the Padma River at Harirampur Upazila, Manikganj

3.2.1 Use of fishing nets

This study from household interviews showed that the migratory and non-migratory fishers of the Padma river used different types of fishing nets in different seasons. This study also recorded (from household interviews) total ten (10) types of fishing nets that were used for fishing by the both migratory and non-migratory fishers of the study sites (Table 6). Length, width and mesh sizeof fishing nets were varied depending on the fishers choices and the capitals involved in fishing as well as the abundance of fish in the Padma river.

Table 6: Comparison of fishing nets used by the migratory and non-migratory fishers of this study sites

Name of nets		Non-migratory fishers				Migratory fishers			
English name	Local name	Length (m)	Width (m)	Mesh size (mm)	Person needed	Length (m)	Width (m)	Mesh size (mm)	Person needed
Cast net	Khepla jal	4-6	6-9	10-30	1	-	-	-	-
Seine net	Ber jal	100-400	5-6	2-4	7-10	300-600	5-6	2-4	8-12
	Ghurnee ber jal	50-60	3-5	15-20	4-6	-	-	-	-
	Badai jal	100-200	5-7	2-5	7-10	150-200	5-7	2-4	8-12
	Kajoli jal	100-200	5-6	3-5	5-8	150-300	5-6	2-5	8-10
Gill net	Current jal	70-150	5-15	2-5	5-10	150-300	5-15	2-4	8-10
	Pachon jal	50-70	1-1.5	50-80	5-6	-	-	-	-
Lift net	Veshal jal	10-15	5-8	5-15	1	-	-	-	-
	Floating veshal jal	7-8	4-5	5-10	4-6	-	-	-	-
	Chala jal	5-6	1-1.2	3-5	1	-	-	-	-

In this study 36.84% migratory and 29.63% non-migratory fishers shared their nets with other fishers who have no own fishing nets for fishing. Above all types of fishing nets were used for fishing in the Padma river by the non-migratory fishers all the year round. But in winter season (November to February), only limited numbers of fishing nets were used for fishing in the river. Among this seine nets (ber jal, kajoli jal and badai jal) and lift nets (veshal jal) were used in maximum times but frequencies of using lift nets were high. In rainy season when heavy rainfall increases the water level and creates flooded condition, then different types of nets are used. But in this study it was found from household interviews that all the year round migratory fishers of the Padma river used only ber jal, badai jal, kajoli jal and current jal. Miah *et al*. (2010) in Shitalakshya river, Narayangonj and Flowra *et al*. (2013) in Baral river, Natore recorded 6 and 7 types of fishing nets respectively, whereas Alam *et al*. (2009) found 8 types of fishing nets in Basantapur beel, Natore, Bangladesh. Figure 18 shows some fishing nets that were used for fishing by the fishers of the Padma river in the study sites (see appendix 8 for more fishing nets pictures).

Figure 18: Fishing nets of the fishers in the study sites: a) lift net: floating veshal; b) seine net: ber jal; c) gill net: current jal and d) cast net: khepla jal

Figure 19 shows some fish species of the Padma river that were caught by the fishers in the study sites (see appendix 8 for more pictures).

Figure 19: Some fishes of the Padma river in the study sites: a) *Tenualosa ilisha;* b)*Labeo rohita;* c)*Wallago attu;* d) *Chitala chitala;*e)*Heteropneustes fossilis* and f)*Mystus aor*

This study found (from household interviews) that most of the fishers (89.04%) used their nets for fishing during daytime but some fishers used at night. The fishers who operated their nets at night, they used luminous floating substances attached with their nets. It helped the fishers to save their nets from any damages that could be happened from crossing the nets by any boats or trawlers. In this study migratory fishers caught mainly large and medium size fish since they used large mesh size nets. All the fishers in the study sites caught different types of fish species from the Padma river such as *Tenualosa ilisha, Labeo rohita, Catla catla, Chitala chitala, Chitala chitala, Notopterus notopterus, Cirrhinus cirrhosous, Pangasius pangasius, Wallago attu, Eutropiichthys vacha, Gudusia chapra, Liza parsia, Rhinomugil corsula, Macrobrachium rosenbergii, Chanda nama, Ailia coila* etc.

3.2.2 Use of fishing traps, lines and hooks

This study found (from household interviews) that non-migratory fishers (13.69%) used various types of fishing traps, lines and hooks such as doyari and bana, polo,ghuni, hazari barshi and konch but migratory fishers did not use any fishing traps, lines and hooks. Fishing traps (doyari) wereset along the banks of the Padma river or shallow part of the floodplains with bana in the evening and hauled up in the next morning. The hazari barshi was also known as "*Don Barshi*" or "*Dom Barshi*" or "*Chhara Barshi*" (Ahmad, 1962). The non-migratory fishers of this study set hazari barshialong the bank of the Padma river in the evening and hauled up it in late night or early in the morning. In case of day fishing, it was hauled up every 2 to 3 hours. Usually the non-migratory fishers of this study used earth worms or small shrimp as bait in line fishing. Flowra *et al*. (2013) found 4 types of traps and 5 types of lines and hooks in Baral river and Alam *et al*. (2009) found 7 types of traps in Basantapur beel, Natore, Bangladesh. Jhingran (1989) were reported that the big sized cat fishes (*Wallago attu*) were generally caught by lines and hooks. In this study sites various types of fishes were caught in the fishing traps, line and hooks such as *Wallago attu, Bagarius bagarius, Mystus aor, Rita rita, Mystus tengara, Clarias batrachus, Heteropneustes fossilis, Clupisoma garua, Channa marulius, Channa punctata, Channa striata, Channa gachua, Glossogobius giuris* etc.

3.2.3 Banned nets

This study found (from household interviews and reconnaissance study) that 84.21% migratory and 50% non-migratory fishers illegally used banned nets (current jal and ber jal) for fishing in the Padma river. Current jal (fishing net of monofilament synthetic fibre) having mesh size less than 4.5 cm is an extremely efficient fishing gear that has declared illegal by the government, because of its potential capability for capturing juveniles of large fish mainly Hilsa (*Tenualosa ilisha*). Ber jal is also a destructive fishing gear that locally known as "mosquito jal" banned for fishing. But using these nets fishers catch all sizes fish including fish eggs to adult. One of the fisher said "Ber Jal is a Gustimara Jal" (Ber Jal can caught all sizes fish including fish eggs to adult fish). As a result it created negative impact on fish production and fish catch.

3.2.4 Use of boats

This study found from household interviews that 98.63% fishers used boats for fishing in the study sites, while 1.85% fishers had no boat. The fishers those had no boat, they tried to catch fish with small (push/pull) nets near the riverbank. Mainly two types of boats named mechanized and non-mechanized were normally used with different types of nets depending on the target species and fishing season in the study sites. In this study the fishers used three types of fishing boats (Table 7) named kosa boat, jolkonna boat and dinghy boat for fishing. Flowra *et al*. (2013) found 4 types of fishing boats in Baral river, Natore, Bangladesh.

Table 7: Types of fishing boats used by the fishers in the study area

Boat name	Non-migratory fishers			Migratory fishers		
	Length (m)	Wide (m)	Man power needed	Length (m)	Wide (m)	Man power needed
Kosa boat	6-10	1-2	5-6	6-10	1-2	5-6
Dinghy boat	3-5	1-1.8	1-2	-	-	-
Jolkonna boat	10-15	1.9-2.06	8-10	12-15	2.0-2.2	8-12

In this study all the migratory fishers (100%) used large sized mechanized fishing boats (Figure 20). But non-migratory fishers used both mechanized (55.56%) (Figure 21) and non-mechanized (42.59%) fishing boats. This study also found that 94.74% migratory and 48.15% non-migratory fishers used 8.5 Horse Power (HP) engine in their boats. In this study both migratory and non-migratory fishers (49.31%) used kosa boat that were usually non-mechanized and small in size but some kosa boats (13.89%) were mechanized (HP 4.5). While 49.31% migratory and non-migratory fishers used jolkonna boat that were mechanized (HP 8.5) and large in size.Different types of boats are essential for assuring a good and effective fishing. The fresh water fishing boat and gears are of traditional types, using from long times without any modifications. Table 8shows differences of the fishing activities of the migratory and non-migratory fishers of the Padma river in the study sites.

Figure 20: Boat of migratory fishers of the Padma river in the study area

Figure 21: Boat of non-migratory fishers of the Padma river in the study area

Table 8: Comparison of fishing activities of the migratory and non-migratory fishers of the Padma river in the study sites

Types of Fishers	Migratory Fishers	Non-migratory Fishers
Types of nets used for fishing	• Seine net i) Ber jal ii) Badai jal iii) Kajoli jal • Gill net i) Current jal	• Cast net i) Khepla jal • Seine net i) Ber jal ii) Ghurnee ber jal iii) Badai jal iv) Kajoli jal • Gill net i) Current jal ii) Pachon jal • Lift net i) Veshal jal ii) Floating veshal jal iii) Chala jal
Types of traps, lines and hooks	-	• Traps i) Doyari and bana ii) Polo iii) Ghuni • Lines and hooks i) Hazari barshi • Spears i) konch
Fishing boats	• Kosa boat • Jolkonna boat	• Kosa boat • Jolkonna boat • Dinghy boat
Use of banned nets	• Current jal • Ber jal	• Current jal • Ber jal

3.3 Climate of the Study Area

3.3.1 Temperature

For temperature analysis, data in the study area were available for thirty eight years from 1977-2014. Temperature analysis revealed that mean maximum annual temperature, mean minimum annual temperature and overall mean temperature in the study area, all are in increasing trend (Figure 22).

This study found that the average annual temperature in the study area increased by 0.0107°C per year. Mean minimum temperature increased by 0.0112°C per year and mean maximum temperature increased by 0.0261°C per annum. The highest mean maximum annual temperature was recorded as 31.66°C in 2009, while the lowest mean minimum annual temperature was 20.07°C in 1992 (1977-2014). All the positive slope of the mean maximum, mean minimum and overall average annual temperature trends in the study sites were increased over the last four decades.

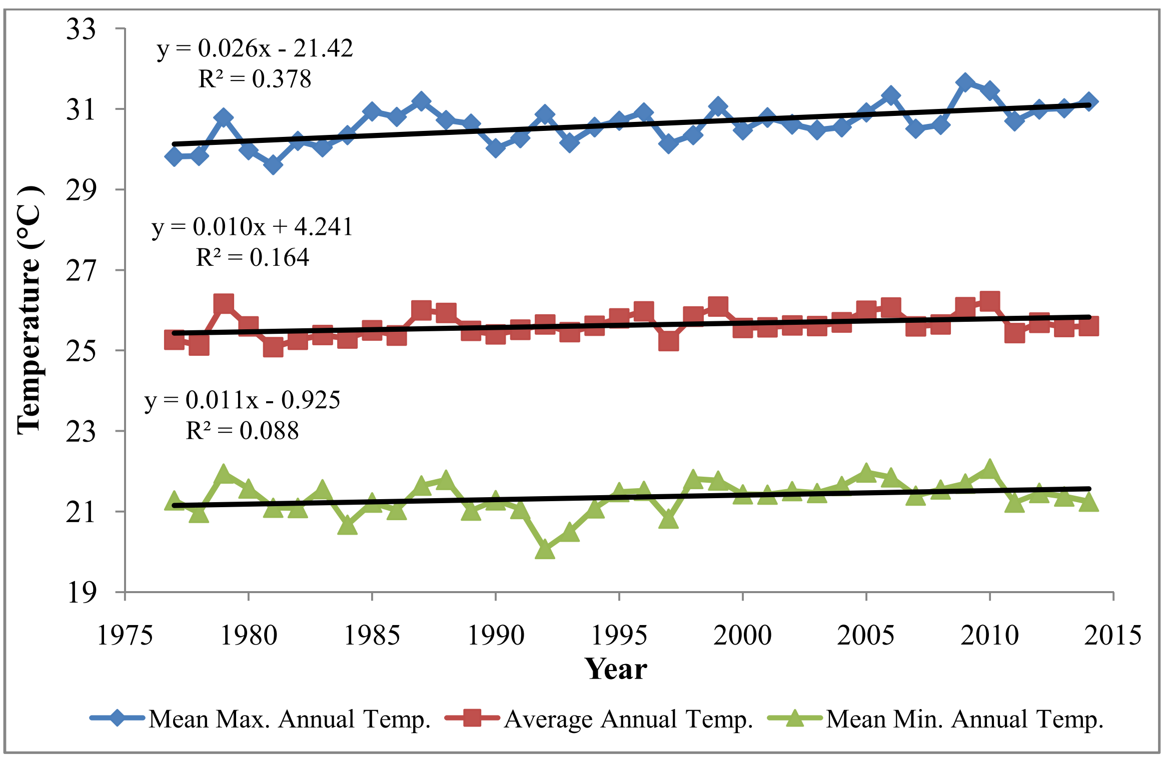


Figure 22: Annual mean temperature in the study area (data from BMD, analysed by the researcher)

Figure 23 shows that the monthly mean maximum, mean minimum and average temperature for November to February is comparatively lower which represent the winter or dry season and relatively cold temperature. The temperature during winter varies from 8.66°C to 15°C in average minimum condition. The average maximum temperature is found in April which is the hottest month in the study area as well as for the whole country. Temperature of June to September is fairly smooth and ranges from 25°C to 30°C in average condition.

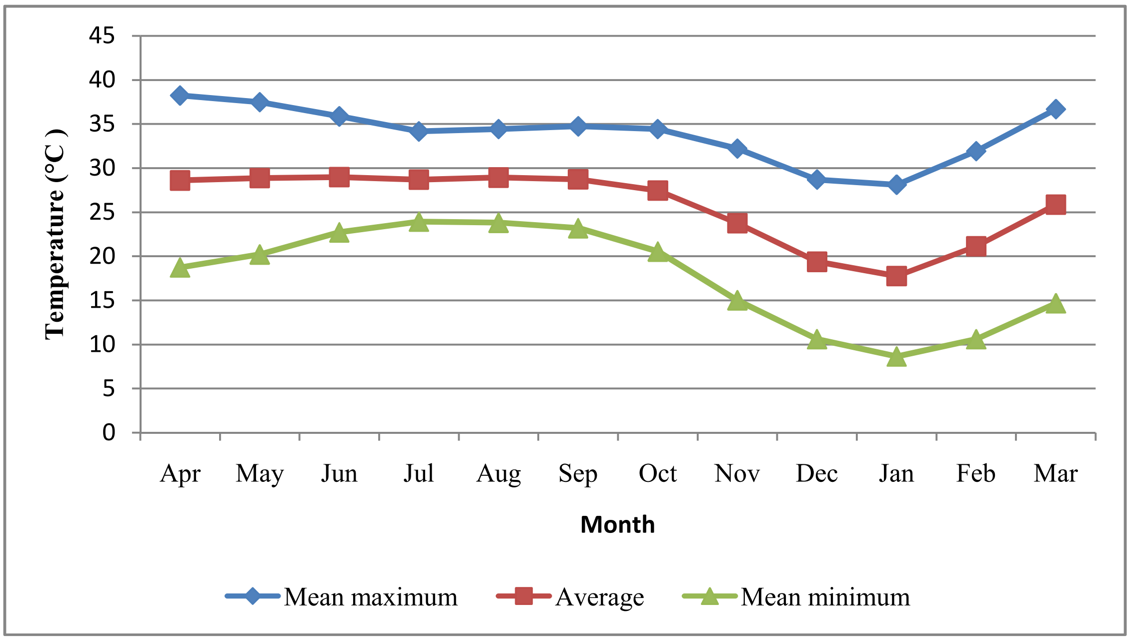


Figure 23: Monthly temperature in the study area(data from BMD, analysed by the researcher)

3.3.2 Rainfall

Forty years of rainfall data (1975-2014) were collected from BMD. These data were used for assessing pattern of rainfall over the years.

Figure 24 shows that 1978 was the hottest (driest; drought prone) year with only 94.17 mm of monthly average rainfall, whereas 1981 was the wettest year with 216.58 mm of average rainfall per month. The negative slope of the rainfall trend line shows that rainfall in the study area has continuously decreased in the past three decades after 1981 and the decreasing rate of mean rainfall was 95.03 mm per year.

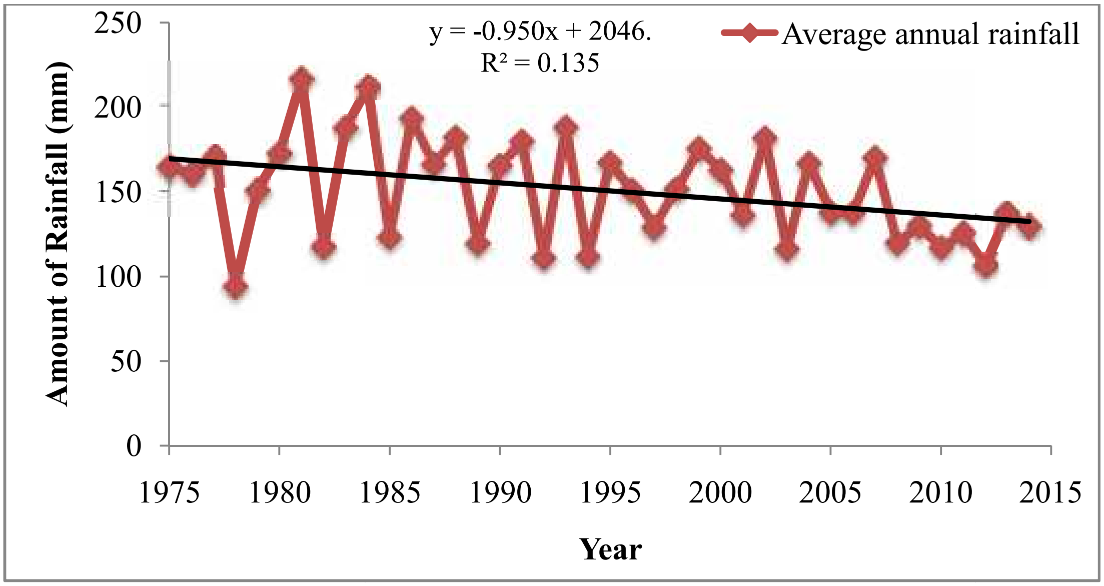


Figure 24: Average annual rainfall in study area(data from BMD, analysed by the researcher)

Mean annual rainfall in the study area was approximately 1,810.58 mm/year. Figure 25 shows the monthly rainfall record from 1975-2014 in the study area**.** Significant rainfall occurs from May to September, and little or no rainfall from November to February. The maximum recorded monthly rainfall was 831 mm in September 1986. The graph (Figure 25) also shows that from May-September is the rainy season, whereas November-February is the winter season.

