Project ID: 718

Competitive Research Grant

Sub-Project Completion Report

on

Study of the Climate Change Impact on Fisheries Resources and Fishers' Especially Women and Children in Selected Climate Hotspot Zone of Bangladesh

Project Duration
May 2017 to September 2018

Department of Fisheries Biology and Genetics
Faculty of Fisheries
Bangladesh Agricultural University
Mymensingh-2202

Submitted to
Project Implementation Unit-BARC, NATP-2
Bangladesh Agricultural Research Council
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Project Implementation Unit
National Agricultural Technology Program-Phase II Project (NATP-2)
Bangladesh Agricultural Research Council (BARC)
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Acronyms

Abbreviation	Elaboration
ACIA	Arctic Climate Impact Assessment
AI	Agreement index
BFDC	Bangladesh Fisheries Development Corporation
BHWDB	Bangladesh Haor and Wetland Development Board
BOD	Biological Oxygen Demand
CBRMP	Community Based Resource Management Project
CEGIS	Centre for Environmental Geographic Information Services
DFID	Department for International Development
DO	Dissolved Oxygen
DoF	Department of Fisheries
E	East
EIFAC	European Inland Fisheries Advisory Commission
EQS	Environmental Quality Standard
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GHG	Greenhouse gases
GIS	Geographical Information System
Ha	Hector
ICEAB	International Conference on Environmental Aspects of Bangladesh
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IWM	Institute of Water Modeling
Km	Kilometer
M	Meter
Mm	Millimeter
Mg	Milligram
N	North
NAS	National Academy of Sciences
NGOs	Non-Government Organizations
NRM	Natural Resource Management
PCA	Principal Component Analysis
Ppt	Parts per thousand
S	Second
SLA	Sustainable livelihood approach
sp	Species
spp.	Species pluralis
SPSS	Statistical Package for Social Science
S-R	Sedgwick-Rafter
SLR	Sea Level Rise
SMF	Sundarbans Mangrove Forests
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	The United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
WFC	World Fish Center

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Executive Summary

Climate change is a contemporary global threat to the whole world especially in the coastal areas like Bangladesh. Bangladesh is extremely vulnerable to climate change impacts because of its geographical location. This research is an attempt to assess the impacts of climate change on fishers' livelihood, fisheries resources, water quality parameters and primary productivity of selected climate hotspot zones namely Sundarbans impact zone, Meghna estuary, high saline zone-Cox's Bazar, Haor basin-Kishoreganj and Charland-Munshiganj. Of the total 164 fish species; 11 Shrimps, 5 Prawns, 5 Crabs and 1 Lobster were documented in Sundarbans. Total 61 fish species belong to 13 orders and 29 families were documented in the river Meghna and 73 species belong to 11 orders and 33 families were recorded simultaneously from the Laukhati and Galachipa rivers. A total of 75 fish species belong to 15 orders and 36 families were documented in the river Padma. Of 84 fish species belong to 36 families under 13 orders were recorded in the Bay of Bengal. Total 79 fish species belong to 27 families under 9 orders were found in Kishoreganj haor region. The range of pH, temperature, salinity and dissolved oxygen (DO) were recorded from 7.1 to 8.7, 25°C to 32.8°C, 1.5 to 23 ppt and 4.3 mg/l to 7.7 mg/l respectively in the rivers of Sundarbans. The average temperature was recorded 30.5 ± 0.90°C, 27.1 ± 1.05°C and 27.4 ± 0.60°C; and average DO was 6.37 ± 1.11 mg/L, 5.63 ± 0.33 mg/L and 6.33 ± 0.51 mg/L in the rivers Meghna, Laukhati and Galachipa respectively. The pH was 8.3 ± 0.59, 8.03 ± 0.50 and 7.8 ± 0.50; salinity was 0.10 ± 0.10 ppt., 0.23 ± 0.13 ppt. and 1.2 ± 0.15 ppt. in the Meghna, Galachipa and Laukhati rivers respectively. The temperature, pH, DO and salinity of water were recorded in the range of 28.7±0.66 to 32.3±0.52, 7.8±0.26 to 8.9±0.41, 7.8±0.26 to 8.9±0.41 ppm and 0.10±0.01 to 0.15±0.01 respectively in the river Padma. The range of temperature, DO, pH and salinity were recorded as 28.77°C to 33.30°C, 7.9 to 8.3mg/l, 7.3 to 8.5 and 0ppt respectively in Kishoreganj haor. Total genera of phytoplankton were 41, 14 and 34; and genera of zooplankton were 24, 12 and 23 respectively in the Meghna, Laukhati and Galachipa rivers respectively. Total 41 phytoplankton and 24 zooplankton genera were identified in the river Padma. In Kishoreganj haor, 23 phytoplankton and 12 zooplankton species were recorded. Fishers' observations compiled from the Sundarbans region indicate increased temperatures and changes in weather patterns, increased extreme events, decreased rainfall, sea level rise and siltation shift in fish species distribution range, and migratory & spawning behaviours. Salinity intrusion gradually increased which lead to alteration in species diversity and productivity. Among all hazards, flood, cyclone and storm were found to affect 50%, 49%, 46% and 57%, 54%, 51% of fishers at Chandpur and Patuakhali districts, respectively. About 62.7% fishers were agreed with the statements such as reduce fish production, damage fishing ground, blockage on migration road, damage biodiversity, increase temperature, enhance soil erosion, reduce rainfall, siltation, reduce water flow, increase storm, changing spawning season, decrease fish production and extinct fish species. In all the regions, women and children were found to be affected severely such as malnutrition, lack of education, lack of treatment opportunity, early marriage etc. Fish kidney, gill and liver were affected due to increasing salinity and temperature in the rivers of Sundarbans and Meghna. Therefore, the present study clearly indicates that there is visible decline of fish species and primary productivity during the last decade due to negative impacts of climate change.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. **Title of the CRG sub-project: Study of the climate change impact on fisheries resources and fishers´ especially women and children in selected climate hotspot zone of Bangladesh**

2. **Implementing organization:** Department of Fisheries Biology and Genetics
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4. **Sub-project budget (Tk):**
   4.1 Total: 4500,000/-
   4.2 Revised (if any):

5. **Duration of the sub-project:**
   5.1 Start date (based on LoA signed): 07 May 2017
   5.2 End date: 30 September 2018

6. **Justification of undertaking the sub-project:**

6.1 Climate change

Climate change has now become a much talked issue in the World. Global warming is expected to cause changes such as higher temperatures, sea level rise and changing rainfall patterns, as well as more abrupt effects, such as an increase in the intensity and frequency of extreme events such as floods, storm surges, cyclones, and salinity intrusion may drastically cause enormous devastations to flora and fauna in Bangladesh. Bangladesh deals with the effects of climate change because of the all too loud alarm bells sounded in recent times about the dangers to which the least developed countries of the world are exposed. Climate-related factors will result losing the means of livelihood of 40 million people in Bangladesh, with the additional fact of 20 million more being displaced by 2050 owing to natural calamities generated by climate change. About one thousand million people (100 crore) of the world will lose their habitat (be the destitute) by the year 2050. Now, one severe effect of climate change will obviously be of people getting uprooted from their land and finding themselves in the unenviable position of having turned into climate refugees. In recent years, climate change has become a major concern. It arises from past and present emissions of greenhouse gases increasing pre-existing concentrations of these gases in the atmosphere (IPCC, 2007a). Following the industrial revolution, humans have increasingly relied on fossil fuels as an energy source. Currently, about 80% of the world's power is generated from fossil fuels (ACIA, 2004). Fossil fuel combustion does produce greenhouse gases that can affect the global climate (Bolin *et al.,* 1986). Although the earth's climate changes naturally in response to differences in solar radiation, volcanic eruptions, and aerosol concentrations, our modern climate is also subject to forcing from greenhouse gases, and this forcing will increase in importance as emissions continue (Mann *et al.,* 1998). However, once fossil fuel combustion increased, concentrations of these gases began to rise (Ficke *et al.,* 2007). The International Panel on Climate change-Assessment Report 4 predicts that global average temperature is expected to increase by 0.2°C per decade over the next two decades. If temperature continue to increase at this rate, it adds, global average temperature increase (from 1905) will reach 1.5°C by 2050 (IPCC, 2007b). For example, the concentration of atmospheric carbon dioxide is now higher than any observed in the last 160,000 years (Dobson, 2001). However, the climate has very complex relationships with the seasonality including variations of temperature, rainfall and day length (Gill and Gerard, 1991). Such seasonal variation has diverse influence on fishing, fish production and livelihoods (Haque, 2007). The variation in the global climate or in regional climate over time, such as variations in sunlight intensity, droughts, greenhouse gas emission, temperature rise, extreme temperature, unexpected rainfall, floods and cyclones, arsenic contamination, losses of ecosystem which caused by processes of internal and external forces (WFC, 2009).