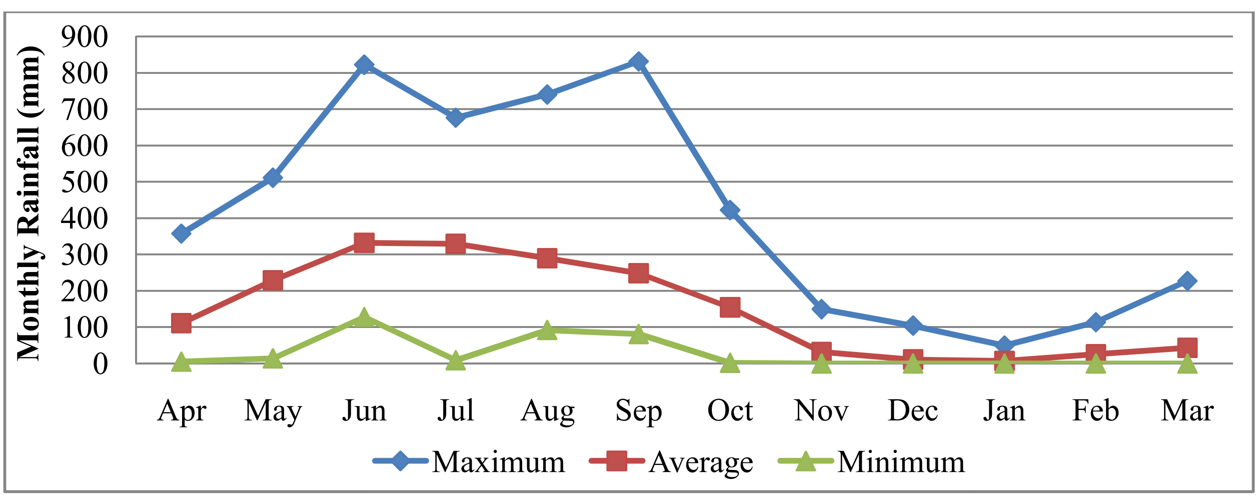


Figure 25: Monthly rainfall in the study area (data from BMD, analysed by the researcher)

3.4 Impacts of Climate Variability and Changes

3.4.1 Climatic shocks ranking

During the reconnaissance study, fishers identified the major climate shocks which affected them throughout their lives including their fishing activities. The ranking of climatic shocks were based on the respondents' opinions. The climatic shocks were ranked (higher to lower) order as: [storm>low rainfall>high temperature>low temperature>fog](Figure 26). From the results, this study found that storm was the main climatic shock that affected the fishers' lives and livelihoods significantly.Finally the rank order of climatic shocks were verified through FGDs.

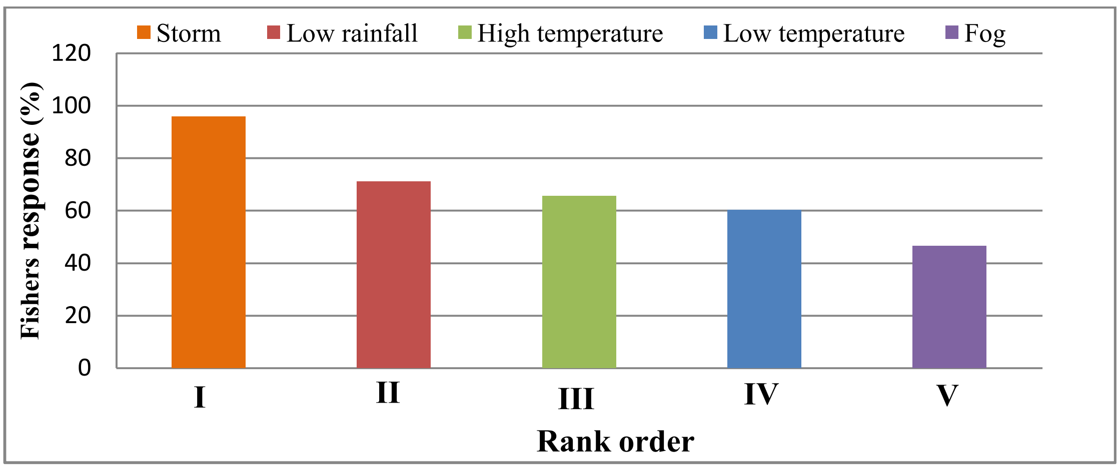


Figure 26: Rank order of the climatic shocks in the study area

3.4.2 Climatic impacts ranking

From household interviews, the major climaticimpactsin fishers lives were identified. The ranking of climatic impacts were based on the respondents opinions. After that it was verified through focus group discussions. The climatic impacts were ranked (higher to lower) order as: [reduced availability of fish catch>destruction of fishing equipment's>riverbank erosion>physical injuries>drought](Figure 27). This study revealed that reduced availability of fish catch was the main climatic impact in the study area. Storms damaged the fishing equipment (boats, nets, traps etc.) and caused physical injuries to the fishers mostly than other climatic shocks. Riverbank erosion displaced the fishers to other area. This climatic impacts also forced them to seek other livelihood options except fishing.

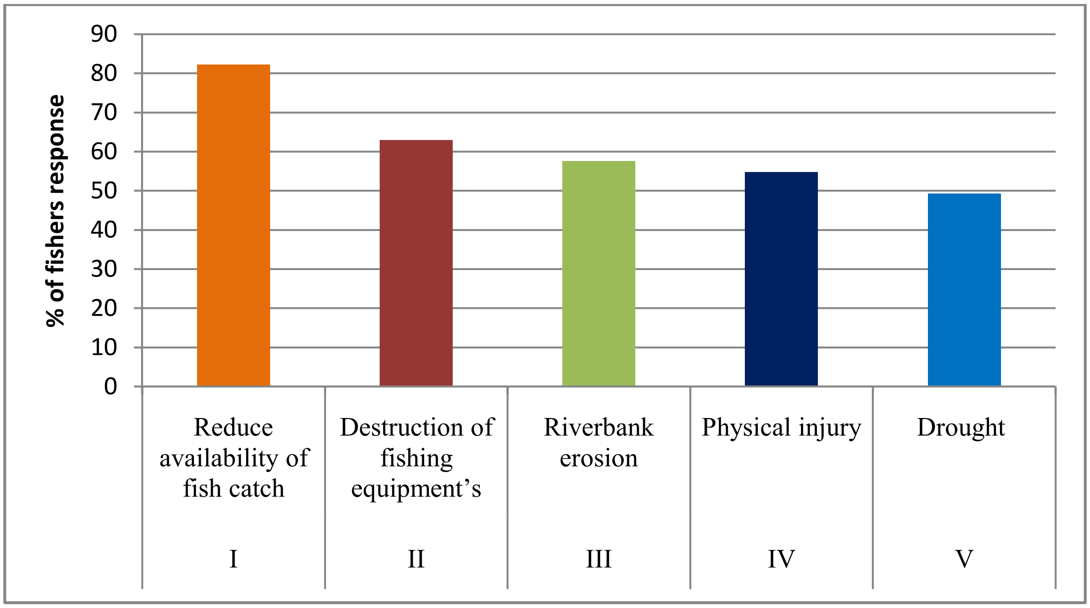


Figure 27: Rank order of climatic impacts faced by the fishers in the study area

3.4.3 Impacts of storm

This study found from household interviews that storm was the main climatic shock that has great adverse impact on the fishing activities and the fishers lives. Storms damaged or destroyed the fishing equipment (boats, nets, traps etc.) and caused physical injuries as well as loss of fishers lives. In this study, storms had broken/damaged 89.0% fishers fishing equipment followed by 57.5% had lost one of their fishing equipment in the Padma river. In 1998 Hurricane Gilbert destroyed 90% of traps and 5% of boats of Jamaican fishers resulting in a loss of revenue and high cost of repairs (Aiken *et al*., 1992).

From FGDs this study found that storms also impact on the physical capital of households or of entire communities, leading not only to decreased harvesting capacity but also to the disruption of infrastructures and services that support livelihoods.

From household interviews, it was found that storms damage physical assets such as fishing boats, nets and gears. Four fishers during interviews reported that they had lost their boats in the Padma river. One key informant reported that fishers lost their fishing nets (large size nets such as seine and gill net) because they did not get enough time to pull those before leaving the river to nearby safe place to save their lives. Storms also uprooted the fishing traps that lost in the river water. In this study, fishers also reported during household interviews that they lost their houses and other infrastructures as a result of storms. So more specifically storm can destroy or severely damage productive assets and infrastructures that agrees with the findings of Adger *et al*. (2005b), Westlund *et al*. (2007), Jallow *et al*. (2009), and Ahmed and Troell (2010).

The loss of productive physical assets and infrastructures can deteriorate the financial condition of the fishers that have significant effects on their livelihoods. Badjeck *et al*. (2010) reported that the loss of houses and community infrastructures can result in displacement, and more broadly disruption of livelihoods.

This study found from FGDs that storms not only damage or destroy physical assets but also can affect the human capital, ranging from safety-at-river to food security. From household interviews, it was found that 91.8% fishers became physically injured (which creates a substantial risk of death, or which causes serious disfigurement, serious impairment of health or serious loss or impairment of the function of any bodily organ).

Physical injuries can reduce the physical capabilities of fishers to operate fishing activities that finally affect their livelihoods(Badjeck *et al*., 2010). One direct impact of storms is loss of life (Islam *et al*., 2014). The loss of lives can be the most dramatic impact of extreme climatic events on human capital, affecting not only surviving household members but also potentially disrupting economic and social activities and systems outside the immediate family (Westlund, 2007). During household interviews, one fisher said, “About 8-10 years ago, three fishers were died on a storm and their fishing equipmentwere lost in water as a result of boat drown”. Two respondents also added that one fisher was died in 2010 for that reason. One of the most devastating cyclones and associated storm-surge-induced floods killed 300,000 people in coastal Bangladesh in 1970 (IPCC, 2007) many of whom were from fishing communities that agrees with this study.In 2007, Cyclone Sidr, struck the south west coast of Bangladesh with an average wind speed of 223 km per hour, causing 3,406 casualties, 55,282 injuries and affecting 8.9 million people (GOB, 2008).

Most of the fishers (98.6%) reported during household interviews that storms had decreased fish catch. Ahmed and Troell (2010), Badjeck *et al*. (2010) and Islam *et al*. (2014) also found reduced fish catch due to storms.

Reduced fish catch means reduced income for fishers which affect their livelihoods negatively.

3.4.4 Impacts of rainfall change

This study found from FGDs that currently the Padma river is facing low level of water due to low rainfall in the rainy season and high temperature in summer. Low rainfall and high temperature jointly reduce the depth of water in this river. Islam (2004) and Vineis *et al*. (2011) also found that the Padma river water depth has reduced as a result of low rainfall. Reduced flow in the Padma river which can increase droughts and can reduce river productivity. As a result the opportunities for fishing in the river reduced and this may affect the rural livelihood systems and reduce diversity of rural livelihoods (Conway *et al*., 2005; Allison *et al*., 2009a).

From household interviews, 86.3% fishers reported that reduced rainfall is the main cause for yields reduction. This study also found from FGDs that easily operating fishing gears that intensify river fishing may also responsible for yields reduction due to low level of water. Again non-fisheries activities such as agriculture production can also be negatively impacted by variations in temperature and reduced rainfall in various parts of the world, particularly in Africa (Lobell *et al*., 2008; Thornton *et al*., 2011).

River is one of the important resources of inland capture fisheries which is linked to the livelihoods of a wide range of people across the country. Change in rainfall and temperature are one of the important climatic shocks that affects the fishers overall livelihoods.

So the dependency on fisheries decreases with time and fishers tend to change their traditional livelihood strategy.

3.4.5 Impacts of temperature change

Thisstudy found that temperature change affects the fishers fishing activities and their livelihoods. Higher temperature is also responsible for the reduced water level of the Padma river. From household interviews, 87.7% fishers reported that higher temperature decreased the fish catch in the Padma river.

Bhuiyan *et al*. (2008) reported that as a consequence of climate change the water temperature has increased that caused reduction of water flow and as a result spawning and nursing grounds of fishes have been drastically affected in recent years. Ali(1999) and Allison *et al*.(2009a) reported that higher water temperatures can change in sex ratios, alter the time of spawning and migrations which has possible impacts on timing and levels of productivity of freshwater systems. Jain *et al*. (2013) reported that the effects of higher temperature on fish are:- decreasing the availability of dissolved oxygen (DO) as a result of diminishing solubility in water, increasing metabolism, respiration and oxygen demand, militating against desirable fish growth and also higher temperature affects the spawning and hatching of eggs in natural environment. Johnson (2012) reported that in Alaska increased stream temperature as a result of high temperatures and lower water levels in fresh water systems can reduce the productivity of spawning and rearing waters. According to O'Reilly *et al*. (2003) fish production has declined in Lake Tanganyika in the recent past largely due to increasing temperature.

In winter the metabolism and growth rate of the fish reduced as a result of low temperature (Halver and Hardy, 2002). Cold waves affects breeding performance and growth of fish species which reduces fish production. Besides, fogginess causes fish mortality in aquaculture pond and small water bodies due to depletion of DO (Rahman *et al*., 2009).

This study shows that cold waves and fogginess also adversely affect fisheries.From household interviews, 95.9% fishers reported that in winter season, they could not catch fish due to low temperature and dense fog. As a result their yields reduced that created negative impacts on their livelihood.

All the migratory fishers reported in FGDs that during cold waves and dense fog, they could not fishing and for this they went back to their home. But 5.56% non-migratory fishers reported during interviews that they were bound to catch fish in that harsh weather for supporting their families. Islam(2013) reported that fish processing, especially open sun fish drying can be drastically affected by low temperature. Manandhar *et al*. (2011) also reported that cold wave combined with dense fog has an adverse impact on agriculture as well as on the livelihood of rural people.

So temperature change has negative impacts on the fish production as well as fish catch.Reduced fish catch means reduced income for fishers which affect their livelihoods negatively.

3.4.6 Impacts of riverbank erosion

From reconnaissance study, this study found that riverbank erosion is one of the climatic impacts that faced by the both fishing communities(Figure 28). River erosion in Bangladesh is no less dangerous than any other sudden and devastating calamities. Though losses are slow and gradual due to river erosion, but they are more destructive and far-reaching. It takes a few decades to make up the losses, which a family has incurred by river erosion.

From household interviews,this study found that 96.30% non-migratory fishers were victimized as a result of riverbank erosion.Anik *et al*.(2012) reported that more riverbank erosion occurred in the winter seasons when water level became lower in the river.A study of CEGIS (2005) shows that bank erosion along the Padma river during 1973-2004 was 29,390 ha. While the erosion of 230 sq. km of Bhola Island, as well as 195 sq. km of Hatiya and Sandwip Islands were due to the shifting flow of the Meghna river channel (Pender, 2010).

Recurrent displacements are common in the study area. The constant threat of riverbank erosion has contributed to a substantial disaster subculture in the study area. In 1995, the Flood Plain Coordination Committee estimated that riverbank erosion caused over 728,000 people to be displaced between 1981-93 along the Jamuna, the Ganges-Padma and the Meghna rivers (Mutton and Haque, 2004).

From field observations, this study found that erosion by the Padma river has taken a serious turn in Harirampur upazila. The embankment that was made to control riverbank erosion in

Harirampur upazila in 2007-08 has already broken. But comparing Dhulsura to Andharmanik, situation is very poor. There was no embankment for controlling riverbank erosion. From FGDs in Dhulsura, it was found that the Padma river has shift about 100 m north-east in 15-20 years. One key informant reported that due to uncontrolled riverbank erosion, the socio-economic developments of Dhulsura were very poor.

Like storms (see section 3.4.3), river bank erosion can also directly impact on the physical capital of households or of entire communities. The loss of physical capitals can deteriorate the financial condition of the fishers that have significant effects on their livelihoods (Badjeck *et al*., 2010). Again most-affected fishers are unable to raise formal bank loans due to lack of collateral. Finally river bank erosion results in displacement and broadly disruption of livelihoods of the fishers. The displacement and resettlement of households due to river bank erosion will involve extra cost and may cut support from some relatives and friends that create impacts on both financial and social capital (Islam, 2013).

a b

Figure 28: Riverbank erosion in the study area: a) Riverbank erosion in Dhulsura and b) riverbank erosion in Andharmanik

About 6.8% respondent in the study reported that fishing was not their family traditional occupation but due to loss their houses and agricultural lands in the Padma river, they were forced to choose fishing as their livelihood supports. Increased riverbank erosion displaced the fishers permanently to other area.One fishers in Dhulsura said “I and my family have experienced displacement as many as seven times due to river erosion”.

Riverbank erosion causes physical and financial losses that affect fishers livelihoods negatively.

3.4.7 Overall impacts of climate variability and changes

Small-scale fishing is a high-risk activity (Coulthard, 2009). Again, climate variability and changes may threaten this fishing activity further in risk (Daw *et al*., 2009).

In this study, storms not only damage or destroy physical assets (boats and gears) but also can affect the human capital (physical injuries or even loss of lives). The loss of productive physical assets and infrastructures can deteriorate the financial condition of the fishers that have significant effects on their livelihoods. Physical injuries can reduce the physical capabilities of the fishers to operate fishing activities, as a result fishing duration reduced that decreased the fish catch (Ahmed and Troell, 2010; Badjeck *et al*., 2010) and finally reduced incomes from fishing. Again river bank erosion also causes physical and financial losses. The displacement and resettlement of households due to river bank erosion will involve extra cost (Islam, 2013). But the affected fishers are unable to raise formal bank loans due to lack of collateral.

Reduced water level and high temperature affected fish spawning, nursing grounds and migrations (Ali, 1999; Bhuiyan *et al*., 2008; Allison *et al*., 2009a) that results in reduced fish catch. Again impacts on fish stock and fishing activities can in turn have an adverse effect on fisheries ancillary activities such as boats and gears making, and ice supply may be reduced due to lesser demand in the event of reduced fishing due to unfavourable weather conditions (Islam, 2013). Reduced fishing may reduce employment and nutritional intake in the fishing communities and beyond. Decreased catches may increase the risk of malnutrition or under-nutrition for communities highly dependent on fish for a source of protein (Ogutu-Ohwayo *et al*., 1997). Reduced fish catch means a reduced supply of fish for processing which may result in market instability.

So this study found that climate variability and change negatively affect fishers lives and overall livelihoods.

3.5 Coping and adaptation strategies

From reconnaissance study, it was found that livelihoods in Andharmanik and Dhulsura have been influenced by climatic shocks and stresses. In this study, 95.89% fishers reported during household interviews that climate variability and changes had affected their livelihoods, while 4.11% fishers opposed who had not noticed any difference in their livelihood(Figure29). Climate variability and changes such as occurrence of storms, changes in rainfall, changes in temperature, riverbank erosion and drought (see section 3.4) impacted their livelihoods in many ways including reduced availability of fish that means a reduction in fish catch, destruction of physical assets and infrastructures, yield risk of health and life, and consequently a decline in their income and consumption. Therefore, the fishers will have to seek coping and adaptation strategies in order to sustain their livelihood.

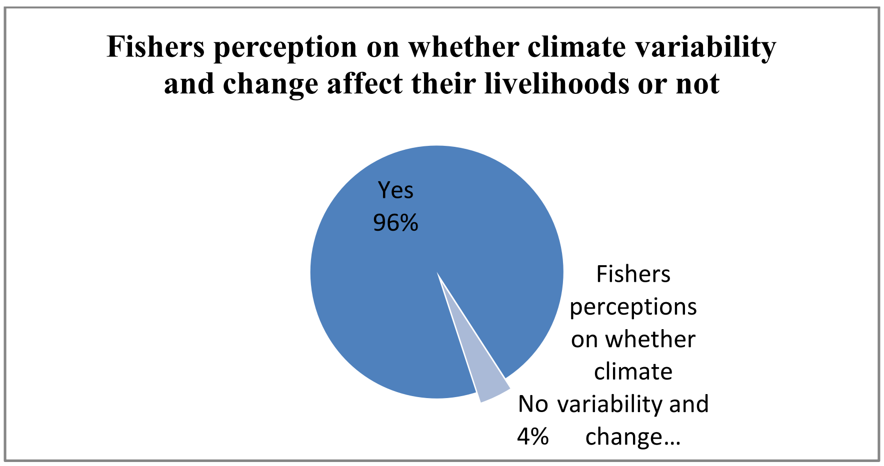


Figure29:Fishers perception on whether or not climate variability and changes affect their livelihoods in the study area

3.5.1 Response to storm

In this study, storm was the main climatic shock that significantly affected fishers livelihoods (see section 3.4.3). So fishers had taken some coping and adaptation strategies to response against storm. The most important coping strategy for the fishers at the time of storm is taking shelter in nearest safe places. About 94.5% respondents in this study reported during household interviews that they usually tried to minimize the impacts by spatial movement into the river.

If the fishers recognize that a storm would be occurred, then they usually do not go out for fishing in the Padma river. But at the time of fishing in the river, if a storm occurs, then the fishers try their best to pull their fishing nets very quickly before leaving the river to nearby safe place to minimize the impacts.

Most of the fishers in this study (from FGDs) had taken shelter to the nearby river bank or "*Ghop*" (nearby canal where wave and air flow is low) during storm to minimize the impacts. Sometimes they tried to keep their boats in the nearest "Char" (a land that emerged from the water) and praised to the God. When the fishers (4.15%) found no safe place to take shelter, then they were stayed in the boat. As the fishers in this study mainly dependent on the Padma river fisheries, so they cannot avoid storm to skip fishing activities.

From household interviews, this study found that making non-mechanized boat mechanized was one of the adaptation strategies of the Padma fishers. Mechanized boatshelped the fishers to move faster in the river during storm. One respondent from Andharmanik said during interviews "about 10 years ago, I used non-mechanized fishing boat. But at the time of storm, I cannot move quickly to take shelter in nearest safe place. So I buy mechanized boat and now I can move quickly".

Since both in Andharmanik and Dhulsura have no shelter house for storms and floods,sothe fishers take shelter in the primary school during storms or floods.

To repair the physical assets and infrastructures that were broken or damaged by storms, fishers selling their productive assets such as gold or livestock (cows, goats etc.), and take informal sources of credit that are only available to fisherfolk, typically with high rates of interest, and unfavorable terms and conditions (Tietze and Villareal, 2003) as a coping strategy.Since fishers income reduced as storm decreased fish catch, so they reduced their household consumption as a coping strategy.

There is uncertainty as nobody knows, what would be happened in the river, if a storm would occurat that time of fishing. For this and other impacts that are mentioned above (see section 3.4), influence the fishers to involve with other non-fishing activities, and more broadly result in disruption of fishers livelihoods (Badjeck *et al*., 2010).

3.5.2 Response to rainfall and temperature change

In this study, it was found that reduced rainfall and high temperatures negatively affected the fishers overall livelihoods (see section 3.4.4 and 3.4.5). So the fishers had to take some coping and some adaptive strategies to overcome the impacts. The most common coping strategies were selling their productive physical assets or livestock to makeup short term impacts. Others coping strategies were reduced household consumption, taking loans from friends, relatives or others.

This study found another strategies against decreasing fish catch was to increase the number of hours spent in fishing and use of more efficient fishing gears. About 86.30% fishers in this study had increased their fishing duration while 13.70% fishers average time spent in fishing was unchanged (Table 9). After taking this strategy, the fishers average time spent in fishing was increased 4.5 hrs/day. This study also found that 42.46% fishers changed their fishing gears to catch more fish. In this study, mainly the non-migratory fishers replaced their cast/lift nets with seine and gill nets. But migratory fishers did not change their fishing gears, as they used large sized seine and gill nets. Another strategy was to increase the numbers of fishing gears by using an additional type of gear or using additional traps. In order to increase the number of fishing gears used, unlike the fishing hours, the fishers bear a financial cost. However, it is difficult to discern whether these responses were adaptation strategies or one-off coping strategies for the dramatic decrease of catch.

As pointed out in the introduction (section 1.4), a coping strategy may overlap and develop into an adaptation strategy. Fishers in this study practiced above strategies (increasing per day fishing duration, using more efficient fishing gears and increasing number of fishing gears) about 5 years or more to increase their income from fishing. So this study regarded these strategies as adaptive strategies.

The fishers who had not increased their per day fishing duration would they had sufficient income to support their family or other sources of opportunities to help them in that adverse conditions.

Table 9: Changing fishing duration of the fishers in this study

No. of fishers	Spent time in fishing (hrs/day)		Change
	5 years ago/more	Present	
7	8	15	7
9	9	14	5
6	10	16	6
10	11	14	3
13	12	15	3
18	13	16	3
2	10	10	-
3	11	11	-
1	12	12	-
4	13	13	-

From FGDs, this study found that because of reduced yields, fishers co-opted with other non-fishing activities to support their livelihoods (see section 3.5.4). Daw *et al*. (2008) noted that during drought the fishers around Lake Chilwa in Malawi opt for other sources of livelihood due to reduction on yields that indicate diversification of rural livelihoods.

During heavy rainfall and scorching sun to catch fish in the river was difficult for fishers. Three non-migratory fishers during household interviews said “We were roasted under scorching sun during fishing in summer as we had no shed in our boat. So we made shed for protecting us from this”. From reconnaissance study,it was found that all the migratory fishers having large boats with shed as they stayed on their boats most of the time.

Judging from the number of cases, intensification of fishing (increasing fishing hours and number of fishing gears) surpassed the diversification of income source (farming agriculture, farm labour, driving vehicles and doing other jobs). The reasons would be like as the fishers take the response that incurs the least (financial) cost. From this point of view, increasing fishing hours requires only more labor (i.e. does not bear any financial cost). If there were ample alternatives that would make the opportunity cost of labor high, they would not have taken this choice to invest more labor on this scale. However, in reality, as described earlier, the income from fishing, becoming curtailed as a result of climatic variability and changes. Subsequently, fishers spend extremely long hours on a boat, trying to exploit the decreasing resources further since they have no other choices. Fishers who have the money invest in more gear, but who are not capable to do that they switch fishing and involve in non-fishery related activities.

3.5.3 Response to riverbank erosion

In this study, tree plantation wasone adaptation strategy for controlling riverbank erosion in the study area. During household interviews, 21.9% fishers reported that they planted trees surrounding their houses to control riverbank erosion or minimize losses from storms.

Embankment construction

In this study, embankment construction was one of the important adaptation strategies for controlling riverbank erosion. From reconnaissance study, it was found that to protect Harirampur upazila from the Padma river bank erosion an embankment was constructed by BWDB in Andharmanikbut. But there found no embankment in Dhulsura.

Embankment construction is an important adaptation strategy for controlling river bank erosion but when it has been constructed in a unplanned way, it would be referred as "maladaptive strategy".In this study, 61.11% non-migratory fishers in Andharmanik considered the embankment construction in Harirampur upazila as a maladaptive strategy (see section 3.6).

Migration

This study found that migration was another important adaptation strategy for riverbank erosion in the study area. During household interviews, most of the non-migratory fishers (96.30%) reported that they had migrated to other distant villages or area as an adaptation strategy of riverbank erosion. Migration may reduce exposure to climatic shocks and stresses for the people (Warner *et al*., 2008). On the other hand, migration may also lead to increased vulnerability, poor livelihood outcomes or maladaptation (Reuveny, 2007).

From FGDs, this study found that fishers had to sell their productive physical assets, reducedtheir household consumption and took some informal loans to cope with the physical and financial losses that occurred as a result of riverbank erosion.

This study found from household interviews that displacement of non-migratory fishers in Andharmanik was comparatively low than Dhulsura. One respondent from Dhulsura during interviews said “I already migrated 7 times as a result of river bank erosion”. Riverbank erosion not only displaced the fishers but also forced them to change their fishery dependent livelihood strategy (see section 3.5.4).

Migration outcomes are influenced by the degree to which migrants depend on the environment for their livelihood and social factors mitigating or exacerbating the impact of climatic stresses and shocks (Kniveton *et al*., 2008). Islam (2013) reported migration may be a viable strategy to respond to climate variability and change and it has generated several positive outcomes for households that resettled.

Cernea (1997) reported that forced migrants can face landlessness, homelessness, under-employment, marginalization, food insecurity, reduced access to CPR and ill health. The migrants may also lose their lifestyle, culture and identity (Mortreux and Barnett, 2009).

3.5.4 Livelihood diversification

In this study, it was found that climate variability and changes significantly affected the fishers livelihoods in the study area (see section 3.4). From household interviews, this study found that livelihood diversification was one of the important adaptation strategies in both the study sites. The livelihood diversification strategies wereagriculture, farm labour, driving vehicle, small business, collecting and selling fire wood(Figure 30). But 42.5% fishers waited for favorable condition rather involving with other livelihood options.

This study also found that the livelihood strategies of non-migratory fishers variedin comparing migratory fishers. From FGDs, this study found that fishers who had diversified livelihood strategies were less vulnerable compared with those that depended solely on fishing.

It has been argued that more diverse fisheries livelihood systems can better adapt to climate change, including climatic disturbances (Allison *et al*., 2007; Turner *et al*., 2007; McClanahan *et al*., 2008). Diversification includes occupational multiplicity (several income generating activities), occupational mobility and diversification outside fisheries (entering or exiting the fishery sector), geographical mobility (migration) (see section 3.5.3) and diversification within-in the fisheries sector (species, multiple gears) (Allison and Ellis, 2001; Brugere *et al*., 2008; Wouterse and Taylor, 2008).

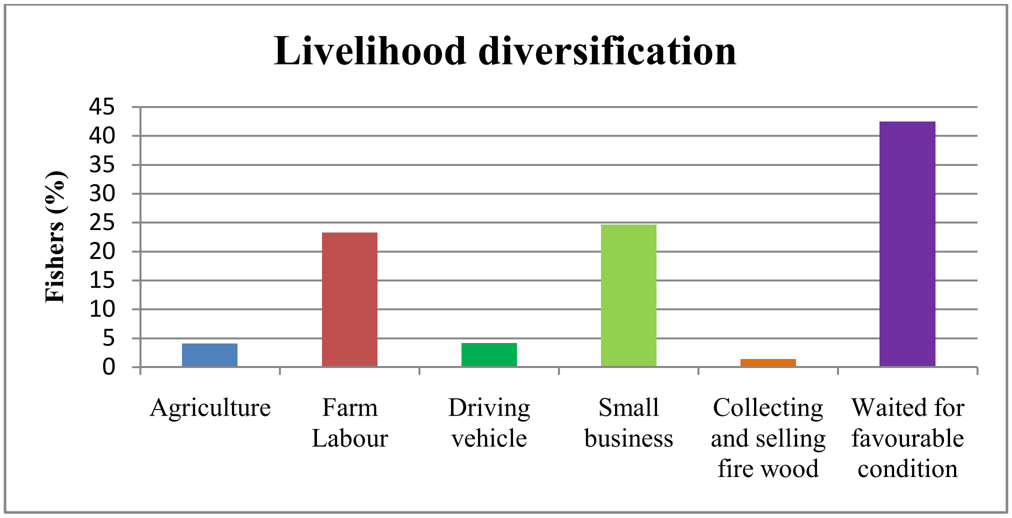


Figure 30: Livelihood diversification of the fishers in the study sites

Occupational mobility in response to climate variability and change is also a common practice in fishing communities. In Lake Chad fishing families diversify into farming (Sarch and Allison, 2001) while droughts affecting agriculture in Africa may encourage more fishing activity (Conway *et al*., 2005).

Diversification through occupational multiplicity is also a primary means by which many individuals reduce risk and cope with future uncertainty (Ellis, 2000; Barrett *et al*., 2001; Wouterse and Taylor, 2008).

3.5.5 Overall coping and adaptation strategies of the fishers

In this study, the overall coping strategies include selling productive assets or livestock, reducing household consumption, employing their children in fishery related activities rather send them to school, temporarily migration, taking loans and in case of storms taking shelter in the nearby canal or ghop.

Adaptation strategies include embankment construction, permanent migration, diversifying livelihoods, increasing the number of hours spent in fishing, using more efficient fishing gears, increasing the number of fishing gears and using mechanized boat for fishing.

In this study, the most common form of coping strategy was the selling of productive assets such as gold or selling of livestock (cows, goats etc.). From household interviews, it was found that 86.30% fishers sold their gold or livestock. Reducedhousehold consumption to cope with reduced income from decreased catch results in malnutrition and under-nutrition (Ogutu-Ohwayo *et al*., 1997). One key informant reported that fishers were taking action against the decreasing catch, but they had to sell what they had saved from their meager income. Due to the reduction of yields, the fishers spent their maximum efforts on intensifying fishing that was the only means that they were able to adopt without any cost.

From FGDs, this study also found that 52.05% fishers stop their children from going to school and involve them in fishing to support their family. Chowdhury *et al*. (2011) reported that due to worse overall socio-economic situation along the Naaf river than the rest of the country as a result of low incomes, which led to children being co-opted in fishery activities rather than taking education among the fishing communities.

Since more than half of the fishers had no education (see section 3.1.5), so they could not take proper adaptation strategy to minimize the impacts. Education and skills upgrading are powerful adaptive strategies for individuals, families and communities (Perry *et al*., 2010). Higher educational attainment may enable fishers to make a broader series of choices, ranging from engaging in safe construction practices to assessing potential risk that result in fewer deaths when an extreme event strikes (Skidmore and Toya, 2007) like storm.

3.6 Maladaptation in the study area

Since 1960, hundreds of water resource development projects have been implemented in Bangladesh including Flood Control and Drainage (FCD), Flood Control, Drainage and Irrigation (FCDI), closures of rivers and canals, channel diversions and withdrawal of water from rivers and natural depressions (beels) for irrigation in the dry season (Ali, 1997). Through these projects the entire country has been converted into a series of polders with earthen embankments. The potential impacts of these development projects on fish and aquatic resources were not considered at the time of planning, design and implementation. The natural migration and recruitment of fishes, and other aquatic animals between rivers and floodplains have been obstructed. As a result, many fish and prawn species of rivers, floodplains and estuaries have become threatened and endangered (IUCN, 2000). Therefore, this water resource development projects can be treated as maladaptation. This maladaptation can result from lack of inter-sectoral coordination.

In this study, it was found that unplanned embankment construction in Andharmanik(see section 2.2.1) had disconnected the Padma river from the nearby beel named"Diyar Beel" and associated floodplains.

The respondents in this study also reported that during floods and heavy rainfall, fish comes from Asam and hilly areas, and small size fishes, eggs, larvae, fingerling, juveniles etc. can go to the nearby beel and "*Chok*" (rice field) with river water before the construction of embankment. But after the construction of embankment, river water cannot go in the beel and rice field, and as a result fish catch reduced by 20%, as estimated by the FGDs participants. Another study showed that fish production can be 50% lower inside flood control schemes compared to outside mainly because of diminished recruitment of migratory fish (Halls *et al*., 1998; Halls *et al*., 2008).

The negative and deleterious impacts of water resource development projects on fish and fisheries of Bangladesh have been studied regionally under the Flood Action Plan (FAP) of the Ministry of Water Resources (MWR). Impact studies of Northwest and Southwest regions covering most of the Ganges-Padma and the Brahmaputra-Jamuna river systems were conducted under FAP-2 and FAP-4 (Ali, 1997).

The Northwest Regional Study conducted under FAP-2 (1991) revealed that fisheries have been identified as one of the worst sub-sectors that affected by flood control developments projects in Bangladesh (Ali, 1997). Construction of a large number of flood protection embankments around and within the floodplain areas under FCD and FCDI projects adversely affected the ecosystem and the habitats of fish populations. An estimated 2.0 million ha of floodplains will be lost to fisheries due to water development projects by 2005 with a loss of fish production of over 1.0 million MT per year (Mazid, 2002).

The Ganges-Padma and Brahmaputra-Jamuna rivers run throughout the Northwest region. Tsai and Ali (1985) identified the existence of two stocks of major carps in these rivers. For the Padma river, the causes of stock decline are: i) construction and operation of Farrakka Dam in India has changed the water flow regime and hydrology of entire the Padma river basin, destroying most of the major carp habitats and also Hilsa migrations and ii) construction of embankments on both banks by the Ganges-Kobadak project further reduced carp habitats. The reasons for the decline of the Brahmaputra river stocks are: i) construction of embankments on the banks of Brahmaputra-Jamuna river that eliminated large proportions of the habitats of major carps, particularly in the Rangpur, Bogra and Tangail basins; ii) heavy sedimentation that occurs in the main stem of the Brahmaputra-Jamuna river and Old Brahmaputra river.

Due to the above changes in the upper and lower the Padma River fisheries there showed major changes with production declining from 5,000 MT in 1983-84 to only 1,000 MT in 1991-92 (Rahman *et al*., 2003). The negative impacts of the Farrakka and other barrages severely affected spawning, nurseries, feeding migrations, and also increased fishing pressure in the upstream river. As a result, landings of Hilsa and other fishes from the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna rivers have sharply declined recently in the country (Mazid, 1998). In particular, reduction of Hilsa catches in those water bodies alone threatened the livelihood of about 2.5 million people engaged in full time fishing.

The Southwest Regional Study conducted under FAP-4 (1993) also revealed that flood control structures destroyed fisheries and caused the destruction of many resident brood stocks of fish. River flows have been altered in both in depth and the duration of flooding, and with it changes in the pattern of siltation that caused detrimental effects on riverine fishes and prawns. Consequently, fisher’s catches and earnings have been reduced and some full-time fishers had to seek other livelihood options to support their families or otherwise move elsewhere (Ali, 1997).