Bangladesh is recognized to be one of the most susceptible countries in the world, highly vulnerable to climatic manifestations (short-term and long-term impacts of climate change) due to its unique geographic location, hydro-geological characters like dominance of floodplains, low elevation from the sea and lastly the socio-economical characters like high population density, high levels of poverty, and overwhelming dependence on nature. Unfortunately, the country's future is now trapped between the melting Himalayas in the north and the encroaching Bay of Bengal to the south. Sea levels rise because warmer water takes up more room than colder water, a process known as thermal expansion. Melting glaciers compound the problem by dumping even more freshwater into the oceans. Rising seas threaten to inundate low-lying areas and islands, threaten coastal populations, damage property and destroy ecosystems such as mangroves that protect coasts against storms and wetlands. The mangrove forests of the low-lying Sundarbans, a world heritage site may disappear. Sea levels have risen between 4 and 8 inches in the past 100 years. Current projections suggest that sea levels could continue to rise between 4 and 36 inches within the next 100 years. A 36-inch increase in sea levels would swamp all low-lying areas and islands around the globe including southern Bangladesh. In addition, the rising sea water would penetrate the country's fertile land and ruin thousands of hectares of cultivable land in the coastal areas. Sea level rise associated with other effects of climate change could displace tens of millions of people in low-lying areas- especially in developing countries. Inhabitants of some small island countries that rest barely above the existing sea level are already planning to abandon their islands.

6.2 Mangroves and the Sundarbans

Mangroves are intertidal wetlands forest which confined to both of the tropical and subtropical regions in the world. The total global area of the mangroves is estimated at only 18.1 million ha (Spalding *et al.,* 1997). More than 41% of the World's mangroves occur in South and Southeast Asia of which Indonesia alone accounts for 23%. A further 20% of the total mangrove area lies in Brazil, Australia and Nigeria (Spalding *et al.,* 1997). In practical, mangroves are prolonged in deltaic habitats. Mangroves are the source of a variety of renewable resources and play a significant role in the local coastal economy and livelihood of the people, in the regional environmental balance and in the national economic development also. The ecological and economic significance of mangrove forests has now been recognized worldwide. Mangroves are characterized by a higher fisheries biodiversity (Chong *et al.,* 1990; Morton, 1990; Robertson and Blaber, 1992; Hong and San, 1993; Sasekumar *et al.,* 1994). About 10 million people of the coastal areas are dependent directly or indirectly on the mangrove for a variety of activities such as agriculture, fishing, cattle rearing, human settlement, collection of housing materials, fuelwood and human foods and employment opportunities (Islam and Haque, 2004). The mangroves are aggravated in the Ganga-Brahmaputra-Meghna Delta, popularly known as the Sundarbans.

The Sundarbans (21º 30′ to 22º 40′ N, 88º 05′ to 89º 55′ E) are the only contiguous and largest mangrove forest system in the world with a total area of over 10,000 square kilometers (Gopal and Chauhan, 2006). Roughly 60% of the Sundarbans fall in Bangladesh, located on the northern limits of the Bay of Bengal and the old Ganges delta (Agarwala *et al.,* 2003). The estimates of the total area of the Sundarbans in the two countries often differ considerably. The area of the Sundarbans in Bangladesh is 599,330 ha (Rahman *et al.,* 1979) and in India it is 426,300 ha (Sanyal, 1983). Of the total area of the Sundarbans in almost 62% is land and the rest water (Christensen, 1984). It consists of a dense network of smaller rivers, channels and creeks which are linked with the Ganga, Brahmaputra and Meghna river system. The River Harinbhanga demarcates the border between India and Bangladesh (Gopal and Chauhan, 2006). The Sundarbans provide critical ecosystem services, fulfill important socio–economic and environmental functions and support coastal livelihoods. Their unique root systems create a great deal of physical roughness, thus capturing and storing vast quantities of sediment from upland and oceanic origin (Raha *et al.,* 2012). By using the Sundarbans as the basic productive unit, large-scale export-oriented aquaculture industries have been developed in the coastal areas of Bangladesh.

In the rivers of the Sundarbans, the surface water flow mainly comes from the Ganges–Padma River Systems through Garai–Madhumati Rivers and from the lower Meghna River through the Swarupkati–Kocha Rivers. The other source of surface water flow is the runoff from the local catchment area (Islam and Haque, 2004). The level of DO, salinity and pH of rivers and its temporal and spatial variation are largely affected by the water flow of these rivers system. In the Ganges River at Harding Bridge, the average minimum flow was 1,920 m^3/s prior to 1975. But in 1975 after the construction of the Farrakka Barrage, water was diverted to Hooghly River in India. Therefore, the average minimum water flow in the Ganges River near Harding Bridge reduced at level 400 m^3/s during 1988–1996. In 1996 after the Ganges Water Treaty was signed by India and Bangladesh, the average minimum flow at Harding Bridge increased to 619 m^3/s (Dasgupta *et al.,* 2015). The huge volume of the freshwater comes to the Sundarbans forest in the monsoon season. But gradually the freshwater flow decreases during the dry season. As a result the saline condition aggravate in the rivers of the Sundarbans that persists until the freshwater flow increases again.

6.3 The Padma and Meghna rivers

The Padma is a major river in Bangladesh. It is the main distributary of the Ganges, flowing generally southeast for 120 km to its confluence with the Meghna River near the Bay of Bengal. The Padma enters Bangladesh from India near Nawabganj and meets the Jamuna near Aricha and retains its name, but finally meets with the Meghna near Chandpur and adopts the name "Meghna" before flowing into the Bay of Bengal. The Ganges originates in the Gangotri Glacier of the Himalaya, and runs through India and Bangladesh to the Bay of Bengal. The Ganges enters Bangladesh at Shibganj in the district of Chapai Nababganj. West of Shibganj, the Ganges branches into two distributaries, the Bhagirathi and the Padma rivers. After the construction of the Farakka Barrage on the Ganges River in West Bengal, the maximum flows in the Padma River were reduced significantly. The flow reduction caused many problems in Bangladesh, including the loss of fish species, the drying of Padma's distributaries, increased saltwater intrusion from the Bay of Bengal, and damage to the mangrove forests of the Sundarbans (Islam, 2006).

Bangladesh lies on a deltaic plain with five major river systems: the Jamuna-Brahmaputra, the Padma-Ganges, the Surma-Meghna, the Padma-Meghna, and the Karnaphuli. Although altitudes up to 105 m above sea level occur in the northern part of the plain, most elevations are less than 10 m above sea level; elevations decrease in the coastal south, where the terrain is generally at sea level. For the time being, these geographical features make Bangladesh vulnerable to various natural disasters, such as floods and cyclones. In terms of the impact of climate change few places in the world will experience the range of effects and the severity of changes that will occur in Bangladesh. Bangladesh ranked fifth most vulnerable country to climate change and hunger in an action aid research report. In the World Risk Index 2011, jointly conducted by United Nations University (UNU), Germany and the Institute of Environment and Human Security said that Bangladesh ranked sixth among countries that are most vulnerable to natural disasters, while second among the Asian countries (Daily Star, 2011). Bangladesh is a very low energy consuming country, and it is pursuing a low carbon growth path, while building its resilience to climate change and reducing the risk of climate change, which shows national development (Daily Star, 2009). Bangladesh is projected to be 0.5 to 0.2 °C warmer than today by the year 2030. The 30 years mean summer temperature in Bangladesh is 27.5 °C and the mean summer temperature is relatively higher during the monsoon than during summer. Winter is the driest season in Bangladesh. The 30 years mean winter rainfall amounts to about 64 mm with a variability of around 53%. By 2030, the best estimate projection is for monsoon rainfall to increase by 10 to 15% and winter rainfall by 5 to 10% (Kafiluddin, 2005). Such integrated predictions of the impact of climate change are beyond the current frontiers of our knowledge, particularly at national or smaller scales.

River plays as a great source of various fishes. There are many rivers in Bangladesh. The Meghna river is one of them. It discharges the joint flow of the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna (joint flow of the Surma- Kushiyara) itself. The Meghna river ends in the Bay of Bengal form huge widespread estuarine is regularly influenced by the strong interactions of biotic and abiotic factors (Kamal and Khan, 2009) due to tropical monsoon (southerly or southwesterly winds) and winter (north and northwest winds). Estuary is exclusively important part of aquatic habitat (Ketchum, 1951) is a great contributor of highly productive ecosystem (Honggang*et al*., 2012) plays a significant role in the global carbon balance (Smith and Hollibaugh*,* 1993) and nutrient recycling (Fisher *et al.*, 1982) and serve as a favorable breeding and nursing environment for many commercially important shell and fin fishes (Haedrich, 1983). It contributes about 53 fish species (Hossain *et al*., 2012). On the contrary, the Laukhati and Galachipa rivers also play as a great source of many aquatic organisms including fish. These resources contribute to the entire Patuakhali district as well as to the whole country in the support of protein. Moreover, many marine, brackish and freshwater animals largely depend on estuarine environment in their life history or entire life cycle. However, all the rivers contribute a lot in the national GDP in Bangladesh. Fish and fisheries products play a significant socio-economic role of Bangladesh in terms of nutrition, income, employment and foreign exchange earnings and depend on fish as the principal source of animal protein. More than 80 percent of the animal protein in the Bangladeshi diet comes from fish products. Fisheries contribution to national GDP is 3.69% (DoF, 2016). This sector contributes about 90% of the nation's animal protein intake, nearly 6 to 8% GDP to national income and 5.77% to the foreign earning of nation (DoF, 2012). Annual fish production was 2,701,370 MT in 2008-09 fiscal year, where annual fish intake by an individual was 17.52 kg and the annual fish demand was 29.74 MT (DoF, 2010). Bangladesh earned TK. 4312.61 crore by exporting 85000 MT of fish and fishery products in foreign countries in 2012-2013 (DoF, 2014). It is estimated that about 1.7 million people are directly and indirectly employed for earning their livelihood related to fisheries sector (DoF, 2014).

Moreover, the Meghna river estuary is the biggest estuary and occupying almost whole central coast of Bangladesh. The Meghna estuary contributes a large portion in the national economy as well as the Galachipa river and the Laukhati river of Patuakhali district also support a great portion of fisheries resources for Bangladesh. Although these fisheries resources of that following river carry high importance but there is no comprehensive report on effects of climate change on fisheries resources and fishers' in these rivers. Therefore, the present investigation was undertaken to evaluate the effects of climate change on fisheries resources and fishers in these rivers.

6.4 Kishoreganj haor region

Haor is basically very low lying river basin area below the level of flood plain, which is also similar to swamp land covered by water almost six months of a year starting from the monsoon (Sarma *et al*., 2010). It is a bowl-shaped large tectonic depression (Kazal *et al.,* 2010) and the most productive ecosystem with huge number of environmental, economic and social value (Sarma *et al.,* 2010). Haor is covering about 25% of the North-Eastern part of Bangladesh (BHWDB, 2011). In addition, it is a mosaic of wetland habitats including rivers, streams and irrigation canals, large areas of seasonally flooded plains and hundreds of haors and beels (Hussain *et al.,* 2007). There are altogether 423 haors comprising an area of about 8000 km^2 situated in seven districts: Sylhet, Moulavibazar, Habiganj and Sunamganj in the north-east, Netrokona and Kishoreganj in the north-central and Brahmanbaria in the central eastern region of Bangladesh (Miah, 2013). The haor region is bordered on three sides by the mountain ranges of India, with Meghalaya to the north, Tripura and Mizoram to the south, and Manipur and Assam to the east. The region extends north to the foot of the Garo and Khasia Hills and east along the upper Surma Valley to the Indian border (Bennett *et al.,* 1995).

Kishoreganj (24°02' to 24°39'N and 90°35' to 91°15' E) is one of the most important haor regionlocated in central Bangladesh which is also a part of the Dhaka division (BBS, 2013) and bounded by Netrokona district in north, by Habiganj and Brahmanbaria districts in east and, by Narsingdi and Brahmanbaria districts in the south and by Mymensingh, Gazipur and Narsingdi districts in the west (BBS, 2013). These districts are mainly surrounded by the Brahmaputra, Meghna, Kalni, Dhanu, Ghorautra, Bauri, Narasunda and Piyain rivers (BBS, 2013). The total area of the district is 273,100 hector and out of these 133,943 hector is haor area (CEGIS, 2012). There are 13 Sub-district (upazilas) in this district and among these, four upazilas (Austogram, Itna, Mithamoin, and Nikli) are fully, five (Bajitpur, Bhairab, Karimgonj, Kuliarchar and Tarail) are partially surrounded by hoar (Khan *et al.,* 2012) and the rest of four upazilas (Hossainpur, Katiadi, Kishoreganj Sadar and Pakundia) are non-haor areas (Khan *et al.,* 2012).

In the rivers of the Kishoreganj haor region, the surface water flow mainly comes from the Meghna River through the Dhanu and Norshunda Rivers (Ahmed, 2012). The other source of surface water flow is the runoff from the local catchment area (Khan, 1994). During monsoon, the Meghna River system carry huge amount of runoff water from the hills of India (Rabby *et al.,* 2011). In the Meghna river system, the peak flow is 19,800 cu m/sec, and the maximum velocity range from 1-2 m/sec with depth varying from 33 m to 44 m and the average discharge of the river is about 6,500 cu m/sec (Khan, 1994). The level of DO, salinity and pH of rivers and its temporal and spatial variation are largely affected by the water flow of Meghna rivers system in Kishoreganj haor region. The huge volume of the freshwater reaches the Kishoreganj haor region in the monsoon season through Meghna river system. But gradually the freshwater flow decreases during the dry season. As a result the water flow condition also changes in Dhanu and Norshunda rivers in Kishoreganj.

The river system of haor region falls under the Meghna basin (Ahmed, 2012). This wet land area is crisscrossed by numerous rivers coming down from the hills of India with huge amount of runoff water during monsoon (Rabby *et al.,* 2011). However, during the post-monsoon, they mostly dry up (Nowreen *et al.,* 2015). Usually the water body in haor region remains at the zero level from January to March (Sarma, 2010) and then starts to increase and again go down from August (Roy, 2015). Mostly, in June and July, the water level reaches the highest point (Salauddin and Islam, 2011). In addition, the average annual rainfall in the haor areas is 4130 mm which is almost double compared to the country rainfall average (Nowreen *et al.,* 2015). However, the physical settings and hydrology of the haor region created countless opportunities as well as constraints for the inhabitants (CEGIS, 2012; Hanif *et al.,* 2015).

6.5 Fish biodiversity

Bangladesh is proud of housing as many as 260 freshwater fish species, 22 exotic fish species, 24freshwater Prawns, 475 marine fish species and 36 marine Shrimps (DOF, 2005). All these fisheries resources will face serious consequences due to the climate change impact unless some mitigating or adapting coping measures are taken against the hazard from now. We can only apprehend about the severity of such disaster but cannot be assured of the kind and extent of the same. This is an area that requires some research urgently. Since reproduction is considered as the most important aspect for continuation of the race and since reproduction is an intricate system usually affected critically by any physical, chemical and biological changes in the environment research on this aspect seems of utmost importance. In a country like Bangladesh the most serious impact of global warming will be due to the change in temperature and intrusion of saline water in the freshwater zone that affect the reproduction of fish and other aquatic animals tremendously. They may cause delay in attaining maturity, less fecundity, poor ovulation of broods and less fertilization, hatching of eggs and survival of larvae.Hussain and Acharya (1994) reported that 53 species of pelagic fish belonging to 27 families and 124 species under 49 families of demersal fish in the Sundarbans. According to Seidensticker and Hai (1983) over 120 species of fish are reported to be commonly caught by commercial fishermen in the Sundarbans. The Sundarbans is also an important breeding ground for indigenous and marine fish species e.g., ilish (*Tenualosa ilisha*), koral (*Lates calcarifer*), fesha (*Liza parsia*), and cetaceans such as the Ganges and Irrawady dolphins (GoB, 2010). The Sundarbans mangrove forest has importance for its greater biodiversity and declared as “The World Heritage Site” by UNESCO in 1997 (Islam, 2003).

Bangladesh is very rich in fish and Shrimp species biodiversity. A total of, 442 marine and 76 species fish from estuarine waters were recorded by IUCN Bangladesh (2000). The marine list, however, contains 73 species whose distribution includes estuaries as well. MOEF (2002) surveys made 87 new records from the St. Martin’s Island. Thus the present total would be 529 (442+87) marine and 149 (76+73) estuarine fish species. However, many of them are not of commercial importance (Amin and Kawsar 2003). There are about 100 commercial species of which 20 fish families are highly commercial, contributing about 82-87% of the total demersal exploitation. In addition abundance of pelagic fishes, e.g. seven species of tuna and skipjack, four species of mackerel, fourteen species of sharks and rays were also found.

Only in St. Martin's Island have favourable substrata of the growth of seaweeds. A preliminary survey of this Island and of the sunderbans area revealed the occurrence of nearly 200 species of seaweeds. There are also 160 taxa of marine phytoplankton in the Bay of Bengal. In addition to fin fish Bangladesh also has a rich diversity of shellfish, especially of Caridean Shrimps, several of which are of commercial interest and export value. About 36 species of Shrimps have been recorded from the marine water of Bangladesh. With a recent record a total of 63 Shrimp and Prawn from inland and marine

Haor consists of diverse types of floral and faunal diversity especially reptiles, birds, fish species, amphibians etc. They play an important role to continue the haor ecosystem (Choudhury, 2016). In haor region, it is estimated that a total of 141 fish species, 11 amphibians, 34 reptiles (6 turtles, 7 lizards and 21 snakes), 206 birds and 31 mammals occur in haor region (Gieson and Rashid, 1997). According to CBRMP (2013) over 126 species of fish are reported to be commonly caught by local fishers in the haor region. Islam *et al*. (2008) recorded 108 species under 29 families of 10 orders from haor region. Kishoreganj haor region is considered as the home of many species of freshwater fishes. There is a great importance of this haor region for fish production, maintaining biodiversity, meeting local and regional demand (Salauddin and Islam, 2011). However, Kishoreganj haor region is also known for its richest SIS (Small Indigenous Fish Species) biodiversity, which contains 30 species belonging to 7 orders and 15 families (Rownok *et al.,* 2014).