The annual inland capture fisheries in the Southwest region declined from 169,600 MT/year in 1983–84 to 119,100 in 1988–89, a net decline of 50,500 over a span of only 6 years (DoF, 2005). In the upper Padma river where fisheries showed major changes, fish production fall of 85% (Ali, 1997).

In this study, the fishers of the Padma provided some solution for this maladaptation. These include if there constructed few culvert in the embankment, then fish could go in the rice field/beel and catch may increase.

3.7 Future adaptation strategies

The climatic variability and change has continuously affected the fishers fishing activities and livelihood strategies. If it continues, then fishers have to seek alternate livelihood strategies to support their family. As a reactive or responsive adaptation strategies, most of the fishers (76.71%) want to take various adaptation strategies. The livelihood strategies that they want to do (Figure 31) are- farm works as labourer, small business, driving vehicle, farming agriculture, household works as labourer and others. But 23.3% fishers reported that they waited for favorable condition for fishing in river. In the mean time they would take loan/dadon from the local money lender/mohajon/aratdar etc.

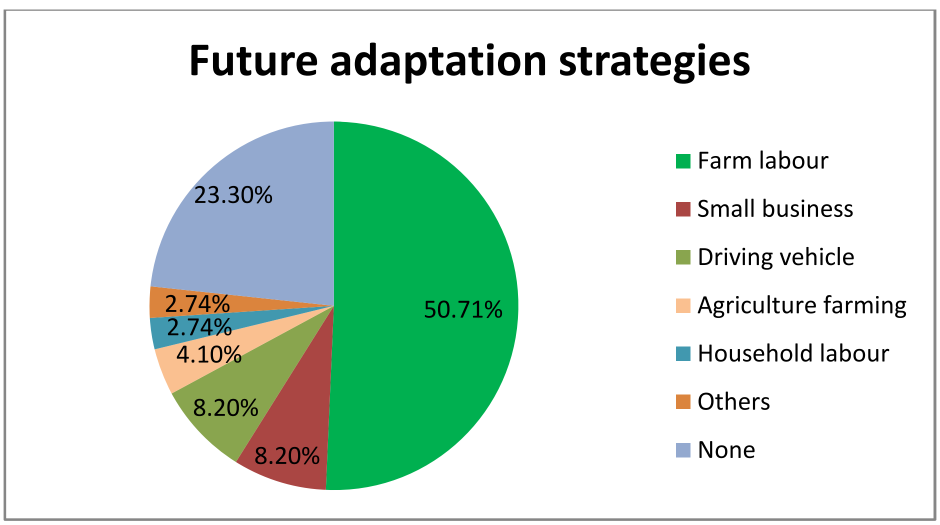


Figure 31: Future adaptation strategies of the fishers in the study area

The results of this study were verified by three household interviews and one FGD at the end of the study. Results from verification study were consistent with the overall findings of the study.

Many researchers cite as a limitation the difficulty generalizing the results to a wider population due to sample size (Hartman and Jugdev, 1998; Schmidt *et al*., 2001), their limited views or specific agenda (Nambisan *et al*., 1999; Niederman *et al*., 1991), and their geographic location (Brancheau et al., 1996). Most researchers recommended further study to refine and verify their results (Keil *et al*., 2002; Nambisan *et al*., 1999; Wynekoop and Walz, 2000), to investigate related sets of research questions (Brancheau *et al*., 1996; Niederman *et al*., 1991), to extend the results to a similar sample, but from other geographical locations (Brungs and Jamieson, 2005) or to an entirely different sample (Schmidt *et al*., 2001). Verification studies can provide rich research opportunities for new researchers.

CHAPTER 4 – CONCLUSIONS

4.1 Summary of the theoretical contribution

This study has assessed the impacts of climatic variability and change and adaptation strategies of the migratory and non-migratory fishers of the Padma river in Manikganj district in Bangladesh.

Following a mixed-method approach the data were collected using semi-structure face-to-face interviews survey, FGDs and key informant interviews as well as from secondary sources. The use of a mixed-method approach throughout the study, has retained rigour through triangulation of data sources while permitting flexibility in data collection and gathering richer in-depth data to deepen the understanding of the issues in this thesis.

Based on the findings of this study it can be said that the fishers of the Padma river have been impacted by several climatic shocks and stresses. Almost all the fishers of the Padma river and their livelihood strategies will face the impacts of storms, low rainfall, high temperature, riverbank erosion and drought, as these are predicted to be exacerbated due to climate change in future. This study also assessed that the fishers have traditionally coped with or adapted to the normal range of climate impacts but not always sufficiently well. In the coming decades the vulnerability of fishery-based livelihoods may substantially increase because of climate change.

Without proper adaptation strategies, increased levels of frequency and intensity of storms will result in greater damage to fishing boats, gear and other physical infrastructures, especially a loss of fishery-related income. It can also cause physical injury as well as greater loss of life.

So the findings of this study indicate a continuous research for proper documentation to the impacts of climate variability and change, in order to move forwards to take a proper improved adaptation strategies to overcome the impacts.

4.2 Summary of practical contribution

This study has focused on the local level to draw detailed insights of the impacts of climatic shocks and stresses and adaptation strategies of the fishers of the Padma river.

The devastating effect of climate change and variability can be seen mostly in geographically vulnerable countries, including Bangladesh. Every year Bangladesh loses much of its resources due to climate variability and change and in recent years all these climatic events have increased their magnitude and frequency.

Therefore, in this thesis, the main focus was to develop an understanding of the fishing activities, climatic impacts and adaptation strategies of the Padma river fishers who are dependent on the Padma river that are vulnerable due to the possible impacts of climate change. To do so, the impacts of climatic shocks and stresses on the Padma river fishers and their adaptation strategies were analyzed.

High temperature and low rainfall can have direct impacts on the water body of the Padma river, which is the only fishing ground for the fishers of Andharmanik and Dhulsura. Riverbank erosion which is a regular and common phenomenon in our country and as a result it displaces the fishers who are living nearby the riverbank. So a comprehensive riverbank erosion management policy should be made nationally. But it must be considered that no development plan that hampers the natural flow of the river should be taken. Timely and effective erosion control measures should be important consideration while making plan.

Migration is one of the adaptation strategies as a result of riverbank erosion. So proper steps for relief and rehabilitation for the migrants should be taken. Development Program for resettlement of migratory fishers can be introduced.

However, caution should be maintained as some adaptation strategies may be maladaptive to other systems. For example, the construction of embankment to protect the Padma riverbank erosion in Andharmanik that disconnected the junction between the Padma river and the nearby beel and associated floodplains.

Through proper education and skills development, the fishers of the Padma river could diversify their livelihood strategies by involving with others activities that are less affected by the climatic variability and change and make them less dependent on climate vulnerable the Padma fisheries. Furthermore policy initiative will be successful if energy sector, telecommunication sector can develop. District and country level studies on these issues may help to generalize the findings. Future research also needs to look at how the implications suggested in this study fit into the wider development area.

This study tries to give a representation of the vulnerability of the Padma river fisheries; however it also suggests further studies on the coping mechanism and adaptation strategies related to decrease climatic shocks and stresses of the fishers of the Padma river in Manikganj, Bangladesh. With these understanding about the impacts and adaptation of the Padma river fisheries dependent communities it will be possible to develop appropriate policies and strategies to reduce the impacts and enhance sustainable adaptation for them. This will ultimately play a significant role in poverty reduction of the dependent people and sustainable development of the country, more broadly.

4.3 Limitation of the study

This study was an academic one with limited time, money constraint and small study area. So, it was probable to have some errors. During fieldwork some odds had to face in collecting data and documents. They were given below-

Time and money constraint: The study area was comparatively remote, so frequent accessibility was difficult. Time provided for the study was very limited. Time for collecting data was not enough. Also qualitative study required more time to analyze the collected data. At the same time, extra time was required to design the research in the light of new developments and insights. To save time, the data collection had been done to reside in the study area some days. Amount of money was also a constraint for this study.

Non-availability of data and documents: Availability of local meteorological data series were limited that might make impact on the climate of the study area. For collecting reliable data, a good understanding between the interviewer and informants was required. If the informants could not take the interviewer with confidence, they might be conservative in providing proper information. For that this study had to give enough time to make good rapport with key informants. But with limited time, it was difficult to ensure that. Another challenge was the difficulty in having documented information from officials. Sometimes documents might not be found readily available and considered confidential. Sometimes the public offices simply declined to provide any data. In case of this study, it was found that getting data from the public offices were quite tough.

Selective study area: The study area was small and selective. There might be some variations as sample was taken from a particular geographical location for time and budget constraint. For this there was a weakness to make statistical inferences (generalizations).

4.4 Future research suggestions

Climate variability and change have the potential to make fishers livelihoods more vulnerable, but they are only occasionally investigated in the context of developing countries or investigated in other sectors such as agriculture. A detailed study on how fishers are vulnerable to past and current climate impacts can provide important insights to address the enhanced level of future impacts or reduce vulnerability for them. Fishers adaptation strategies are also very important to assess. In order to draw general conclusions more confidently on the impacts of climate variability and change and adaptation strategies of the fishers to it, a wide range of in-depth climate data analysis would be required.

To establish with more confidence that migration and livelihood diversifications can be a viable adaptation strategy to climate change, more evidence is needed on its supports from other contexts. It is necessary to do more study on how migration will affect the fishers livelihood strategies. In order to build a strong scientific basis, more study is needed to accurately identify, measure and characterize the impacts of climatic variability and change that have faced by the Padma river fishers. Future study should focus on the better understanding of the ranking of climatic shocks and stresses and their impacts on the fishing activities and livelihood strategies of the fishers in order to develop robust means for overcoming them and enabling to take proper adaptation strategies.

This thesis focuses mainly on the fishers of the Padma river of two study sites (Andharmanik and Dhulsura) in Harirampur upazila, Manikganj district, Bangladesh. Taking into account the fishers of the Padma river of intra-Harirampur may provide some new insights of the impacts of climate variability and change and their adaptation strategies to overcome the impacts. The findings of such a study could also contribute to an understanding of these issues in other parts of the Bangladesh with similar environmental, socio-economic and livelihood conditions.

So more study is needed at multiple scales and sectors to find alternative livelihood strategies in the context of wider development. Cross nation comparative such studies may also help countries learn from each other. Government with the support of national and international organizations have to work on the issue of climate change by updating knowledge and developing technical skills of the human resources to mitigate the effect of climate change.

REFERENCES

ABOBI, S.M. and ALHASSAN, E.H. 2015. A Review of Fisheries-Related Human Migration in the Gulf of Guinea. *J. Coast. Zone Manag.***18**(1): 395.

ABURTO, J., GALLARDO, G., STOTZ, W., CERDA, C., MONDACA-SCHACHERMAYER, C. and VERA, K. 2013. Territorial user rights for artisanal fisheries in Chile–intended and unintended outcomes. *Ocean Coast. Manag.***71**: 284-295.

ADGER, W.N., HUQ, S., BROWN, K., CONWAY, D. and HULME, M. 2003. Adaptation to climate change in the developing world. *Prog. Dev. Stud.***3**(3): 179-195.

ADGER, W.N., ARNELL, N.W. and TOMPKINS, E.L. 2005a. Successful adaptation to climate change across scales. *Glob. Environ. Chang.***15**(2): 77-86.

ADGER, W.N., HUGHES, T.P., FOLKE, C., CARPENTER, S.R. and ROCKSTROM, J. 2005b. Social-ecological resilience to coastal disasters. *Science.***309**: 1036-1039.

AGRAWALA, S., OTA, T., AHMED, A.U., SMITH, J. and VAN-AALST, M. 2003. Development and climate change in Bangladesh: Focus on coastal flooding and the Sundarbans. OECOD, France.

AGRAWAL, A. 2010. Local institutions and adaptation to climate change. In: Mearns, R. and Norton, A. (eds.). Social dimensions of climate change: Equity and vulnerability in a warming world.World Bank, Washington DC. 173-198 pp.

AHMAD, N. 1962. Fishing gear of East Pakistan. Government of East Pakistan. Directorate of Fisheries, Dhaka. 37 pp.

AHMED, A.U. and MIRZA, M.M.Q. 1998. Review of causes and dimensions of floods with particular reference to flood'98: National perspectives. Perspectives on Flood 1998. University Press Ltd. Dhaka, 67-84 pp.

AHMED, M.K., AMEEN, M. and SULTANA, S. 2002. Impact of global climate change and variability on fisheries resources of Bangladesh. Water and Climate in Bangladesh. Dhaka: IUCN, Bangladesh.

AHMED, M.S., ALAM, M.S. and AKTHER, H. 2009. Livelihood assessment of a Jatka fishing community at north Srirumthi village, Chandpur, Bangladesh. *S. Pac. Stud.***29**: 1-12.

AHMED, N. and TROELL, M. 2010. Fishing for prawn larvae in Bangladesh: An important coastal livelihood causing negative effects on the environment. *Ambio*. **39**(1): 20-29.

AHMED, M.K., HALIM, S. and SULTANA, S. 2012. Participation of women in aquaculture in three coastal districts of Bangladesh: Approaches toward sustainable livelihood. *World J. Agric. Sci*.**8**(3): 253-268.

AHMED, N., RAHMAN, S., BUNTING, S.W. and BRUGERE, C. 2013. Socio-economic and ecological challenges of small-scale fishing and strategies for its sustainable management: A case study of the Old Brahmaputra river, Bangladesh. *Singap. J. Trop. Geogr.***34**(1): 86-102.

AIKEN, K.A., BACON, P.R. and MOOYOUNG, R.R. 1992. Recovery after Hurricane Gilbert: Implications for disaster preparedness in the fishing industry in Jamaica. Proceedings of the Forty-Four Annual Gulf and Caribbean Fisheries Institute. 42, 261 pp.

ALAM, M.S., FLOWRA, F.A., SALAM, M.A., KABIR, A.K.M.A. and ALI, H. 2009. Fishing gears, fish marketing and livelihood status of the poor fishermen around the Basantapur beel at Lalpur upazila. *J. Agrofor. Environ.***3**(1): 173-177.

ALI, M.Y. 1997. Fish, water, and people: Reflections on inland open water fisheries resources of Bangladesh. University Press Ltd. Dhaka.

ALI, M.Y. 1999. Fish Resources Vulnerability and Adaptation to Climate Change in Bangladesh. In: Huq, S., Karim, Z., Asaduzzaman, M. and Mahtab (eds.). Vulnerability and Adaptation to Climate Change for Bangladesh. Kluwer Academic Publishers, Dordrecht. 113-124 pp.

ALLISON, E.H. and ELLIS, F. 2001. The livelihoods approach and management of small-scale fisheries. *Mar. Policy.***25**(5): 377-388.

ALLISON, E.H., ADGER, W.N., BADJECK, M.C., BROWN, K., CONWAY, D., DULVY, N.K. and PERRY, A. 2005. Effects of climate change on the sustainability of capture and enhancement fisheries important to the poor: Analysis of the vulnerability and adaptability of fisherfolk living in poverty. Fisheries Management Science Programme. Department for International Development, UK.

ALLISON, E.H., ANDREW, N.L., OLIVER, J. and CENTER, W. 2007. Enhancing the resilience of inland fisheries and aquaculture systems to climate change. *J. SAT Agric. Res*.**4**(1): 35.

ALLISON, E.H., BEVERIDGE, M.C. and VAN BRAKEL, M. 2009a. Climate change, small-scale fisheries and smallholder aquaculture. In: WRAMNER, P., CULLBERG, M. and ACKEFORS, H. (eds.). Fisheries, Sustainability andDevelopment. Stockholm: Royal Swedish Academy of Agriculture and Forestry. 109-122 pp.

ALLISON, E.H., PERRY, A.L., BADJECK, M.C., ADGER, W.N, BROWN, K., CONWAY, D., HALLS, A.S., PILLING, G.M., REYNOLDS, J.D., ANDREW, N.L. and DULVY, N.K. 2009b. Vulnerability of national economies to the impacts of climate change on fisheries. *Fish Fish.***10**(2): 173-196.

ANDREW, N.L., BENE, C., HALL, S.J., ALLISON, E.H., HECK, S. and RATNER, B.D. 2007. Diagnosis and management of small-scale fisheries in developing countries. *Fish Fish.***8**(3): 227-240.

ANIK, S.I. and KHAN, M.A.S.A. 2012. Climate change adaptation through local knowledge in the north eastern region of Bangladesh.*Mitig. Adapt. Strateg. Glob. Change.***17**(8): 879-896.

ANTWI-AGYEI, P., DOUGILL, A., FRASER, E.G. and STRINGER, L. 2013. Characterizing the nature of household vulnerability to climate variability: Empirical evidence from two regions of Ghana. *Environ. Dev. Sustain.* 1-24 pp.

BADJECK, M.C., ALLISON, E.H., HALLS, A.S. and DULVY, N.K. 2010. Impacts of climate variability and change on fishery-based livelihoods. *Mar. Policy*. **34**(3): 375-383.

BANGLAPEDIA. 2004. National Encyclopedia of Bangladesh. Asiatic Society of Bangladesh, Dhaka, 2004.

BANGLAPEDIA. 2011. National Encyclopedia of Bangladesh. Asiatic Society of Bangladesh, Dhaka, 2011.

BARNETT, J. and O'NEILL, S. 2010. Maladaptation. *Glob. Environ. Chang.***20**(2): 211-213.

BBS. 1991. Statistical yearbook of Bangladesh Bureau of Statistics. Statistics Division. Ministry of planning, Government of the People's Republic of Bangladesh, Dhaka. 673 pp.

BBS. 2001. Bangladesh Population Census 2001. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. 466 pp.

BBS. 2004. Statistical yearbook of Bangladesh Bureau of Statistics. Statistics Division. Ministry of planning, Government of the People's Republic of Bangladesh, Dhaka. 673 pp.

BBS. 2011. Bangladesh Population Census 2001. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. 466 pp.

BERKES, F. and JOLLY, D. 2002. Adapting to climate change: Social-ecological resilience in a Canadian western Arctic community. *Conserv. Ecol.***5**(2): 18.

BARRETT, C.B., REARDON, T. and WEBB, P. 2001. Nonfarm income diversification and household livelihood strategies in rural Africa: Concepts, dynamics and policy implications. *Food Policy.***26**(4): 315-331.

BHUIYAN, S.S., JOADDER, M.A.R. and BHUIYAN, A.S. 2008. Occurrence of fishes and non-fin fishes of the River Padma near Rajshahi, Bangladesh. *University J. Zool.* Rajshahi University. **27**: 99-100.

BLUNT, A., D'OYLEY, V. and BARNHARDT, R. 1994. Education and development: Lessons from the third world. Calgary: Detselig Enterprises.

BRANCHEAU, J.C., JANZ, B.D. and WETHERBE, J.C. 1996. Key issues in information systems management: 1994-95 SIM Delphi results. *MIS Quart.***20**(2): 225-243.

BRANDER, K. 2010. Impacts of climate change on fisheries. *J. Mar. Sys.***79**(3): 389-402.

BRUGERE, C., HOLVOET, K. and ALLISON, E.H. 2008. Livelihood diversification in coastal and inland fishing communities: Misconceptions, evidence and implications for fisheries management. Working Paper, Sustainable Fisheries Livelihoods Programme (SFLP) FAO/DFID, Rome.

BRUNGS, A. and JAMIESON, R. 2005. Identification of legal issues for computer forensics. *Inform. Syst. Manage.***22**(2): 57 - 66.

BURGESS, J. 1996. Focusing on fear: The use of focus groups in a project for the Community Forest Unit, Countryside Commission. *Area.* 130-135 pp.

BURTON, I. 1996. The growth of adaptation capacity: Practice and policy. In Adapting to Climate Change. Springer, New York. 55-67 pp.

BURTON, I. 1997. Vulnerability and adaptive response in the context of climate and climate change. *Clim. Change.* **36**(1-2): 185-196.

BWDB. 2007. Bangladesh Water Development Board. Annual Flood Report 2007. Flood Forecasting and Warning Centre Processing and Flood Forecasting Circle, Dhaka, Bangladesh.

CALDWELL, J.C. 1979. Education as a factor in mortality decline an examination of Nigerian data. *Popul. Stud.* 395-413 pp.

CEGIS. 2003. Ganges River: Morphological Evolution and Prediction. Center for Environmental and Geographic Information Services (CEGIS), Dhaka, Bangladesh. 11-13 pp.

CEGIS. 2005. Prediction of Bank Erosion and Morphological Changes of the Jamuna and Padma Rivers 2005, Prepared for EMIN and JMREM Projects, Dhaka, Bangladesh. 125 pp.

CERNEA, M. 1997. The risks and reconstruction model for resettling displaced populations. *World dev.***25**(10): 1569-1587.

CHAMBER, R. and CONWAY, G.C. 1992. Sustainable Livelihoods: Practical Concepts for the Twenty-First Century, IDS Discussion Paper. 296 pp.

CHEUNG, W.W., LAM, V.W., SARMIENTO, J.L., KEARNEY, K., WATSON, R. and PAULY, D. 2009. Projecting global marine biodiversity impacts under climate change scenarios. *Fish Fish.***10**(3): 235-251.

CICIN-SAIN, B. 1993. Sustainable development and integrated coastal management. *Ocean Coast. Manag.***21**(1): 11-43.

CICIN-SAIN, B., KNECHT, R.W., JANG, D. and FISK, G.W. 1998. Integrated coastal and ocean management: Concepts and practices. Island Press, Washington, DC.

CHOWDHURY, M.S.N., HOSSAIN, M.S., DAS, N.G. and BARUA, P. 2011. Small-scale Fishermen along the Naaf River, Bangladesh in Crisis: A framework for management. *Mesopot. J. Mar. Sci.***26**(2): 146-169.

COCHRAN, W.G. 2007. Sampling techniques. John Wiley and Sons, New York, London.

COCHRANE, K., YOUNG, C.D.E., SOTO, D. and BAHRI, T. 2009. Climate change implications for fisheries and aquaculture: Overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper No. 530. Rome: Food and Agriculture Organization of the United Nations.

COLDWELL, D. and HERBST, F. 2004. Business Research, Cape Town, Juta Academic.

CONWAY, D., ALLISON, E., FELSTEAD, R. and GOULDEN, M. 2005. Rainfall variability in East Africa: Implications for natural resources management and livelihoods. *Phil. Trans. R. Soc. A*.**363**(1826): 49-54.

COULTHARD, S. 2008. Adapting to environmental change in artisanal fisheries-insights from a South Indian Lagoon. *Glob. Environ. Chang.***18**(3): 479-489.

COULTHARD, S. 2009. Adaptation and conflict within fisheries: Insights for living with climate change. Adapting to Climate Change: Thresholds, Values, Governance. 255 pp.

COULTHARD, S., JOHNSON, D. and MCGREGOR, J.A. 2011. Poverty, sustainability and human wellbeing: A social wellbeing approach to the global fisheries crisis. *Glob. Environ. Chang*.**21**(2): 453-463.

CPD. 2015. Centre for Policy Dialogue, State of the Bangladesh Economy in FY2015.

CRAIG, P., PONWITH, B., AITAOTO, F. and HAMM, D. 1993. The commercial, subsistence, and recreational fisheries of American Samoa. *Mar. Fish. Rev.***55**(2): 109-116.

CRESWELL, J.W. 2007. Qualitative inquiry and research design: Choosing among five approaches (2nd edition).Thousand Oaks, California, Sage Publications, Inc.

CRESWELL, J.W. and CLARK, V.L.P. 2007. Designing and conducting mixed methods research.Thousand Oaks, California, Sage Publications, Inc.

CURRAN, S.R. 2002. Migration, social capital and the environment: Considering migrant selectivity and networks in relation to coastal ecosystems. *Popul. Dev. Rev*. **28**: 89-125.

CUSHING, D.H. 1982. Climate and fisheries. London, Academic Press.

DASTAGIR, M.R. 2015. Modeling recent climate change induced extreme events in Bangladesh: A review. *Weather Clim. Extrem.***7**: 49-60.

DAVIS, I. 2014. Disaster risk management in Asia and the Pacific. Routledge, London, UK.

DAW, T., ADGER, W.N., BROWN, K. and BADJECK, M.C. 2009. Climate change and capture fisheries: Potential impacts, adaptation and mitigation. In: Cochrane, K., Young, C. D., Soto, D. and Bahri, T. (eds.). Climate Change Implications for Fisheries and Aquaculture: Overview of Current Scientific Knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome: Food and Agriculture Organization of the United Nations.

DE VAUS, D.A. 2002. Surveys in social science research (5th edition). Routledge, London.

DFID. 1999. Sustainable livelihoods guidance sheets. London: Department for International Development, UK. 11 pp.

DOF. 2005. Fishery Statistical Year Book of Bangladesh 2003-2004. Department of Fisheries, Dhaka, Bangladesh.

DOF. 2012. National fish week, 2012. Compendium (In Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh. 144 pp.

DOF. 2013. National fish week, 2013. Compendium (In Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh. 144 pp.

DOF. 2015. National fish week, 2015. Compendium (In Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh. 148 pp.

DRINKWATER, K.F., BEAUGRAND, G., KAERIYAMA, M., KIM, S., OTTERSEN, G., PERRY, R.I., PÖRTNER, H.O., POLOVINA, J.J. and TAKASUKA, A. 2010. On the processes linking climate to ecosystem changes. *J. Mar. Sys.***79**(3): 374-388.

EAKIN, H. and BOJORQUEZ-TAPIA, L.A. 2008. Insights into the composition of household vulnerability from multicriteria decision analysis. *Glob. Environ. Chang*.**18**(1): 112-127.

EHLER, C.N., CICIN-SAIN, B., KNECHT, R., SOUTH, R. and WEIHER, R. 1997. Guidelines to assist policy makers and managers of coastal areas in the integration of coastal management programs and national climate-change action plans. *Ocean Coast. Manag.* **37**(1): 7-27.

ELLIS, F. 2000. Rural livelihoods and diversity in developing countries. Oxford, Oxford university press, UK.

ENGLAND, K.V. 1994. Getting personal: Reflexivity, positionality and feminist research. *Prof. Geogr.* **46**(1): 80-89.

ERIKSEN, S.H., BROWN, K. and KELLY, P.M. 2005. The dynamics of vulnerability: Locating coping strategies in Kenya and Tanzania. *Geogr. J.* **171**(4): 287-305.

FAO. 2005. Reducing fisherfolk's vulnerability leads to responsible fisheries. Rome: Sustainable Fisheries Livelihood Programme, Food and Agriculture Organization of the United Nations.

FAO. 2008. Report of the FAO expert workshop on climate change implications for fisheries and aquaculture. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2012. The state of world fisheries and aquaculture 2012. Rome: Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations.

FAO. 2013. Report of the FAO expert workshop on assessing climate change vulnerability in Fisheries and Aquaculture. Rome: Food and Agriculture Organization of the United Nations. 29 pp.

FAO. 2014. The State of World Fisheries and Aquaculture 2014: Opportunities and challenges. Rome: Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations.

FARUQUE, M.H. and AHSAN, D.A. 2014. Socio-economic status of the Hilsa (*Tenualosa ilisha*) fishermen of Padma river, Bangladesh. *World Appl. Sci. J.***32**(5): 857-864.

FISCHER, G., SHAH, M., TUBIELLO, F.N. and VAN-VELHUIZEN, H. 2005. Socio-conomic and climate change impacts on agriculture: An integrated assessment, 1990–2080. *Phil. Trans. R. Soc. B.***360**(1463): 2067-2083.

FLOWRA, F.A., ISLAM, M.A., JAHAN, S.N., SAMAD, M.A. and ALAM, M.M. 2013. Status and decline causes of fishing activities of the Baral river, Natore, Bangladesh. *J. Sci. Foundation*. **9**(1-2): 115-124.

FREGENE, B.T. 2002. Poverty Assessment of Fishing Communities of Lagos State, Nigeria. Department of wildlife and Fisheries Management, Nigeria.

FREGENE, B.T. 2007. Profile of Fishermen Migration in Nigeria and Implications for a Sustainable Livelihood, Nigeria.

FRSS. 2014. Fisheries Statistical Report of Bangladesh. Fisheries Resources Survey System (FRSS), Department of Fisheries, Bangladesh. **30**: 52.

FRSS. 2015. Fisheries Statistical Report of Bangladesh. Fisheries Resources Survey System (FRSS), Department of Fisheries, Bangladesh. **31**: 57.

GILBERT, M.R. 1994. The politics of location: Doing feminist research at "Home". *Prof. Geogr.* **46**(1): 90-96.

GHOSE, B. 2014. Fisheries and Aquaculture in Bangladesh: Challenges and Opportunities. *Annals Aquacult. Res.***1**(1): 1001.

GLANTZ, M.H. 2005. Climate variability, climate change and fisheries. Cambridge, Cambridge university press, UK.

GOB. 2008. Government of the People's Republic of Bangladesh. Cyclone Sidr in Bangladesh: Damage, Loss and Needs Assessment for Disaster Recovery and Reconstruction, Dhaka, Bangladesh.

GOB. 2009. Government of the People's Republic of Bangladesh. Bangladesh Climate Change Strategy and Action Plan, Dhaka, Ministry of Environment and Forests, Dhaka, Bangladesh.

GOODESS, C.M. 2013. How is the frequency, location and severity of extreme events likely to change up to 2060?. *Environ. Sci. Policy.***27**: S4-S14.

GOSS, J.D. 1996. Introduction to focus groups. *Area.* 113-114 pp.

GOSS, J.D. and LEINBACH, T.R. 1996. Focus groups as alternative research practice: Experience with trans-migrants in Indonesia. *Area.* 115-123 pp.

HAHN, M.B., RIEDERER, A.M. and FOSTER, S.O. 2009. The livelihood vulnerability index: A pragmatic approach to assessing risks from climate variability and change-a case study in Mozambique. *Glob. Environ. Chang*.**19**: 74-88.

HALDER, P., ALI, H., GUPTA, N., AZIZ, M.S.B. and MONIR, M.S. 2011. Livelihood status of fresh fish, dry fish and vegetable retailers at Rajoir upazila of Madaripur district, Bangladesh. *Bangladesh Res. Pub. J.***5**(3): 262-270.

HALLS, A.S., HOGGARTH, D.D. and DEBNATH, K. 1998. Impact of flood control schemes on river fish migrations and species assemblages in Bangladesh. *J. Fish Biol*. **53**: 358-380.

HALLS, A.S., PAYNE, A.I., ALAM, S.S. and BARMAN, S.K. 2008. Impacts of flood control schemes on inland fisheries in Bangladesh: Guidelines for mitigation. *Hydrobiologia.***609**(1): 45-58.

HALVER, J.E. and HARDY, R.W. 2002. Fish nutrition. Academic press, New York, USA.

HARTMAN, F. and BALDWIN, A. 1995. Using technology to improve the Delphi method. *J. Comput. Civil Eng.* **9**: 244 - 249.

HEIDERSON, M.A. and LEON, E.R. 1996. Patterns and Trends in Michigan Migrant Education. JSRI Statistical Brief No. 8, the Julian Samora Research Institute. Michigan State University, East Lansing, Michigan.

HENDERSON, R.H. and SUNDARESAN, T. 1982. Cluster sampling to assess immunization coverage: A review of experience with a simplified sampling method. Bull. *World Health Organ.*__60__(2): 253.

HOPKINS, P.E. 2007. Thinking critically and creatively about focus groups. *Area.* 39(4), 528-535.

HORNBY, A.S. 2005. Oxford Advanced Learner's Dictionary of Current English (7th edition). Oxford, Oxford University Press, UK.

HOSSAIN, M.L., MAHMUD, J., KHOKON, Z.H. and ISLAM, S. 2005. Padma, Tatthyakosh (in Bengali), Dhaka, Bangladesh. **1**: 1-182.

HOSSAIN, M.M., ISLAM, M.A., RIDGWAY, S. and MATSUISHI, T. 2006. Management of inland open water fisheries resources of Bangladesh: Issues and options. *Fish. Res.*__77__(3): 275-284.

HOSSAIN, M.I., SIWAR, C., MOKHTAR, M.B., DEY, M.M. and JAAFAR, A.H. 2009. Socio-economic condition of fishermen in seasonal floodplain beels in Rajshahi district, Bangladesh. *Res. J. Soc. Sci.*__4__: 74-81.

HOSSAIN, M.S., RAHMAN, M.F., THOMPSON, S., NABI, M.R. and KIBRIA, M.M. 2013. Climate change resilience assessment using livelihood assets of coastal fishing community in Nijhum Dwip, Bangladesh. *Pertanika J. Sci. & Technol.*__21__: 397-422.

HOWDEN, S.M., SOUSSANA, J.F., TUBIELLO, F.N., CHHETRI, N., DUNLOP, M. and MEINKE, H. 2007. Adapting agriculture to climate change. *Proc. Natl. Acad. Sci.*__104__(50): 19691-19696.

HUGHES, R., ADNAN, S. and DALAL-CLAYTON, B. 1994. Floodplains or flood plans? International Institute for Environment and Development and Research and Advisory services, London.

HUSSAIN, M.G. 2010. Freshwater fishes of Bangladesh: Fisheries, biodiversity and habitat. *Aquat. Ecosyst. Health Manag.***13**(1): 85-93.

IPCC. 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. In: MCCARTHY, J. J., CANZIANI, O. S., LEARY, N., DOKKEN, D. AND WHITE, K. (eds.). Cambridge, Cambridge University Press, UK.

IPCC. 2007. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change.In: PARRY, M.L., CANZIANI, O.F., PALUTIKOF, J.P., VAN DER LINDEN, P.J. and HANSON, C.E. (eds.). Cambridge, Cambridge University Press, UK.

IPCC. 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. In: FIELD, C.B., BARROS, V., STOCKER, T.F., QIN, D., DOKKEN, D.J., EBI, K.L., MASTRANDREA, M.D., MACH, K.J., PLATTNER, G.K., ALLEN, S.K., TIGNOR, M. and MIDGLEY, P.M. (eds.). Cambridge University Press, Cambridge, UK.

ISLAM, M.S. and HOSSAIN, M.A. 1983. An account of the fishes of the Padma near Rajshahi, Bangladesh. *Raj. Fish. Bull.***1**(2): 1-31.

ISLAM, M.M. and SADO, K. 2000. Development of flood hazard maps of Bangladesh using NOAA-AVHRR images with GIS. *Hydrolog. Sci. J.***45**(3): 337-355.

ISLAM, M.N. 2004. Eco-biology of freshwater Gobi, *Glossogobius giuris* (Hamilton) of the river Padma in relation to its fishery: A review. *J. Biol. Sci*.**4**(6): 780-793.

ISLAM, M.F. and RASHID, A.B. 2011. Riverbank erosion 93isplaces in Bangladesh: Need for institutional response and policy intervention. *Bangladesh J. Bioeth.***2**(2): 4-19.

ISLAM, M.M. 2013. Vulnerability and adaptation of fishing communities to the impacts of climate variability and change: Insights from coastal Bangladesh. University of Leeds, School of Earth and Environment, England.

ISLAM, A.K.M.N., DEB, U.K., AL-AMIN, M., JAHAN, N., AHMED, I., TABASSUM, S., AHAMAD M.G., NABI, A., SINGH, N.P., BYJESH. K. and BANTILAN, C. 2013a. Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience- Quantifying Vulnerability to Climate Change in Bangladesh. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 36 pp.

ISLAM, M.R., HOQUE, M.N., GALIB, S.M. and RAHMAN, M.A. 2013b. Livelihood of the fishermen in Monirampur Upazila of Jessore district. *Reg. Environ. Change*. **1**(1): 37-41.

ISLAM, M.M., SALLU, S., HUBACEK, K. and PAAVOLA, J. 2014. Vulnerability of fishery-based livelihoods to the impacts of climate variability and change: Insights from coastal Bangladesh. *Reg. Environ. Change.***14**(1): 281-294.

IUCN. 2000. Red Book of Threatened Fishes of Bangladesh. IUCN: The World Conservation Union, Dhaka, Bangladesh: IUCN. 116 pp.

JAIN, S., SHARMA, G. and MATHUR, Y.P. 2013. Effects of temperature variations on fish in lakes. *Int. J. Eng. Res. Tech.***2**(10): 2516-2523.

JALLOW, B.P., TOURE, S., BARROW, M.M. and MATHIEU, A.A. 1999. Coastal zone of the Gambia and the Abidjan region in Côte d'Ivoire: Sea level rise vulnerability, response strategies, and adaptation options. *Clim. Res.***12**(2-3): 129-136.

JOHNSON, T. 2012. Fisheries Adaptation to Climate Change. Alaska Sea Grant Marine Advisory Program, University of Alaska Fair Banks.

KABIR, K.R., ADHIKARY, R.K., HOSSAIN, M.B. and MINAR, M.H. 2012. Livelihood Status of Fishermen of the Old Brahmaputra River, Bangladesh. *World Appl. Sci. J.***16**(6): 869-873.

KARIM, N. 1995. Disasters in Bangladesh. *Nat. Hazards*. **11**: 247-258.

KEIL, M., TIWANA, A. and BUSH, A. 2002. Reconciling user and project manager perceptions of IT project risk: A Delphi study. *Inform. Syst. J.***12**(2): 103 - 119.

KELL, L.T., PILLING, G.M. and O'BRIEN, C.M. 2005. Implications of climate change for the management of North Sea cod (*Gadus morhua*). *ICES J. Mar. Sci.***62**(7): 1483-1491.

KINNEAR, B.P.R. and GRAY, C.D. 2012. IBM SPSS statistics 19 made simple. Hove, Psychology Press.