6.6 Water quality parameters

Salinity intrusion due to reduction of freshwater flow affected groundwater and increased soil salinity are major concerns of Bangladesh. Cyclones and tidal surge are adding to the existing problems (Abedin, 2010). Among the Southern areas of Bangladesh especially Chandpur and Patuakhali region are the most vulnerable to the impacts of salinity intrusion, as it is saline intruded area (Rahman, 2009). This vulnerability is adding more pressure to the existing problems such as dry season water scarcity for the increased population in Bangladesh (ADB, 2005). Because of salinity intrusion a significant change has taken place in fisheries sector. In the case of fishery, increased salinity affects spawning ground leading to substantial reductions in the inland open water fishery (Rabbi and Ahmed, 1997). Various fish species cannot get suitable environment in this region for reproduction (Ali, 1999). Most indigenous fish species are on the verge of extinction in these areas because of salinity intrusion, siltation of rivers, their tributaries and different water bodies.Water salinity of Sundarbans mainly depends on the volume of freshwater discharges from the upstream river systems, the tributaries of Ganges. The salinity and the water circulation pattern of the Sundarbans are induced by the ocean currents and the strong tidal currents in the coastal waters. A reduction in freshwater inflows and siltation of the tributaries of the Ganges and other rivers increase in river salinity in the Sundarbans. Salinity increased from 2 ppt to 20 ppt at Mongla in the Pussur River from 1962 to 2008 (Dasgupta *et al.,* 2015). Normally, the average salinity of the rivers in the coastal area is higher in the dry season than in the monsoon because of lack of freshwater flow from upstream. The salinity generally increases almost linearly from October (post-monsoon) to late May (pre-monsoon), with the gradual reduction in the freshwater flow (Dasgupta *et al.,* 2015). Because of heavy rainfall and freshwater flow from upstream through the river system during monsoon season in the Sundarbans, the salinity level drops gradually. The salinity levels are at the minimum in the wet season, usually during September or early October (Dasgupta *et al.,* 2015). Both tidal effects of brine water and freshwater flow from upstream river mixed together and determine the amount of salinity in water. At the river of the Sundarbans, the range of salinity varies with the spring or neap tide. Tidal amplitudes during spring tides are around 2.5 to three times higher than the neap tides (Dasgupta *et al.,* 2015). In Sundarbans, during spring tides the higher water levels result in greater amount of saline water entering inland. The salinity level at the Bay of Bengal during the dry season is also comparatively high; and saline water intrudes through the major rivers, namely the Baleswar, Jamuna, lower Meghna, Malancha, Pussur, Sibsa, and Tnetulia, through tidal effects (Dasgupta *et al.,* 2015). The land topography of the region is very flat; strong tidal effects at times travel up to 200 km upstream of the coast. Consequently, the region is severely affected by salinity intrusion (Dasgupta *et al.,* 2015). Several studies in Bangladesh indicate that coastal zone vulnerability will become more acute in a changing climate from the combined effects of sea level rise (SLR), changes in upstream river discharge, and increased frequency of more intense cyclones (Cruz *et al.,* 2007; CEGIS, 2006; IWM, 2005).

Temperature cannot regulate by fishes as they are cold-blooded animals (Moyle and Cech, 2004). Their body temperatures are virtually identical to their environmental temperatures. These fishes may thermoregulate behaviorally, by selecting thermally heterogeneous microhabitats (Nevermann and Wurtsbaugh, 1994; Brio, 1998; Ficke *et al.,* 2007), but they are compelled by the range of temperatures available in the environment (Ficke *et al.,* 2007). All kinds of body activities of a fish including growth, reproduction, and activity are directly influenced by changes in temperature (Wohlschlag *et al.,* 1968; Schmidt-Nielsen, 1990; Franklin *et al.,* 1995). The body temperature may control all biochemical reaction rates. Therefore, increasing mean temperatures can affect individual fish by altering physiological functions such as thermal tolerance, growth, metabolism, food consumption, reproductive success, and the ability to maintain internal homeostasis in the face of a variable external environment (Fry, 1971). Temperature tolerance ranges are species-specific and most of the fish species of the Sundarbans are eurythermal (wide tolerance range) species such as *Mugil cephalus*. But fish populations of the Sundarbans that are faced with changing thermal regimes may increase or decrease in abundance, alter their distribution patterns, experience range expansions or contractions, or face extinction.Elevated temperatures positively alter the breathing rates, feed consumption, enzyme activities, oxygen consumption and feed metabolism (Smith, 1989), thereby affecting fish growth. The growth rate will determine how fast maturity size is attained, the fecundity, recruitment into the exploitable phase of the population and ultimately influence increase in population size (Smith, 1989). The body temperature may control all biochemical reaction rates in fishes.

Dissolved oxygen (DO) is much less concentrated in water than in air (Moyle and Cech, 2004). Oxygen enters the water column through diffusion from the atmosphere (this is potentially facilitated via turbulence, upwelling patterns and mixing) and by photosynthetic production (Kalff, 2000; Stickney, 2000). All aquatic plants, animals and microbial are used DO from water through respiration and DO highly decrease in the water column especially at night when photosynthesis stops. DO concentrations of 5 mg/l or more are acceptable for most aquatic organisms (Stickney, 2000), and concentrations below 2–3 mg/l are considered hypoxic (Doudoroff and Warren, 1965; Kalff, 2000). Water temperature has an inverse relationship with DO in water. For example, water at 0°C holds about 14.6 mg/l, but water at 25°C can only hold about 8.3 mg/l (Kalff, 2000). Because the aerobic metabolic rates of fishes increase with temperature, an increase in temperature both decreases the DO supply and increases the biological oxygen demand (BOD) (Kalff, 2000). Fishes exposed to elevated water temperatures through climate change can face a serious problem where the decreased supply of oxygen cannot meet the increased demand of DO levels. Available DO in water will depend on a multitude of factors such as ambient temperature, water current, tidal influence, upwelling regimes, biological oxygen demand, and local climate (e.g., wind mixing). Whether or not the incidence of hypoxia or anoxia increases in individual systems remains to be seen (Ficke *et al*., 2007). When the level of DO in water reduced and the oxygen consumption rate exceeds it leads to hypoxia. Certain level of oxygen is required for the life of all fishes. This level of requirement of oxygen is critical level, above and below it the fish does not survive (Doudoroff and Shumway, 1967). Reduction in DO occur in all waters and it affects the fish life. The effect of reduced oxygen on metabolism, development, growth and locomotion of fishes has been investigated (Doudoroff and Warren, 1965). The different DO level affects different life stages of fish. Sometimes hatching of egg is accelerated by reduced oxygen and sometimes it is delayed (Doudroff and Shumway, 1970). Low DO effects the egg production and hatching period in fish. Fish activity can increase or decrease at reduced oxygen concentration. The fish is able to detect low oxygen concentration in water and try to avoid it. In natural condition fish avoid lethal level successfully when oxygenated water is accessible. Water temperature has an inverse relationship with DO in water.

The pH of water affects the normal physiological functions of aquatic organisms, including the exchange of ions with the water and respiration. Such important physiological processes operate normally in most aquatic biota under a relatively wide pH range (e.g., 6-9 pH units). There is no definitive pH range within which all freshwater aquatic life is unharmed and outside which adverse impacts occur. Rather, there is a gradual “deterioration” in acceptability as pH values become further removed from the normal range (Alabaster and Lloyd, 1980). The acceptable range of pH to aquatic life, particularly fish, depends on numerous other factors, including prior pH acclimatization, water temperature, dissolved oxygen concentration, and the concentrations and ratios of various cations and anions (NAS, 1972). Alabaster and Lloyd (1980) identified the pH range that is not directly lethal to freshwater fish as 5.0-9.0. With few exceptions, pH values between 6.5 and 9.0 are satisfactory, on a long-term basis, for fish and other freshwater aquatic life. The pH of most inland freshwaters containing fish ranges from about 6ppt to 9ppt (Shaikh and Yeragi, 2003), with most waters, particularly those with healthy, diverse, and productive fish and macro invertebrates communities having a pH between approximately 6.5 and 8.5 units (Kratz *et al.,* 1994). In establishing water quality criteria for pH, USEPA (1999) stated that, although fish had been found at pH values from 4-10, the safe range was 5-9 and for maximum productivity the pH should be maintained between 6.5 and 8.5. However, there are few such organisms, and their extreme tolerances are not reflective of the pH tolerated by the majority of organisms occurring in a given aquatic ecosystem.

6.7 Primary and secondary productivity

Primary productivity is very essential for fish species growth and distribution in natural waterbodies. Primary production is largely depends on nutrient concentration in aquatic environment. Fluctuations in primary production is largely depends on variation in nutrient concentrations caused by changes flow of water and upwelling regimes in rivers. Variation in nutrients has significant impacts on benthic macroalgal abundance and evenness, with subsequent effects on overall production (Lotze and Worm, 2002). Mangroves are considered to exceptionally higher primary productivity than other wetland habitat types (Clough, 1992; Primavera, 1996). Hussain and Acharya, (1994) listed 34 species of phytoplankton belonging to the families Volvocaceae, Palmelaceae, Ulvaceae, Cladephoraceae, Zygnemaceae, and Codiaceae, the Division Chlorophyta was represented by nine species under six genera in the Sundarbans. Division Cyanophyta was represented by 16 species under 9 genera belonging to the families Chroococcaceae, Oscillatoriaceae, Nostocaceae, and Rivulariaceae. Bacillariophyta was represented by 16 genera and 35 species and the Euglenophyta was represented by two genera and two species. The mangroves of Bangladesh are tremendously rich in zooplankton production. Thirteen major taxa of zooplankton namely, Copepods, Amphipods, Mysids, Acetes, Chaetognaths, Polychaetes, Lucifers, Hydromedusae, Shrimp larvae, fin fish larvae, Crab larvae, Squilla, and horse-shoe Crab larvae were found to occur in the rivers of Sundarbans region (Islam and Haque, 2004). Mahmood (1995) recorded 23 species of ichthyoplankton dominated by *Glossogobius giuris, Odontablyopsus rubiundus, Mugil spp.* and the other common coastal fishes. Normally, primary productivity is comprised of the primary producers or phytoplankton and zooplankton, the secondary producers (Battish, 1992). The primary productivity represents the biological wealth of the water body, constituting a vital link in the food chain (Boyed, 1982). Haor is considered to exceptionally higher primary productivity than other wetland habitat types (Muzaffar and Ahmed, 2007). In any aquatic ecosystem the phytoplankton works as the backbone of food chain that in turn keep the predatory animals alive in wetlands and other aquatic environments. The phytoplankton communities of the haor are very much linked with zooplankton and fish productivity (Muzaffar and Ahmed, 2007). Muzaffar and Ahmed (2007) found 107 genera of phytoplankton in haor region and representing six classes. Azher *et al.* (2006) listed 75 (60 phytoplankton and 15 zooplankton) plankton where Chlorophyceae and Copepoda was the most dominant group of phytoplankton and zooplankton in Kishoreganj haor region.

6.8 Effects of climate change on fishers´ livelihood

Climate change is a serious threat to the Sundarbans with its high concentrations of population and economic activity in this region. The potential impacts of climate change in Sundarbans areas include progressive inundation from increasing temperature, sea level rise, rapid cyclone, storm damage, loss of wetlands, loss of freshwater fish habitat, increased salinity from saltwater intrusion and loss of biodiversity. In Sundarbans, the livelihood of numerous fishing communities are supported by fisheries sector and it also plays an important role to national economy. Over 3.5 millions of people living around the Sundarbans are directly or indirectly dependent on ecosystem services (Giri *et al*., 2007; Biswas *et al*., 2007). Fishers of the Sundarbans are already being affected by changes that are ultimately driven by rising global atmospheric temperatures. For example, coastal fishers in Bangladesh face increased frequency and severity of hurricanes, coupled with the greater penetration of saline water into coastal land due to thermal expansion of the warming oceans (Unnikrishnan *et al.,* 2006). The implications of climate change for saltwater intrusion and its impact on livelihoods and adaptation alternatives have not been investigated in great detail (World Bank, 2009). However, sporadic measurement of soil and water salinity along coastal areas indicates intrusion of saline waterfront landward in many areas (Mohal *et al.,* 2006). Unimaginable evidence indicates that increased salinity from saltwater intrusion poses an imminent threat to livelihoods and public health through its impacts on agriculture, aquaculture, infrastructure, coastal ecosystems, and the availability of freshwater for household and commercial use (DFID, 2007; Hussain, 2008). The problem of saltwater intrusion is expected to become more severe in low-lying coastal areas throughout the world, with increased sea level caused by climate change (Bates *et al.,* 2008; Akhter and Khan, 2012).However, all approaches suggest that the Sundarbans fisheries are highly sensitive to climate change. Species composition of water body also changed according to water temperature. Dominance of warmer water species are increase with increase of temperature increases. Warming and changes in oxygen content will potentially lead to an average decrease in maximum body size of exploited fish stocks 14–24% by 2050 relative to 2000 (Cheung *et al.,* 2013). These changes will challenge the sustainability of fisheries and their management particularly for countries with fewer alternative resources and lower adaptive capacity (Boyd *et al.,* 2014). Impacts of climate change on the fisheries sectors are still not well-studied (Boyd *et al.,* 2014). There are fewer studies of the climate change impacts on fisheries resources and fishers´ for developing countries particularly Bangladesh.

A vulnerability perspective explains the climate changes are exposed to in different locations in Bangladesh particularly climate hotspot zones. The lives, livelihoods and resources of fishers´

community particularly women and children will be affected in different ways. Many fish species have a narrow range of optimum temperatures related both to their basic metabolism and the availability of food organisms. Depending on the species, the area it occupies may expand, shrink or be relocated. No specific research has yet been conducted in these issues in Bangladesh. In these circumstances a research should be taken to save the fisheries resources and improve or keep the existing livelihood of fishers´ community. The research will be run in three phases. In the first phase a questionnaire survey regarding the changes in availability of important fish species and livelihood of fishers' community will be made to ascertain the nature and rapidity of change in the selected species of selected climate hotspot zones namely Sundarbans impact zone, Meghna estuary, high saline zone-Cox's Bazar, Haor basin-Kishorganj and Charland-Munshiganj. In the second phase histological and molecular study of the fishes of selected regions will be done. The histological study will help to ascertain the severity and mode of change of reproductive potential of the concerned species of the selected regions depending on which some preventive and/or remedial measures can be suggested. The study on primary productivity and water quality parameters will also be carried out. These data on primary productivity will indicate the suitability of the habitats for the fish species concerned. A very little work has been conducted on the above-mentioned issues. Therefore, a research on this issue is utmost important save the fisheries resources and improve the fishers´ livelihood in Bangladesh.

7. Sub-project goal: Find out the changes in fisheries resources due to climate change and recommendation for better livelihood of the affected fishers´ community.

8. Sub-project objective (s):

The specific objectives of the project are as follows:

i. To determine the changes in livelihood (education, health, nutrition, water sanitation, children and women protection and migration) of fishers´ particularly women and children in selected climate hotspot zone;

ii. To determine the changes in availability of fish species through survey, as well as the primary productivity and water quality parameters of climate hotspot zone and non-affected areas;

iii. Histopathological analysis of gonad, liver, gills, muscles and kidney of the fishes of climate hotspot zone with those of non-affected ones and evaluation of eggs and sperm quality.

9. Implementing location (s): Sundarbans impact zone, Meghna estuary, high saline zone-Cox's Bazar, Haor basin-Kishorganj and Charland-Munshiganj.

10. Methodology in brief:

10.1. Profile of the Study area

The Sundarbans is the largest mangrove forest in the World, is situated at the south of the Tropic of Cancer and at the northwest of the Bay of Bengal (21° 30′ –22° 30′ N, 89° 00′ –89° 55′ E). The Sundarbans extends within five districts in Bangladesh namely Khulna, Bagerhat, Shatkhira, Barguna and Firojpur. Most of the area of the Sundarbans is represented by Khulna, Bagerhat and Shatkhira. The northern part of Sundarbans becomes less saline during the rainy season due to flood waters from 177 rivers and canals. It becomes more saline during the dry season as the supply of freshwater from upper riverside decrease and saline waters enter from the Bay of Bengal at high. The water environment in Sundarbans is a unique amalgamation of marine, brackish and freshwater ecosystem with estuarine characteristics. This combination has possessed a highly productive ecosystem and a valuable biodiversity including endangered species. It has a tropical monsoonal climate with average annual maximum and minimum temperatures 30°C and 21°C and average annual rainfall of 1800 mm, respectively. The Sundarbans forest consists of 10,200 km^2 of coastal area of which 5,937 km^2 and 4,263 km^2 of protected Reserve forests are located in Bangladesh and India, respectively (Nandy and Kushwaha, 2010). This study focuses on the Bangladesh Sundarbans (Figure 1). The Sundarbans is considered to be climate-prone area in Bangladesh. Although limited quantitative data on climate change effects in the Sundarbans is available, floods, droughts, heat waves and sometimes cyclones are common features at this area. The socio-economic condition of the people in the Sundarbans is strongly influenced by various natural forces. The study carried out in Khulna Sadar, Bagerhat Sadar, Mongla, Digrajbazar, Shatkhira, Shemnagar, Koira, Paikgacha, Goroikhali, and Mongla port vicinity of the Sundarbans area. The study was conducted in the Boro station fish landing centre, Biponibug bazar near the Meghna river at Chandpur district and Patuakhali new market, Dashmina fish market near the Galachipa and Laukhati river at Patuakhali district (Figure 2), Louhajang, Munishiganj (Figure 3), Kishoreganj haor region (Figure 4) and the Bay of Bengal of Cox's Bazar (Figure 5). This study was carried out for the period of the year from July 2017 to June 2018.