KHAN, M.R., MIAH, M.I., HOSSAIN, M.B., BEGUM, A. and MINAR, M.H. 2013. Fish biodiversity and livelihood status of fishing community of Tista river, Bangladesh. *Global Veterinaria.***10**(4): 417-423.

KLIASHTORIN, L.B. 2001. Climate change and long-term fluctuations of commercial catches: The possibility of forecasting. FAO Fisheries Technical Paper No. 410. Rome: Food and Agriculture Organization of the United Nations. 86 pp.

KNIVETON, D., SCHMIDT-VERKERK, K., SMITH, C. and BLACK, R. 2008. Climate change and migration: Improving methodologies to estimate flows. IOMMigration Research Series 33. Geneva: International Organization for Migration.

KREFT, S., ECKSTEIN, D., JUNGHANS, L., KERESTAN, C. and HAGEN, U. 2014. Global Climate Risk Index 2015:Who Suffers Most From Extreme Weather Events? Weather-related Loss Events in 2013 and 1994 to 2013. Germanwatch publishers. Germany.

KOTRLIK, J.W.K.J.W. and HIGGINS, C.C.H.C.C. 2001. Organizational research: Determining appropriate sample size in survey research. *Inf. Technol. Learn. Perform. J.***19**(1): 43.

LATIFA, G.A. and ASADUZZAMAN, M. 2014. Fish diversity and livelihood patterns of the fishers of Turag River, Bangladesh. In: Khan, M.A.R., Ali, M.S., Feeroz, M.M. and Naser, M.N. (eds.). The Festschrift on the 50th Anniversary of the IUCN Red List of Threatened Species^{TM}, Dhaka, Bangladesh: IUCN. 27-34 pp.

LEHODEY, P., ALHEIT, J., BARANGE, M., BAUMGARTNER, T., BEAUGRAND, G., DRINKWATER, K., FROMENTIN, J.M., HARE, S.R., OTTERSEN, G., PERRY, R.I. and ROY, C. 2006. Climate variability, fish, and fisheries. *J. Climate.***19**(20): 5009-5030.

LINDEN, M. and SHEEHY, N. 2004. Comparison of a verbal questionnaire and map in eliciting environmental perceptions. *Environ. Behav.***36**(1): 32-40.

LOBELL, D.B., BURKE, M.B., TEBALDI, C., MASTRANDREA, M.D., FALCON, W.P. and NAYLOR, R.L. 2008. Prioritizing climate change adaptation needs for food security in 2030. *Science.***319**(5863): 607-610.

MARQUETTE, C.M., KORANTENG, K.A., OVERA, R. and ARYEETEY, E.B.D. 2002. Small-scale fisheries, population dynamics, and resource use in Africa: The case of Moree, Ghana. *Ambio.***31**(4): 324-336.

MARTIN, A. and SHERINGTON, J. 1997. Participatory research methods implementation, effectiveness and institutional context. *Agr. Sys.***55**(2): 195-216.

MAZID, M.A. 1998. An overview of Hilsa fisheries research in Bangladesh. In: Mazid, M.A. and Blabber, S.J.M. (eds.). Hilsa Fisheries Research in Bangladesh. Proceedings of BFRI/ACIAR/CSIRO workshop on 1998, March 3-4. Dhaka, Bangladesh. Fisheries Research Institute, Mymensingh, Bangladesh. 6-10 pp.

MAZID, M.A. 2002. Development of Fisheries in Bangladesh: Plans and strategies for income generation and poverty alleviation. Momin offset press, Dhaka, Bangladesh. 176 pp.

MCCLANAHAN, T.R., CINNER, J.E., MAINA, J., GRAHAM, N.A.J., DAW, T.M., STEAD, S.M., WAMUKOTA, A., BROWN, K., ATEWEBERHAN, M., VENUS, V. and POLUNIN, N.V.C. 2008. Conservation action in a changing climate. *Conserv. Lett.***1**(2): 53-59.

MCNAY, L. 2003. Having it both ways: The incompatibility of narrative identity and communicative ethics in feminist thought. *Theory Cult. Soc.***20**(6): 1-20.

MET OFFICE. 2011. Climate: Observations, projections and impacts- Bangladesh. Met Office Hadley Centre and Department of Energy and Climate Change of the United Kingdom.

MIAH, M.I., FERDAUSI, R., HASAN, K.R., SIDDIQ, M.A. and FARID, S.M. 2010. Species composition and gear used in fishing during pre-monsoon period in the Shitalakshya river at Siddirgonj area, Narayangonj. *J. Agrofor. Environ.***4**(1): 71-73.

MILES, M.B. and HUBERMAN, A.M. 1994. Qualitative data analysis: A sourcebook of new methods.Thousand Oaks, Sage Publications, Inc.

MIRZA, M.M.Q. 2002. Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. *Glob. Environ. Change*.**12**(2): 127-138.

MIRZA, M.M.Q. 2003. Three recent extreme floods in Bangladesh: A hydro-meteorological analysis. *Nat. Hazards.***28**(1): 35-64.

MANANDHAR, S., VOGT, D.S., PERRET, S.R. and KAZAMA, F. 2011. Adapting cropping systems to climate change in Nepal: A cross-regional study of farmers' perception and practices. *Reg. Environ. Change.***11**(2): 335-348.

MOHANTY, B., SHARMA, A., SAHOO, J. and MOHANTY, S. 2010. Climate change: Impacts on fisheries and aquaculture. In: Simard, S. (ed.). Climate Change and Variability. Europe: Sciyo, InTech. **7**: 119-138.

MOHSIN, A.B.M., HAQUE, S.M.M., GALIB, S.M., FAHAD, M.F.H., CHAKI, N., ISLAM, M.N. and RAHMAN, M.M. 2013. Seasonal abundance of fin fishes in the Padma river at Rajshahi district, Bangladesh. *World J. Fish Mar. Sci.***5**(6): 680-685.

MORTREUX, C. and BARNETT, J. 2009. Climate change, migration and adaptation in Funafuti, Tuvalu. *Glob. Environ. Change.***19**(1):105-112.

MUTTON, D. and HAQUE, C.E. 2004. Human vulnerability, dislocation and resettlement: Adaptation processes of river-bank erosion-induced displacees in Bangladesh. *Disasters.***28**(1): 41-62.

NAMBISAN, S., AGARWAL, R. and TANNIRU, M. 1999. Organisational mechanisms for enhancing user innovation in information technology. *MIS Quart.***23**(8): 365 - 395.

NELSON, J.M. 1976. Sojourners versus new urbanites: Causes and consequences of temporary versus permanent city ward migration in developing countries. *Econ. Dev. Cult. Change.***24**(4): 721-757.

NIEDERMAN, F., BRANCHEAU, J.C. and WETHERBE, J.C. 1991. Information systems management issues for the 1990s. *MIS Quart.***15**(4): 475 - 500.

O'BRIEN, K., LEICHENKO, R., KELKAR, U., VENEMA, H., AANDAHL, G., TOMPKINS, H., JAVED, A., BHADWAL, S., BARG, S., NYGAARD, L. and WEST, J. 2004. Mapping vulnerability to multiple stressors: Climate change and globalization in India. *Glob. Environ. Change.***14**(4): 303-313.

OGUTU-OHWAYO, R., HECKY, R.E., COHEN, A.S. and KAUFMAN, L. 1997. Human impacts on the African great lakes. *Environ. Biol. Fishes.***50**(2): 117-131.

O'REILLY, C.M., ALIN, S.R., PLISNIER, P.D., COHEN, A.S. and MCKEE, B.A. 2003. Climate change decreases aquatic ecosystem productivity of Lake Tanganyika, Africa. *Nature.***424**(6950): 766-768.

OSBAHR, H., TWYMAN, C., ADGER, W.N. and THOMAS, D.S. 2010. Evaluating successful livelihood adaptation to climate variability and change in southern Africa. *Ecol. Soc*. **15**(2): 27.

PAAVOLA, J. 2008. Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environ. Sci. Policy.***11**(7): 642-654.

PARRY, M., ROSENZWEIG, C. and LIVERMORE, M. 2005. Climate change, global food supply and risk of hunger. *Phil. Trans. R. Soc. B.***360**(1463): 2125-2138.

PAUL, B., FARUQUE, H. and AHSAN, D.A. 2013. Livelihood status of the fishermen of the Turag river, Bangladesh. *Middle East J. Sci. Res.***18**(5): 578-583.

PAUL, B.K. and BHUIYAN, R.H. 2004. The April 2004 tornado in north-central Bangladesh: a case for introducing tornado forecasting and warning systems. Quick Response Research Report 169. Natural Hazards Center, Boulder, CO.

PENDER, J.S. 2010. Climate change: Its impacts and possible community based responses in Bangladesh. Church of Bangladesh.

PERRY, R.I., OMMER, R.E., ALLISON, E.H., BADJECK, M.C., BARANGE, M., HAMILTON, L. and SUMAILA, U.R. 2010. The human dimensions of marine ecosystem change: Interactions between changes in marine ecosystems and human communities. Marine Ecosystems and Global Change. Oxford, Oxford University Press, UK. 221-252 pp.

PITTOCK, J. 2011. National climate change policies and sustainable water management: Conflicts and synergies. *Ecol. Soc.***16**(2): 1-25.

POWELL, R.A. and SINGLE, H.M. 1996. Focus groups. *Int. J. Qual. Health Care.***8**(5): 499-504.

PRACTICAL ACTION. 2009. Temporal and spatial variability of climate change over Nepal 1976-2005. Practical Action Nepal Office, Kathmandu, Nepal.

PRIYA, D. andDANIEL, S. 2003. Seasonal migration for livelihood in India: Coping accumulation and exclusion. Working Paper No. 220. Overseas Development institute, London.

RAHMAN, M.K., AKHTER, J.N., NIMA, A., AHMED, S.U. and MAZID, M.A. 2003. Studies on geo-morphology, ecology and fish production of the 92 rivers of Rajshahi Division, Bangladesh. *Bangladesh J. Fish. Res.***7**: 141– 150.

RAHMAN, A., ALAM, M., MAINUDDIN, K., ALI, L., ALAUDDIN, S.M., RABBANI, M.G., MIAH, M.M.U, RABI-UZZAMAN, M. and AMIN, S.M.A. 2009. The probable impacts of climate change on poverty and economic growth and the options of coping with adverse effect of climate change in Bangladesh. Support to monitoring PRS and MDGs in Bangladesh, Planning Commission, Government of the People's Republic of Bangladesh & UNDP Bangladesh.

RAHMAN, M.M., HOSSAIN, M.Y., AHAMED, F., FATEMATUZZHURA, B.R.S., ABDALLAH, E.M. and OHTOMI, J. 2012. Biodiversity in the Padma distributary of the Ganges river, Northwestern Bangladesh: Recommendations for conservation. *World J. Zool.***7**(4): 328-337.

RAO, G. B. 2001. Household coping/survival strategies in drought-prone regions: A case study of Anantapur district. Andhra Pradesh, India SPWD-Hyderabad Centre.

REUVENY, R. 2007. Climate change-induced migration and violent conflict. *Polit. Geogr.***26**(6): 656-673.

ROBSON, C. 2002. Real world research (2nd edition). Blackwell Publishers, Oxford, UK.

RYAN, G.W. and BERNARD, H.R. 2003. Techniques to identify themes. *Field Methods.***15**(1):85-109.

SADOVY, Y. 2005. Trouble on the reef: The imperative for managing vulnerable and valuable fisheries. *Fish Fish.***6**(3): 167-185.

SALLU, S.M., TWYMAN, C. and STRINGER, L.C. 2010. Resilient or vulnerable livelihoods? Assessing livelihood dynamics and trajectories in rural Botswana. *Ecol. Soc.***15**(4): 1-33.

SAMAD, M.A., ASADUZZAMAN, M., GALIB, S.M., KAMAL, M.M. and HAQUE, M.R. 2010. Availability and consumer preference of small indigenous species (SIS) of the river Padma at Rajshahi, Bangladesh. *Int. J. BioRes.***1**(5): 27-31.

SARCH, M.T. and ALLISON, E.H. 2000. Fluctuating fisheries in Africa's inland waters: Well adapted livelihoods, maladapted management.In: Proceedings of the 10th international conference of the institute of fisheries economics and trade. Corvallis, Oregon. 1-11 pp.

SATTERTHWAITE, D., HUQUE, S., REID, H., PELLING, M. and ROMERO, P.L. 2007. Adapting to climate change in urban areas: The possibilities and constraints in low and middle-income nations. London: International Institute for Environment and Development. 112 pp.

SCHMIDHUBER, J. and TUBIELLO, F.N. 2007. Global food security under climate change. *Proc. Natl. Acad. Sci.***104**(50): 19703-19708.

SCHMIDLIN, T.W. 2009. Risk factors and social vulnerability. In: Preprints of the international forum on tornado disaster risk reduction in Bangladesh, Dhaka, Bangladesh. Wind Engineering Research Center, Tokyo Polytechnic University.

SCHMIDT, R., LYYTINEN, K., KEIL, M. and CULE, P. 2001. Identifying software project risks: An international Delphi study. *J. Manage. Inform. Syst.***17**(4): 5 - 36.

SENEVIRATNE, S.I., NICHOLLS, N., EASTERLING, D., GOODESS, C.M., KANAE, S., KOSSIN, J., LAU, Y., MARENGO, J., MCINNES, K., RAHIMI, M., REICHSTEIN, M., SORTEBERG, A., VERA, C. and ZHANG, X. 2012. Changes in climate extremes and their impacts on the natural physical environment. Managing the risks of extreme events and disasters to advance climate change adaptation. 109-230 pp.

SCHERAGA, J.D., EBI, K.L., FURLOW, J. and MORENO, A.R. 2003. From science to policy: Developing responses to climate change. In: MCMICHAEL, A.J., LENDRUM, D., CORVALAN, C.F., EBI, K.L., GITHEKO, A. and SCHERAGA, J.D. (eds.). Climate change and human health risks and responses. World Health Organization, World Meteorological Organization, United Nations Environment Programme, Copenhagen, Denmark. 237-266 pp.

SCHULTZ, T.W. 1975. The value of the ability to deal with disequilibria. *J. Econ. Lit.* 827-846 pp.

SHOJI, M. 2010. Does contingent repayment in microfinance help the poor during natural disasters?. *J. Dev. Stud.***46**(2): 191-210.

SKIDMORE, M. and TOYA, H. 2007. Economic development and the impacts of natural disasters whitewater. *Econ. Lett*. **94**(1): 20-25.

SMIT, B., BURTON, I., KLEIN, R. J. and WANDEL, J. 2000. An anatomy of adaptation to climate change and variability. *Clim. Change.***45**(1): 223-251.

STRAUSS, A. 1987. Qualitative Analysis for Social Scientists, Cambridge, Cambridge University Press.

STRAUSS, A. and CORBIN, J. 1990. Basics of Qualitative Research: Grounded Theory Procedures and Techniques.London, Sage Publications, Inc.

SULTANA, P. and THOMPSON, P. 2008. Gender and local floodplain management institutions: A case study from Bangladesh. *J. Int. Dev*.**20**(1): 53-68.

TAWARI, F. 2002. Dissemination of research findings on nomadic education in Nigeria (the migrant fishermen education experience): Issues and Directions. In International Conference Organized by International Extension College, Cambridge and Sponsored by DFID at Rock View Hotel Abuja-Nigeria. 16th-19th January2002. 6 pp.

THORNTON, P.K., JONES, P.G., ERICKSEN, P.J. and CHALLINOR, A.J. 2011. Agriculture and food systems in sub-Saharan Africa in a 4°C+ world. *Phil. Trans. R. Soc. A*.**369**(1934): 117-136.

TIETZE, U. and VILLAREAL, L.V. 2003. Microfinance in fisheries and aquaculture. Guidelines and case studies. Rome: Food and Agriculture Organization of the United Nations.

TOL, R.S.J., KLEIN, R.J.T., JANSEN, H.M.A. and VERBRUGGEN, H. 1996. Some economic considerations on the importance of proactive integrated coastal zone management. *Ocean Coast. Manag*.**32**(1): 39-55.

TOMPKINS, E.L., NICHOLSON-COLE, S.A., BOYD, E., HURLSTON, L.A., BROOKS, G.H, CLARKE, J., TROTZ, N., GRAY, G. and VARLACK, L. 2005. Surviving climate change in small islands. A guidebook. Tyndall Centre for Climate Change Research, UK.

TSAI, C.F. and ALI, L. 1985. Open water fisheries (carp) management programme in Bangladesh. *Fish. Inf. Bull.* **2**(4): 1-51.

TURNER, R.A., CAKACAKA, A., GRAHAM, N.A.J., POLUNIN, N.V.C., PRATCHETT, M.S., STEAD, S.M. and WILSON, S.K. 2007. Declining reliance on marine resources in remote South Pacific societies: Ecological versus socio-economic drivers. *Coral Reefs*.**26**(4): 997-1008.

TWYMAN, C., MORRISON, J. and SPORTON, D. 1999. The final fifth: Autobiography, reflexivity and interpretation in cross-cultural research. *Area*. 313-325 pp.

ULLAH, M.B. and RAHMAN, M.H. 2015. Assessing vulnerability and adaptation to climate change by farming communities in southwestern coastal Bangladesh. *J. Environ. Sci. Nat. Resour.***7**(2): 31-35.

UNDP. 2004. A Global Report: Reducing disaster risk: A challenge for development. UNDP: New York, USA.

UNISDR. 2009. Terminology on disaster risk reduction. Geneva, Switzerland. 8 pp.

USMAN, H.M., ABDULLAHI, J. and USMAN, H. 2011. Contributions of seasonal migrants fishermen towards fishing activities in Baga, Kukawa. Local government of Borno State, Nigeria.*J. Environ. Issues Agric. Dev. Count.***3**(2): 101-109.

VINCENT, K. 2007. Uncertainty in adaptive capacity and the importance of scale. *Glob. Environ. Change.***17**(1): 12-24.

VINEIS, P., CHAN, Q. and KHAN, A. 2011. Climate change impacts on water salinity and health. *J. Eepidemiol. Glob. Health.***1**(1): 5-10.

WARNER, K., DUN, O. and STAL, M. 2008. Climate change and displacement: Field observations and empirical research. *Forced Migr. Rev.***38**:13-15.

WELCOMME, R.L. 1983. River basins. FAO Fisheries Technical Paper No. 202. Rome: Food and Agriculture Organization of the United Nations. 60 pp.

WESTLUND, L. 2007. Disaster response and risk management in the fisheries sector. FAO Fisheries Technical Paper No. 479. Rome: Food and Agriculture Organization of the United Nations. 51 pp.

WMO 2012. Coordination: Review of terminology/classification of tropical cyclones. The seventh tropical cyclone RSMCS/TCWCS technical coordination meeting. West Java, Indonesia: World Meteorological Organization.