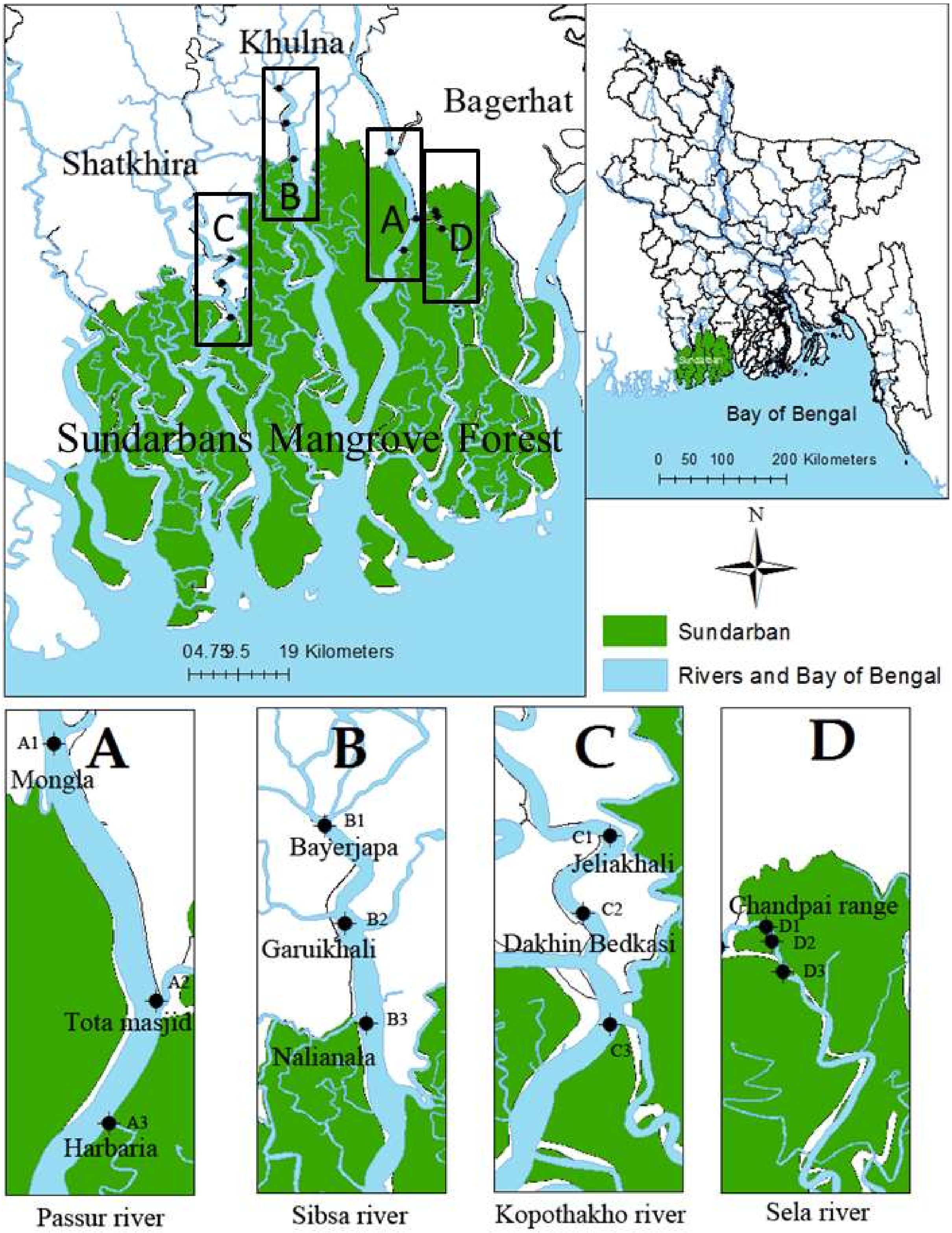

Figure 1: Study area and sampling stations of the Sundarbans regions

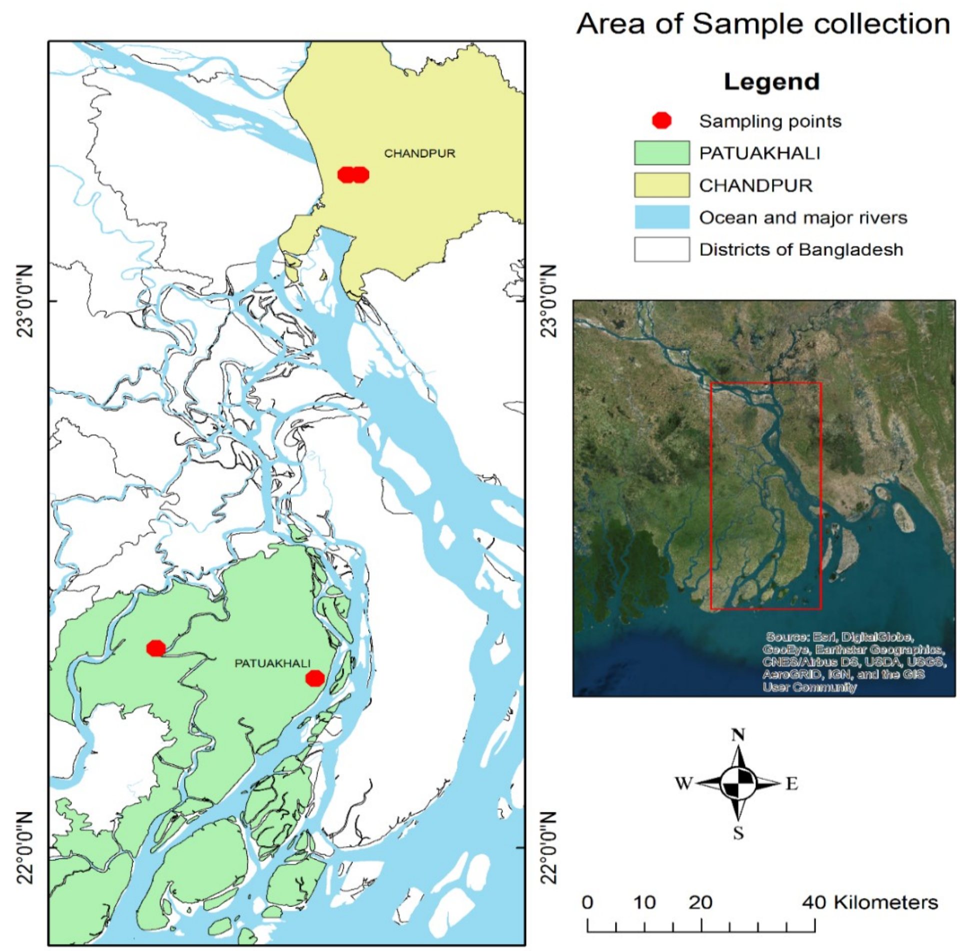

Figure 2: Map showing the study areas of Chandpur and Patuakhali

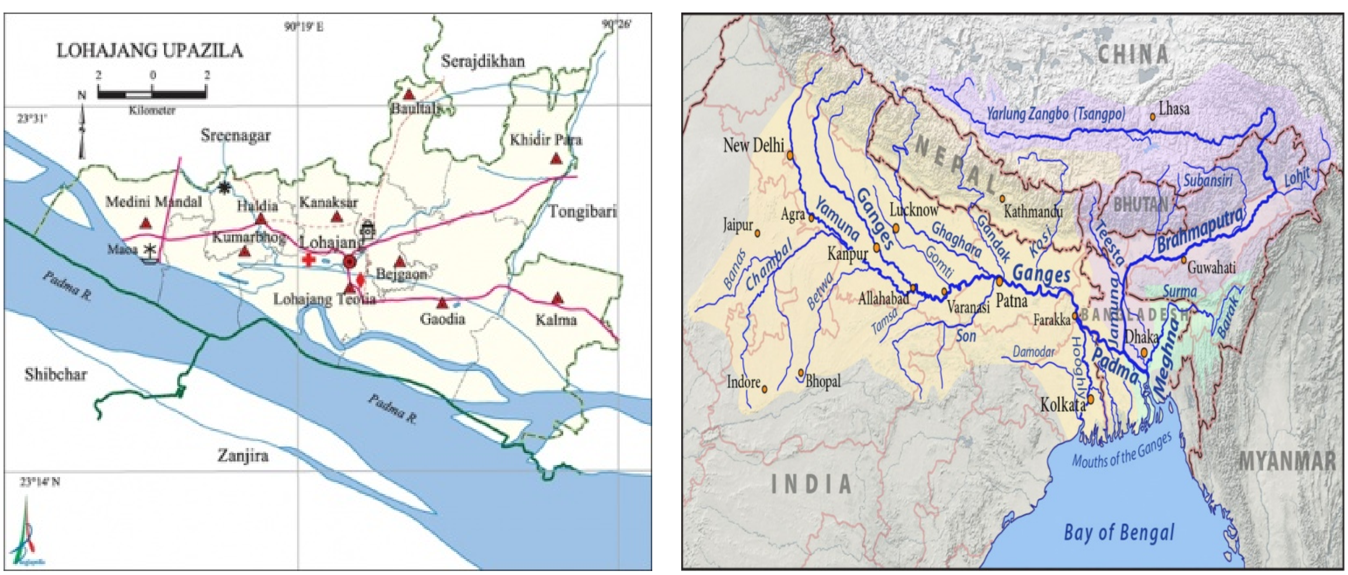

Figure 3: Map showing the study areas Padma, Louhaganj, Munshiganj

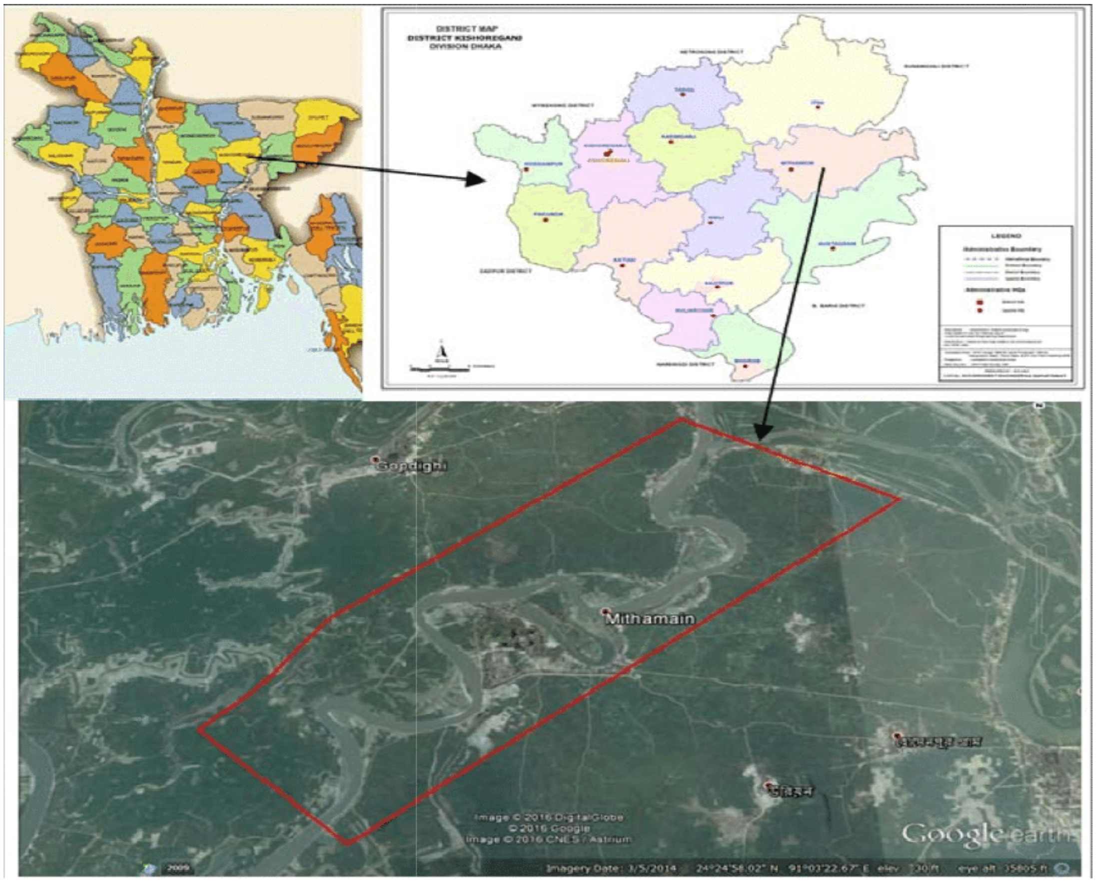

Figure 4: Map showing the study areas of Kishoreganj Haor region

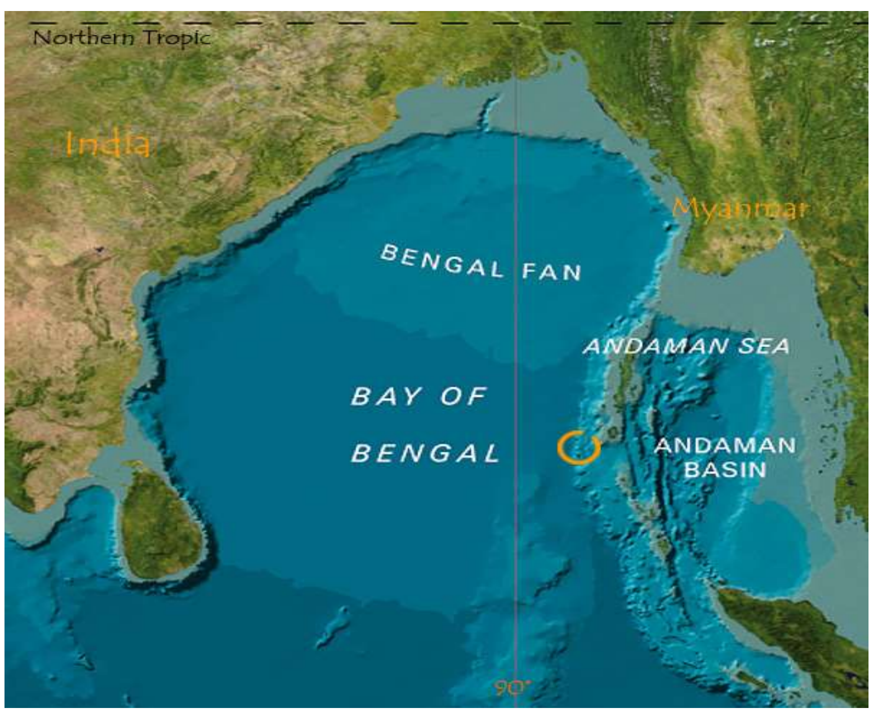

Figure 5: Map showing the study areas of the Bay of Bengal, Cox's Bazar

10.2. Water quality parameter analysis

Basic water qualities of the study areas were monitored such as pH (pHep Tester-HANNA Instruments 98107, Romania), salinity (HANNA Instruments 96801 Refractometer, Romania), DO (Dissolved Oxygen Meter-5509, China) and Temperature (Celsius thermometer) of water were determined in the field immediately with the help of respective instruments.

10.3. Plankton Collection

Plankton samples were collected from four main rivers of the Sundarbans, Meghna river of Chandpur, Laukhati and Galachipa river of Patuakhali, Padma river of Munshiganj, Bay of Bengal and Kishoreganj haor. Each stream was also divided into three stations. Sampling was done at 12 stations from May 2017 to August 2018. Phytoplankton and zooplankton samples were collected both qualitatively and quantitatively from 12 stations by using simple conical tow-net oblique, which mesh size is 40 µm and the samples were preserved in 4% formalin in plastic container.

10.3.1 Identification

Phytoplankton cells were enumerated under a light microscope by using Sedwick-Rafter cell. A series of pencil and ink drawing on postcards of the species of the observed were prepared to identify the organisms. Identification was done by observation under microscope and got some help of following book: Division of Chlorophyceae- Chlorophyta (Arnold, 1989).

10.3.2 Counting

For phytoplankton counting, the Sedgwick-Rafter (S-R) cell was used which is 50 mm long 20 mm wide and 1 mm deep. Before filling the S-R cell with sample, the cover glasses were diagonally placed across the cell and then samples were transferred with a large bore pipette so that no air bubbles in the cell covers were formed. The S-R cell was let stranded for at least 15 minute to settle plankton. Then phytoplankton on the bottom of the S-R cell was counted enumerated by compound microscope. By moving the mechanical stage, the entire bottom of the slide area was examined carefully. Organisms lying between two parallel cross hairs were counted as they passed a vertical line. Number of phytoplankton in the S-R cell was derived from the following formula-