WORLD BANK. 2010. World development report: Development in a changing climate-concept note. World Bank, Washington, DC. 45 pp.

WORLD FISH CENTER. 2009. Climate change: Research to meet the challenges facing fisheries and aquaculture. Issues Brief 1915, The World Fish Center, Penang, Malaysia. 8 pp.

WOUTERSE, F. and TAYLOR, J.E. 2008. Migration and income diversification: Evidence from Burkina Faso. *World Dev.***36**(4): 625-640.

WYNEKOOP, J.L. and WALZ, D.B. 2000. Investigating traits of top performing software developers. *Inform. Technol. Peopl.***13**(3); 186 - 197.

YANEZ, E., BARBIERI, M.A., SILVA, C., NIETO, K. and ESPINDOLA, F. 2001. Climate variability and pelagic fisheries in northern Chile. *Prog. Oceanogr.***49**(1): 581-596.

ZEREEN, F., ISLAM, F., HABIB, M.A., BEGUM, D.A. and ZAMAN, M.S. 1999. Inorganic pollutants in the Padma River, Bangladesh. *Environ. Geol.* **39**(9): 1059-1062.

APPENDICES

Appendix 1- River fisheries of Bangladesh

At present the fisheries sector in Bangladesh, playing a very vital role in poverty alleviation, generating employment opportunities, producing animal proteins, earning foreign currency and increasing Gross Domestic Product (GDP) and Gross National Product (GNP) (Hussain, 2010). The area of water resource is about 4.9 million hectare (ha), which is about 34% of our total area of Bangladesh (Miah, 2010). In 2010-2011, about 5.5 million people were directly involved in fisheries as the main source of earning (Ghose, 2014). In addition, lives and livelihoods of another 12 million people depend indirectly on this sector those who are classified as subsistence fishers, part-time fishing labourers, aquaculture operators, fish traders and processors (Hossain *et al*., 2006, DoF, 2012).Figure 1 showing the total fish production of Bangladesh in 2013-14 (DoF, 2015).

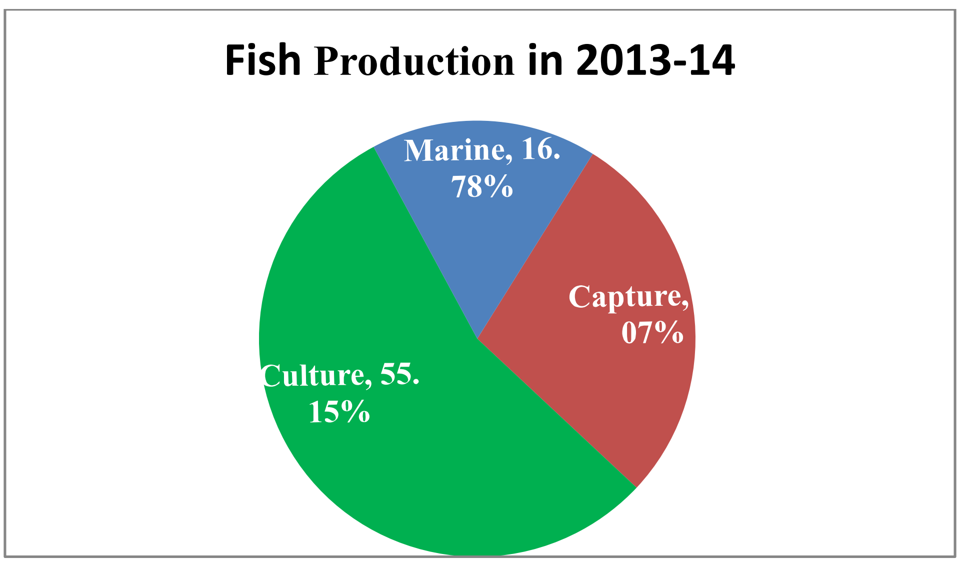


Figure 1: Total fish production of Bangladesh

Frozen shrimp, fish and other fishery products rank fourth in the export earnings of the country (DoF, 2013). Importantly fisheries, from both capture and culture provide about 60% of the population's total animal protein intake of the country (DoF, 2015). Fisheries is a key source of essential minerals, vitamins and fatty acids, vital factors in child development and adult health. Table 1 showing some general information of Bangladesh fisheries.

Table 1: General information on fisheries resources of Bangladesh (2013-2014)

Fish Production:	
Total fish production including Inland and Marine Fisheries	3,548,115 MT
Contribution of Fisheries to National Economy:	
Price of fish in GNP (Present market price)	Tk. 53,316 crore
Contribution to GDP	3.69%
Contribution to Agriculture	22.60%
Exported Fish & Fish related Goods:	
Amount	77,328 MT
Price	Tk. 4,898.22 crore
Contribution to foreign exchange	2.01%
Fish Intake & its Demand:	
Yearly fish intake per person	19.30 kg
Yearly fish demand per person	21.90 kg
Daily fish demand per person	60 g
Contribution to animal protein (approx.)	60%
Number of fishermen:	
Total number of inland and marine fishermen (approx.)	20.00 Lakh
Number of fish farmers:	
Total Fish farmers involved in fish and shrimp farming (approx.)	40.00 Lakh

Source: Department of Fisheries (DoF, 2015)

Bangladesh has the third largest aquatic fish biodiversity in Asia, after China and India, with about 800 species in fresh, brackish and marine waters (Hussain, 2010). Numerous rivers intersect the vast alluvial tract, streams and tidal creeks which are largely formed by the fertile deltaic region of three mighty rivers - the Padma (which is known as Ganges in India), the Brahmaputra (Jamuna) and the Meghna. The Padma is one of the important trans-boundary rivers (Table 2) of Bangladesh. Bangladesh is traversed with the greatest number of these rivers, almost exclusively trans-international. Bangladesh has a total of 58 major rivers that enter the country either from India or from Myanmar (Banglapedia, 2011).

Table 2: Catchment Area of Major Trans-Boundary Rivers

Rivers	Total catchment area (sq. km)	Country-wise catchment area (sq. km)				
		India	Nepal	Bhutan	China	Bangladesh
Brahmaputra	552,000	195,000	-	47,000	270,000	39,000
Ganges (Padma)	1,087,3000	860,000	147,000	-	33,520	46,300
Meghna	82,000	47,000	-	-	-	35000
Total	1,721,300	1,102,000 (64.02%)	147,480 (8.57%)	47,000 (2.73%)	304,420 (17.69%)	120,400 (7%)
Source: Joint River Commission Bangladesh, Ministry of Water Resources, The People's Republic of Bangladesh, 2014						

The network of 700 rivers (Islam, 2011; Banglapedia, 2004) / 800 rivers (CEGIS, 2003) / 230 rivers (Dastagir, 2015) and their tributaries cover a total length of 24,000 km (BBS, 2001). In 3.91 million ha open inland water body, about 0.85 million ha is river and estuary (DoF, 2015). Thus, fish and fisheries constitute an integral part of lives and livelihoods of the millions of people in Bangladesh, particularly the poor and marginal fisher-folks.

Bangladesh has vast inland open water (3.91 million ha) which is contributing 28.07% of total fish capture (Figure 2) in 2013-14 (DoF, 2015). Total fish production from inland water area in the year 2013-14 was 2.95 MT which was 83.22% of the total catch. In case of marine fisheries, it was 0.59 MT in 2013-14, as against 16.78% of the total catch (DoF, 2015).

In 2009-10 the annual fish production rate was 7.32% that was the highest production rate but in 2012-13 and 2013-14 the annual fish production rate continuously decreased and became 4.55% and 4.04% respectively that were the least production rate comparing with any other years (DoF, 2015).

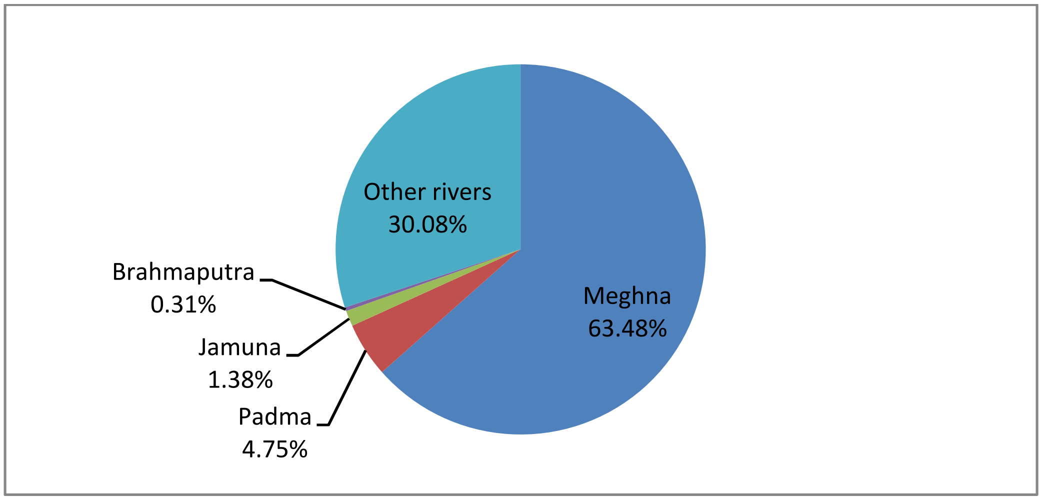


Figure 2: Total catch in percentage of all rivers of Bangladesh (2012-13)

Figure 3 showing the riverine fish production trends of Bangladesh from 1999 to 2014 (FRSS, 2015).

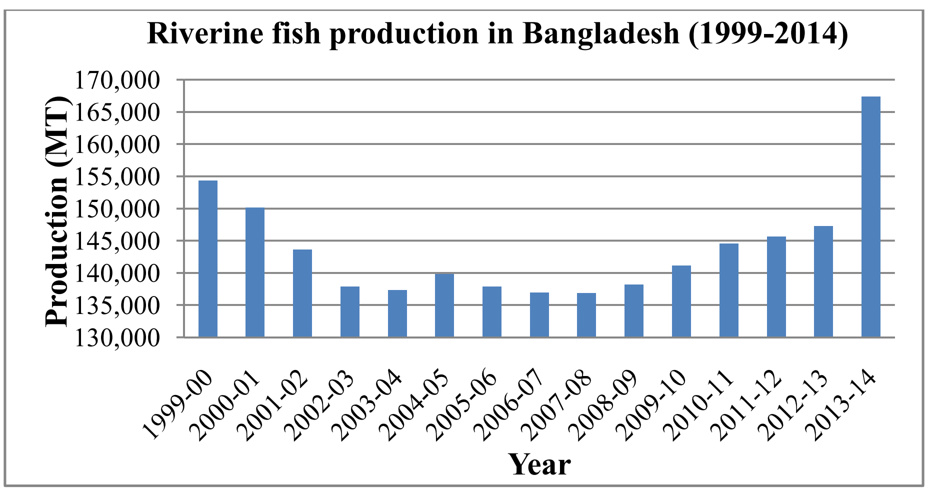


Figure 3: Riverine fish production trend of Bangladesh (1999-2014)

People living in village beside the rivers and natural depressions (beels) harvest the fish almost round the year without any prior investment except catching devices perhaps more than any other countries (Flowra, 2013). The population of Bangladesh depends on wild fish for food and the generation of income. A large portion rural family are engaged in part time fish capture from the rivers and beels (Hughes *et al*., 1994).

Appendix 2- Adaptation to climate change

Adaptation is defined as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007).

In the climate change literature, adaptation to climate change is defined as an adjustment in ecological, social or economic systems, in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of change, or take advantage of new opportunities (Daw *et al*., 2009).

In other words, adaptation is an active set of strategies and actions taken by people in reaction to, or in anticipation of, change in order to enhance or maintain their well-being. Adaptation can therefore involve both building adaptive capacity to increase the ability of individuals, groups or organizations to predict and adapt to changes, as well as implementing adaptation decisions, i.e. transforming that capacity into action.

Fishing communities need to adapt to cyclones, floods, variations in temperature and rainfall, sea level rise, drought and land erosion, and their impacts to face the challenge of climate change (Islam *et al*., 2014). In addition to reducing exposures to these shocks and stresses, adaptation of fishing communities would need adjustment within livelihood assets, strategies (fishing, pre-harvest activities such as boats making and financing; post-harvest activities such as processing and marketing) and transforming structures and processes.

Several studies have emphasized to understand the potential for adaptation to future climate change, the need to first investigate current and past adaptation strategies to climate change or variability and what has constrained or facilitated those adaptations (Adger *et al*., 2003; Eriksen *et al*., 2005). Examining current and past adaptations will provide specifically greater insights into the social aspects of adaptation, the constraints on adaptation and the processes of adaptation (Adger, 2003).

Livelihoods diversification to address climate variability has occurred outside and inside fisheries, where the households are involved in several income generating activities (Allison *et al*., 2009a). Daw *et al*. (2009) showed that migration among fishers has occurred in response to climate-mediated fluctuations in fish abundance which is considered a part of livelihood diversification (Wouterse and Taylor, 2008). Coulthard (2009) highlights the difference between adaptations in the face of resource fluctuations that involve diversifying livelihoods in order to maintain a fishery.

Increased risk associated with fishing activities is often considered a consequence of climate change (Daw *et al*., 2009) and adaptation strategies have preliminary been proposed to reduce this risk. To address the impacts of future climate change in fisheries several preliminary adaptation options or strategies have been proposed (Daw *et al*., 2009; Badjeck *et al*., 2010). Adaptation strategies may be successful or maladaptive and may not be so simplistic.

Adaptation strategies will require to be context and location specific and to consider impacts both short-term (e.g. increased frequency of severe events) and long-term (e.g. reduced productivity of aquatic ecosystems). Smit *et al*. (2000) summarized adaptation options which based on their purpose, mode of implementation, or on the institutional form they take.

Community, national and regional levels of adaptation will clearly require and benefit from stronger capacity building, through awareness raising on climate change impacts on fisheries and aquaculture, promotion of general education and targeted initiatives in and outside the sector. Adaptations by other sectors will have impacts on fisheries, in particular inland fisheries and aquaculture (e.g. irrigation infrastructure, dams, fertilizer use runoff), and will require carefully considered trade-offs or compromises.

Appendix 3- Migratory fishers

Migration refers to move, either temporarily or permanently, from one place or area to another. It is also regarded as one of the most important demographic factors affecting environment which is most difficult to adequately assess (Curran, 2002).

Fisheries-related human migration is defined as temporary or permanent movement of fisher folks, fish processors, fish traders and fisheries workers from one defined location to another destination with movement being mainly and primarily, as a result of shift in fisheries and fishing activities (Abobi *et al*., 2015).The movement could also be driven by economic and political factors, fisheries resource availability and population pressure. Fisheries-related human migration has strong spatio-temporal dynamics (Abobi *et al*., 2015). But according to Tawari (2002) a migrant fisher is one who leaves his natural community and moves from one habitation to another in fulfillment of his occupation.

The push factors such as (favourable climate, better food supply, freedom, profitable employment, availability of water for fishing or wetland for cultivation during dry season etc.) and the pull factors such as (shortage of food, poverty, riverbank erosion, drought, flood, lack of job to do in a particular season etc.) that influence the people to migrate from their usual or permanent place of residence to another (Priya and Daniel, 2003).

Rao (2001) refers to three types of migration in his study of socio-historical contexts as:- Type 1: migration which is for coping and survival. Type 2: migration is defined as migration for an additional work/income. Type 3: migration is for better remuneration, work environment and opportunity to use skills or acquire new skills.

Temporary migration to places where fish is available is a prevalent feature of artisanal fisheries worldwide (Aburto *et al*., 2013). The migration of fishers is a process that has been shaped by historical patterns of resource availability, in addition to economic and political factors rather than simply a reaction to recent human population pressure (Marqutte *et al*., 2002).

Migrants contribute to the GDP and also support their families back. There are conflicts as results of migrants fishing and in some cases resulted in political interferences. Migrants have limited privileges in some destinations. Migrants in some cases have no rights to own a land (Abobi *et al*., 2015).

Seasonality of fisheries resources due to climate changes is possibly the most significant cause of fisher folks seasonal migration which normally last for a period of 6 months. Socio-economic standings and political stability are major determining factors of long or permanent fisheries-related migration (Abobi *et al*., 2015). Long-term migration of fishers spans over years. Fisheries driven migration is male- dominated. The prospects for continued fishers and fish workers migration is high and it anticipated that seasonality of different fisheries regime will dictate the pace tempo-spatial dynamics of the fisher folks mobility (Abobi *et al*., 2015). Small-scale fishers use smaller boats and gear, and land smaller quantities of fish than large-scale/commercial fishing boats.

In Gulf of Guinea more than 50% of migrants may go on short-term expeditions lasting between 1 and 3 months. Among the remaining migrants, the largest portion stayed away for 6 months while a smaller proportion stayed away for 4 years or more. Migration is undertaken both by men and women, since many men travel with their wives on their expeditions to perform housekeeping and fish processing activities (Abobi *et al*., 2015).

People's livelihoods are primarily affected by seasonality and they have limited or no control on it (Fregene, 2002). Due to the constant reduction in fish stocks and inadequacy of most of the areas for small-scale agriculture, the last options for the improvement of their livelihood conditions entails to migrate to other areas within or outside the country. It is clear that seasonal variation of fisheries resources due to climate changes is the main cause of fisheries-related human migration in the Gulf of Guinea (Abobi *et al*., 2015).

Due to lack of skills other than fishing and appropriate fishing inputs, inland fishers have continued to migrate to various water bodies which have been over exploited, while industrial development and trawlers have destroyed the marine fishing grounds of artisanal fishers. It is also unfortunate that in this period of the 21^{st} century some fishers do not see the need to educate their children, but prefer to use them as cheap sources of labor, while others lack the financial means to train their children (Abobi *et al*., 2015) .

The lack of alternative sources of livelihood and other skills except that of fishing learnt from their fathers, will continue to encourage those have not been adequately educated to continue as migrant fishers.

Appendix 4- Semi-structured interviews

SEMI-STRUCTURED INTERVIEWS

A. Introduction and explanation of ethical issues

B. Respondent and household information

Union name: Harirampur	District name: Manikganj	Date:
Village name:		
Ward number:		
Union name:		
Household ID:		
Random number:		

1. Name of the respondent:
2. Religion: Islam/Sonatan (Hindu)/Others………..
3. Age (years):
4. Gender: Male/Female
5. Years of education:
6. Phone (if any):
7. Household member (including absent members who contribute to the household): ….

Household member	Age (years)	Years of education
Son(s):		
Daughter(s):		
Other(s):		

C. Fishing activities of the respondent

1. Which type of fisher are you?
   a. Migratory
   b. Non-migratory
2. Which type of fisher are you based on your standard basis of practices?
   a. Full-time
   b. Part-time
   c. Occasional

3. How many years are you involve in fishing? ....
4. Is fishing your family traditional occupation? Yes/No.
   a. If no, then why did you choose to live on fishing? …………………………..
5. Do you have any alternative occupation? Yes/No.
   a. If yes, then specify
      i. Agriculture
      ii. Small business
      iii. Driving vehicle
      iv. Others
6. Have any other household members involve in fishing activities? Yes/No.
   a. If yes, then how many? ....
7. How many percentage of your household income comes from fishing? ....
8. Where are you fishing? The Padma river/Others ....
9. Do you use net(s) for fishing? Yes/No.
   a. If yes, then which types of nets you use for fishing?

Types of nets	Local name	Size of net (approximately)			No. of operating person	Local name of catchable fish species
		Length (m)	Width (m)	Mesh size (mm)		
Cast net	Khepla jal					
Seine net	Ber jal					
	Ghurnee ber jal					
	Badai jal					
	Kajoli jal					
Gill net	Current jal					
	Pachon jal					
Lift net	Veshal jal					
	Floating veshal jal					
	Chala jal					
Others						

9.1 Do you use your own net(s)? Yes/No.
   a. If no, then from where you get your net(s)?
      i. Sharing with other fishers

ii. Aratdar
iii. Money lender
iv. Any NGO
v. Others

9.2 Do you use any net that is banned for fishing? Yes/No

a. If yes, then
   i. Name of the net: ………………………………………………………………
   ii. Mesh size (mm): ………………………………………………………………
   iii. Why do you use that net? ....

10. Do you use trap(s) for fishing? Yes/No.

a. If yes, then which types of traps you use for fishing?

Name of traps	Size of trap (Approximately)			Made with	Local name of catchable fish species
	Height (ft)	Length (ft)	Width/Dia. (ft)		
Doyari and bana					
Polo					
Hancha					
Others					

11. Do you use line and hook(s) for fishing? Yes/No.

a. If yes, then which types of line and hooks you use for fishing?

Types of gear	Name of gear	No. of hooks	Person needed	Boat needed	Local name of catchable fish species
Hook and line	Chip barshi				
	Hajari barshi				
	Wheel barshi				
Others					

12. Do you use spear(s) for fishing? Yes/No.

a. If yes, then which types of spears you use for fishing?
   i. Konch
   ii. Teta
   iii. Angta
   iv. Others

13. Do you use boat(s) for fishing? Yes/No.
    a. If yes, then which types of boat(s) you use for fishing?

Boat name	Measurement of the boat		Gear used in boat	Man power needed
	Length (m)	Wide (m)		
Kosa boat				
Dinghy boat				
Jolkonna boat				
Others				

13.1Do you use your own boat(s) for fishing? Yes/ No.

a. If yes, then
   i. Number of boat(s):
   ii. Types of boat(s): Mechanized/Non-mechanized
      a) If mechanized, then the power of engine (HP):……………………..
b. If no, then from where you collect your boat for fishing?
   i. Aratdar
   ii. Mohajon
   iii. Money lender
   iv. Any NGO
   v. Others

14. When is the fishing season(s)?
    i. …………………..
    ii. …………………..
    iii. …………………...
15. When do you go for fishing? …………………………………………………………
16. How many times you go for fishing per day? ....
17. What is the duration of your fishing operation per day (hour/day)?.................................
18. What is the average amount of catch per day (kg/day)? ....
19. Where do you sell your catch?
    a. Arat (fish auction centre)
    b. Local market
    c. Others

20. Have you kept any fish from your catch for household consumption? Yes/No.
    a. If yes, then is it sufficient for your household member? Yes/No.
    b. If no, then why have you not kept any fish for your household? ....
    ....…………….................
21. Are you bound to sell your catch to the aratdar/mahajon/money lender? Yes/No.
    a. If yes, then why?................................ ....
22. From fishing, what is the average annual income of your household (Tk./year) (income will be calculated after deducting expenses)? … …………..………………… ………
23. Are you satisfied with the present occupation? Yes/No.
    a. If yes, then what are the reason(s) behind that?..….
    b. If no, then what are the reason(s) behind that?..

D. Impacts of climate variability and change

1. Before this interview, have you heard about climate variability and change?
   a. Yes
   b. No
   c. Don't know
2. Has climate variability and changes such as storm, low rainfall, high temperature, low temperature, fog, high rainfall and flood had any effect on your fishing activities?Yes/No.
3. Has climate variability and change such as storm, low rainfall, high temperature, low temperature, heavy rainfall and flood had any effect on your fishing techniques? Yes/No.
   a. If yes, then which types of impacts…………………… ………………………..
4. Has climate variability and change such as storm, low rainfall, high temperature, low temperature, heavy rainfall and flood had any effect on your fishing equipment(Boats, gears etc.)? Yes/No.
   a. If yes, then what are the effects on your fishing equipment?

Climate Variability and change	Damaged	Drown	No effect
Storm			
Low rainfall			
Heavy rainfall			
High temperature			

Low temperature			
Fog			

5. Has climate variability and change such as storm, low rainfall, high temperature, low temperature, heavy rainfall and flood had any effect on your fishing duration? Yes/No.
   a. If yes, then mention about it……………………………………………………… ………………………………………………………………………………………..
6. What is the present fish production in your area? Increased/decreased
   a. If decreased, then what is the main cause for reduction of fish production?
      i. Storm
      ii. Low rainfall
      iii. Heavy rainfall
      iv. Flood
      v. Low temperature
      vi. High temperature
      vii. Fog
      viii. Others
7. Has climate variability and change such as storm, low rainfall, high temperature, low temperature, heavy rainfall and flood had any effect on your fish catch? Yes/No.
   a. If yes, then ndicate the impact of the following climate variability and change on fish catch around your area.

Climate variability and change	Increased	Decreased	No effect
Storm			
Low rainfall			
Heavy rainfall			
High temperature			
Low temperature			
Fog			
Others			

8. Has storm any impact(s) on fisher life? Yes/No.
   a. If yes, then what are the impacts of storm on fishers life?
      i. Loss of life as a result of boat drown

ii. Causes physical injury
iii. Both
iv. Others

9. Has climate variability and change such as storm, low rainfall, high temperature, low temperature, heavy rainfall and flood had any effect on your livelihood as a fisher? Yes/No.
   a. If yes, then what impacts has climate variability and change had on your livelihood?
      i. Loss of income from fishing
      ii. Fishing equipment damaged or lost
      iii. Reduced access to food due to loss of revenue from fishing
      iv. Risk of malnutrition and under-nutrition by family due to reduced access to fish as a source of protein
      v. Others
10. Have you experienced any extreme climate variability and change in your life?
    a) Yes
    b) No
    c) Cannot remember
       i. If yes, please explain..
       ………………………………………………………………………………...
       ……………………………………………………………………………….
11. Please rank five climatic shocks that had affected fishers fishing activities as well as overall livelihood strategies in your area based on your opinion.

Climatic shocks	Rank
Storm	
Low rainfall	
Heavy rainfall	
Low temperature	
High temperature	
Fog	
Others	

12. Please rank five climatic stresses that had affected your fishing activities and livelihood strategies.

Climatic stresses	Rank

Reduced availability of fish	
Destruction of fishing equipment's	
Riverbank erosion	
Physical injury	
Drought	
Flood	
Others	

E. Coping and adaptation strategies to the impacts of climate variability and change

1. Have you taken any coping strategies against the impacts of climate variability and change such as reduced catch, destruction of fishing equipment, riverbank erosion, physical injuries, drought etc.? Yes/No.
   a. If yes, then what are the coping strategies?
      i. Selling productive assets or livestock
      ii. Reducing current consumption
      iii. Co-opted children in fisheries related activities or stop them from going to school
      iv. Temporary migration
      v. Taking loan
      vi. Others
2. In case of storm, what are your coping strategies?
   i. Nothing
   ii. Stay in the boat
   iii. Try to reach the river bank
   iv. Try to go to the adjacent canal (ghop) where air and water flow is low
   v. Others
3. Have you taken any adaptive strategies against the impacts of climate variability and change such as reduced catch, destruction of fishing equipment, riverbank erosion, physical injuries, drought etc.? Yes/No.
   a. If yes, then what are the adaptation strategies?
      i. Embankment construction
      ii. Permanent migration
      iii. Diversifying livelihoods
      iv. Increasing the number of hours spent in fishing

v. Using more efficient fishing gears
vi. Using mechanized boat for fishing
vii. Tree plantation
viii. Others

3.1 If you have increased your fishing duration, then answer below:

Time spent in fishing (hrs/day)		Changed in duration
Before 5 years/ more	present	

3.2 If you have used more efficient fishing gear, then mention below:

Gear used for fishing		Remarks
Before 5 years/ more	present	

3.3 If you increase the number of fishing gears? Yes/No

4. What are your livelihood diversification strategy?
   a. Nothing
   b. Agriculture
   c. Farm labour
   d. Driving vehicle
   e. Small business
   f. Collecting and selling fire wood
   g. Waited for favorable condition
   h. Others
5. Have any shelter(s) house for storm in your area? Yes/No.
   a) If yes, then how many?...
6. Have any embankment(s) in your area for controlling river erosion? Yes/No.
   a. If yes, then how many embankment(s)?...

6.1 Have any negative impact(s) of the embankment(s) construction? Yes/No.

a. If yes, then how please describe ………………………………………… ………

7. Have any embankment(s) in your area for controlling flood? Yes/No.

a. If yes, then how many?..

8. If your primary occupation (fishing) is severely affected by climate variability and change, then what will be your future adaptation strategy?
    - i. None
    - ii. Farm work as labourer
    - iii. Driving vehicle
    - iv. Agriculture
    - v. Household work as labourer
    - vi. Small business
    - vii. Others

Appendix 5- Checklists for focus group discussions

1. What are the main climatic variability and changes in your area?
2. What are the impacts of climatic variability and changes (especially storm) on the fishing activities?
3. What are the adaptation strategies to the impacts of climatic variability and changes?
4. What are the impacts of embankment construction?
5. How these climatic variability and changes affected your livelihoods?

Appendix 6- Checklists for key informant interviews

1. What is your perception about the climatic variability and changes?
2. From your knowledge and experience, what are the climatic variability and changes that affected the fishers?
3. What are the overall impacts of those climatic variability and changes on the fishers?
4. What are the adaptation strategies to the impacts of climatic variability and changes?

Appendix 7- Supplementary tables

Table 1: World fisheries and aquaculture production and utilization

	2007	2008	2009	2010	2011	2012
	(Million tonnos)					
PRODUCTION						
Capture						
Inland	10.1	10.3	10.5	11.3	11.1	11.6
Marine	80.7	79.9	79.6	77.8	82.6	79.7
Total capture	90.8	90.1	90.1	89.1	93.7	91.3
Aquaculture						
Inland	29.9	32.4	34.3	36.8	38.7	41.9
Marine	20.0	20.5	21.4	22.3	23.3	24.7
Total aquaculture	49.9	52.9	55.7	59.0	62.0	66.6
TOTAL WORLD FISHERIES	140.7	143.1	145.8	148.1	155.7	158.0
UTILIZATION[1]						
Human consumption	117.3	117.3 120.9	123.7	128.2	131.2	136.2
Non-food uses	23.4	22.2	22.1	19.9	24.5	21.7
Population (billions)	6.7	6.8	6.8	6.9	7.0	7.1
Per capita food fish supply (kg)	17.6	17.9	18.1	18.5	18.7	19.2

Note: Excluding aquatic plants. Totals may not match due to rounding.
1 Data in this section for 2012 are provisional estimates.

Table 2: Inland waters capture: major producer countries

2012 Ranking	Country	Continent	2003	2011	2012	Variation 2003-2012	Variation 2011-2012
			(Tonnos)			percentage	
1	China	Asia	2 135 086	2 232 221	2 297 839	7.6	2.9
2	India	Asia	757 353	1 061 033	1 460 456	92.8	37.6
3	Myanmar	Asia	290 140	1 163 159	1 246 460	329.6	7.2
4	Bangladesh	Asia	709 333	1 054 585	957 095	34.9	–9.2
5	Cambodia	Asia	308 750	445 000	449 000	45.4	0.9
6	Uganda	Africa	241 810	437 415	407 638	68.6	–6.8
7	Indonesia	Asia	308 656	368 578	393 553	27.5	6.8
8	United Republic of Tanzania	Africa	301 855	290 963	314 945	4.3	8.2
9	Nigeria	Africa	174 968	301 281	312 009	78.3	3.6
10	Brazil	Americas	227 551	248 805	266 042	16.9	6.9
11	Russian Federation	Europe/Asia	190 712	249 140	262 548	37.7	5.4
12	Egypt	Africa	313 742	253 051	240 039	–23.5	–5.1
13	Thailand	Asia	198 447	224 708	222 500	12.1	–1.0
14	Democratic Republic of the Congo	Africa	230 365	217 000	214 000	–7.1	–1.4
15	Vietnam	Asia	208 872	206 100	203 500	–2.6	–1.3

(Source: The State of World Fisheries and Aquaculture, 2014)

Table 3: Fisheries production rate of Bangladesh on the basis of fiscal year

Fiscal Year	Annual Production Rate (%)
99-2000	7.02
2000-01	7.20
01-02	6.14
02-03	5.70
03-04	5.20
04-05	5.42
05-06	5.08
06-07	4.79
07-08	5.05
08-09	5.39
09-10	7.32
10-11	5.60
11-12	6.54
12-13	4.55
13-14	4.04

(Source: Department of Fisheries DoF, 2015)

Appendix 8- Photographs

a)Conducting household interviews with migratory fisher

b) Conducting household interviews with non-migratory fisher

c) Conducting FGD with non-migratory fishers

d) Conducting FGD with migratory fishers

e) Conducting key informant interviews with Majib Uddin Chowdhury, Assistant fisheries officer, Harirampur upazila, Manikganj

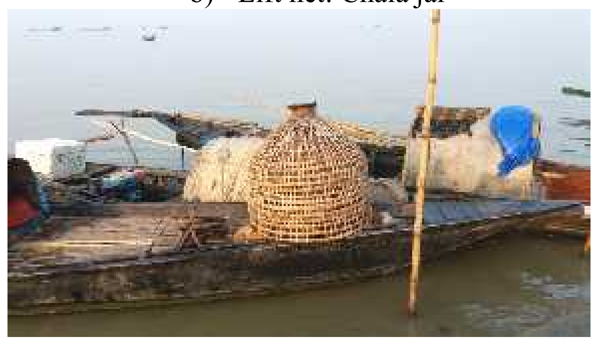
f) Conducting key informant interviews with Satya Ranjan Saha, Project officer (In-charge), BARCIK, Harirampur upazila ,Manikganj

Figure 1: Photographs of primary data collection

a) Lift net: Veshal jal

b) Lift net: Chala jal

c) Fishing trap: Doyari



d) Fishing trap: Polo

Figure 2: Fishing nets and traps used in the study sites

a) *Catla catla*

b) Colisa fasciata

c) Channa punctata

d) Macrobrachium lamarrei

Figure 3: Fishes of the Padma river in the study sites

Appendix 9- Random Numbers

11164	36318	75061	37674	26320	75100	10431	20418	19228	91792
21215	91791	76831	58678	87054	31687	93205	43685	19732	08468
10438	44482	66558	37649	08882	90870	12462	41810	01806	02977
36792	26236	33266	66583	60881	97395	20461	36742	02852	50564
73944	04773	12032	51414	82384	38370	00249	80709	72605	67497
49563	12872	14063	93104	78483	72717	68714	18048	25005	04151
64208	48237	41701	73117	33242	42314	83049	21933	92813	04763
51486	72875	38605	29341	80749	80151	33835	52602	79147	08868
99756	26360	64516	17971	48478	09610	04638	17141	09227	10606
71325	55217	13015	72907	00431	45117	33827	92873	02953	85474
65285	97198	12138	53010	94601	15838	16805	61004	43516	17020
17264	57327	38224	29301	31381	38109	34976	65692	98566	29550
95639	99754	31199	92558	68368	04985	51092	37780	40261	14479
61555	76404	86210	11808	12841	45147	97438	60022	12645	62000
78137	98768	04689	87130	79225	08153	84967	64539	79493	74917
62490	99215	84987	28759	19177	14733	24550	28067	68894	38490
24216	63444	21283	07044	92729	37284	13211	37485	10415	36457
16975	95428	33226	55903	31605	43817	22250	03918	46999	98501
59138	39542	71168	57609	91510	77904	74244	50940	31553	62562
29478	59652	50414	31966	87912	87154	12944	49862	96566	48825
96155	95009	27429	72918	08457	78134	48407	26061	58754	05326
29621	66583	62966	12468	20245	14015	04014	35713	03980	03024
12639	75291	71020	17265	41598	64074	64629	63293	53307	48766
14544	37134	54714	02401	63228	26831	19386	15457	17999	18306
83403	88827	09834	11333	68431	31706	26652	04711	34593	22561
67642	05204	30697	44806	96989	68403	85621	45556	35434	09532
64041	99011	14610	40273	09482	62864	01573	82274	81446	32477
17048	94523	97444	59904	16936	39384	97551	09620	63932	03091
93039	89416	52795	10631	09728	68202	20963	02477	55494	39563
82244	34392	96607	17220	51984	10753	76272	50985	97593	34320
96990	55244	70693	25255	40029	23289	48819	07159	60172	81697
09119	74803	97303	88701	51380	73143	98251	78635	27556	20712
57666	41204	47589	78364	38266	94393	70713	53388	79865	92069
46492	61594	26729	58272	81754	14648	77210	12923	53712	87771
08433	19172	08320	20839	13715	10597	17234	39355	74816	03363
10011	75004	86054	41190	10061	19660	03500	68412	57812	57929
92420	65431	16530	05547	10683	88102	30176	84750	10115	69220
35542	55865	07304	47010	43233	57022	52161	82976	47981	46588
86595	26247	18552	29491	33712	32285	64844	69395	41387	87195
72115	34985	58036	99137	47482	06204	24138	24272	16196	04393
07428	58863	96023	88936	51343	70958	96768	74317	27176	29600
35379	27922	28906	55013	26937	48174	04197	36074	65315	12537
10982	22807	10920	26299	23593	64629	57801	10437	43965	15344
90127	33341	77806	12446	15444	49244	47277	11346	15884	28131
63002	12990	23510	68774	48983	20481	59815	67248	17076	78910
40779	86382	48454	65269	91239	45989	45389	54847	77919	41105
43216	12608	18167	84631	94058	82458	15139	76856	86019	47928
96167	64375	74108	93643	09204	98855	59051	56492	11933	64958
70975	62693	35684	72607	23026	37004	32989	24843	01128	74658
85812	61875	23570	75754	29090	40264	80399	47254	40135	69916

Source: A Million Random Digits with 100,000 Normal Deviates by the Rand Corporation. New York: The Free Press, 1955.