$$\mathrm{No/ml} = \frac{\mathrm{C} \times 1000}{\mathrm{L} \times \mathrm{D} \times \mathrm{W} \times \mathrm{S}}$$

Where,

C = Number of Organisms (phytoplankton and zooplankton) Counted.

L = Length of each strip (S-R cell length) in mm.

D = Depth of a strip (whipple grid image width) in mm.

S = Number of strips counted

W = Width of the strip (whipple grid image width) in mm.

Number of cells per mm was multiplied by a correction factor to adjust the number of organisms per liter.

10.4 Data collection of fisheries resources

Data of fisheries resources was collected through direct visit of fish markets and fish landing centers. Many literature reviews was carried out to collect quantitative and qualitative data on different indicators that assess the status of fisheries resources of the Sundarbans, river of Padma, Meghna, Laukhati and Galachipa, Bay of Bengal and Kishoreganj haor, the climate change effects on these fisheries related to the change in species specific organ compositions and activities, species distribution, species composition and the subsequent impacts on socio-economic sector and fishers livelihood in that area. Data on the effects of climate change on fisheries are represented which are related to the impacts of climate change on fish diversity, distribution, and specific organ compositions change. Present data of fisheries resources of Sundarbans,river of Padma, Meghna, Laukhati and Galachipa, Bay of Bengal and Koshoreganj haor were collected by monthly routine investigations. Routine investigations were done to monitor the availability and diversity of fishery resources of Sundarbans along with Khulna sadar fishery ghat, Rupsha fishery ghat, Digrajbazar fish market, Mongla fish market, Bagerhat fishery ghat, Bagerhat fish market, Paikgacha fish market, Goraikhali fish market and parts of some river area (passur, sibsha, rupsha, vhoirob, sela). The investigations were followed by the monitoring of these local fish markets, fishery ghat, fisherman boat while capturing in rivers and different places where fishes generally are grounded after being caught. The collected fish's data were identified by using different books namely Fresh water fishes of Bangladesh (Rahman, 2005), Encyclopedia of flora and fauna of Bangladesh (Rahman *et al.,* 2009) and the Fish resources of the Bay of Bengal (Quddus and Shafi, 1983). The investigated values were assimilated with the previous studies in the Sundarbans to understand the existing scenario or any changes that occurred.

10.5 Data collection of fishers

Data derive from a large study on fishers´ communities that collated observations of climate change impacts and adaptive response by fishers of Sundarbans, Chandpur, Patuakhali, Munshiganj, Kishoreganj and Cox's Bazar. Here "observation" means a primary observation either cited or stated in the source material by individuals or groups who are identified as subsistence-oriented fishers (i.e., fishers depending on the fishery for subsistence) (Savo *et al.*, 2016). This definition retrenches observations from modern commercial fishers as well as secondary assessments from researchers (i.e., impacts assessed by researchers in fishers' communities) (Savo *et al.,* 2017). To inquire into the livelihood of fishers and the impact of climate change on them, a total of 120 fishermen in each area were interviewed by the structured questionnaire at their houses, boats, markets and local areas. The fisher folk survey sites were Bogakochua, Andarmanik, Tripoltola, Bojragram, Itampur and Dangmari under Bagerhat district; Noakati, Goraikhali, Boalia, Mamudkati, Srikantopur, Koira, Beyara and Sadar under Khulna district; Shemnagar, Asasoni, Debduar, Durgapur under Shatkhira district. The final-questionnaire included the questions on the socio-demographic conditions like age, sex, religion, marital status, family members, types of family, education, house status, sanitary facilities, medical facilities, drinking water sources, current facilities, land status, safety and security etc. It has also included socio-economic questions like income sources, daily or monthly income (peak season and banned season), loan facilities, amount of loan, amount of interest (%), source of loan, savings and Government and NGOs facilities etc. To assess the potential impact of climate change on Sundarbans fisheries and fishers, some special questions were included to the questionnaire to understand the causes of vulnerability, and highlight the role of fisheries in fishers life and food security in the country. Therefore, a part of questionnaire also discussed about local temperature, rainfall, wind flow, cyclone, flood, drought, sea level rise, salinity, land erosion, freshwater flow, siltation, fishing status, fish production and factors affecting the level of fish production. All observations were collocated into four groups: changes in weather and climate, changes in the physical components of the environment, changes in the fisheries resources and impacts on well-being of fishers´ specially women and children. Further, all four groups e.g., changes in weather and climate, changes in the physical components of the environment, changes in the fisheries resources and impacts on well-being of fishers specially women and children were sub-classified into 8, 7, 11 and 15 sub-groups, respectively. Each sub-group was evaluated as rare, occational, high, moderately high and extremely high event through ranking within 1 to 5 categories which was determined by the rate of the frequency of occurrence of each event in the study area.

10.6 Histology

This research focused on fish species of Sundarbans, rivers of Padma, Meghna, Laukhati and Galachipa, Kishoreganj haor region and Bay of Bengalwhich have commercially importance and play an important role in the food web. The studied fish species were Gold-spot mullet, *Liza parsia* (Hamilton, 1822); Sea bass, *Lates calcarifer* (Bloch, 1790); Long whiskers catfish, *Mystus gulio* (Hamilton, 1822); Croakers pama, *Otolithoides pama* (Hamilton, 1822); Gray eel-catfish, *Plotosus canius* (Hamilton, 1822); Paradise threadfin, *Polynemous paradiseus* (Linnaeus, 1758); Flathead sillago, *Sillaginopsis panijus* (Hamilton, 1822); Elongated mudskipper, *Pseudapocryptes elongates* (Cuvier, 1816), Bar eyed goby, *Glossogobius giuris*(Hamilton, 1822) and Hilsa shad, *Tenualosa ilisha* (Hamilton, 1822).

10.6.1. Observation of histology of muscle, gill, liver and kidney of fish species

Muscle, gill, liver and kidney of above mentions fishes were collected by dissecting with surgical kit. The muscle, gill, liver and kidney of each fish were preserved in 10% buffered formalin with labeled vials for further study.

10.6.1.1. Specimen collection and histological process

The preserved samples after cutting into square size were taken out in a perforated plastic holder, which was covered by perforated steel plates. Cleaning, infiltration and dehydration process were carried out in an automatic tissue processor using a series of alcohol of increasing concentrations, two changes of xylene and finally through molten wax (three series) as mentioned in Table 1.

Paraffin embedded blocks were cut by microtome knife at 5-6 µm size and left the sections into a water bath at a temperature of 40°C. The sections were placed on a glass slide and kept overnight on a slide drier hot plate at a temperature of 20°C. Then the sections were stained routinely with haematoxylene and eosin (H and E) as per the schedule given in Table 2.

Table 1. Time schedule in the automatic tissue processor

Sl No	Step of process	Time (hour)	Process
1	50% Alcohol	1	Dehydration
2	80% Alcohol	2	
3	100% Alcohol	2	
4	100% Alcohol	2	
5	100% Alcohol	2	
6	100% Alcohol	2	
7	100% Alcohol	2	
8	Xylene	2	Clearing
9	Xylene	1	
10	Molten wax	1	Infiltration
11	Molten wax	2	
12	Molten wax	2	
	Total	21	

Table 2. Staining procedure for histological study

Sl No	Staining process	Solution	Times (min)
1	Clearing	Xylene	3
2		Xylene	3
3	Rehydration	100% Alcohol	2
4		100% Alcohol	2
5		95% Alcohol	2
6		80% Alcohol	2
7	Running tap water		5
8	Staining	Haematoxylene	1 dip
9	Running tap water		25
10	Counter stain	Eosine	1
11	Dehydration	70% Alcohol	1
12		95% Alcohol	2
13		100% Alcohol	2
14		100% Alcohol	2
15	Clearing	Xylene	2
16		Xylene	2

10.6.1.2. Microscopic examination of muscle, liver, kidney and gill

The stained sections were mounted on the glass slide with Canada balsam (mountant) and covered by cover slips and studied under a compound microscope (OPTIA B-350, Italy) at 40 and 100 magnification. The photographic records were done simultaneously for the study.

10.6.1.2 Data analysis and map building

The collected fishermen data consistent from the study areas were analyzed with the tenets of grounded theory so as to detect and clarify emergent patterns rather than rely on prior assumptions (Glaser and Strauss, 2012) and then presented in textual and graphical forms to understand the impact of climate change on fishers' livelihood status as well as the constraints of fisher folks. GIS software consisted of an interface from Mapinfo and digitized maps from ArcGIS 10.5. The GIS software was used to view the statistical results and map of the Sundarbans mangrove forest. Other statistical data were analyzed using Microsoft office 10 and SPSS and then presented in textual and graphical forms.

11. Results and discussion:

11.1. Fish in the Sundarbans

A total of 186 species of brakishwater fishes, marine water fishes, fresh water fishes, Prawns, Shrimps, Crabs and Lobsters were recorded in the study areas. Among them fish, Shrimps, Prawns, Crabs and Lobster species were recorded as 163, 11, 5, 5 and 1 in number, respectively. In this study under class chondrichthyes, 8 species of shark and ray were recorded belonging to 4 families (Table 3). Teleost fish were recorded 155 species belonging to 58 families under 14 orders (Table 4). Under class crustacea, total 22 species were recorded belonging to 8 families (Table 5). Among them, 5 species of Prawn were belonging to 2 families, 11 species of Shrimp belonging to 3 families, 5 species of Crab belonging to 3 families and 1 species of Lobster belonging to a family.

Table 3. List of fishes under Chondrichthyes class in the Sundarbans

Order	Family	Species	Local name
Lamniformes	Carcharhinidae	*Scoliodon sorrakowah*	Thutte hangor
		Carcharhinus melanopterus	Kala hangor
	Sphyrnidae	*Sphyrna blochii*	Moishya
Rajiformes	Rhinobatidae	*Rhynchobatus djiddensis*	Pitambori
	Dasyatidae	*Himantura uarnak*	Housh
		Himantura walga	Housh
		Amphotistius zugei	Saplapata
		Pastinachus sephen	Saplapata

Table 4. List of fishes under Osteichthyesclass in the Sundarbans

Order	Family	Species	Local name
Osteoglossiformes	Notopteridae	*Chitala chitala*	Chital
		Notopterus notopterus	Foli
Elopiformes	Elopidae	*Elops machnata*	Elope
Anguiliformes	Muraenesocidae	*Muraenesox cinercus*	Kamila
		Congresox talabonides	Kamila
Clupeiformes	Engraulidae	*Colia ramacarati*	Olua, Amadi
		Colia neglecta	Olua, Amadi
		Colia dussumieri	Olua, Amadi
		Setipinna phasa	Phasa
		Setipinna taty	Phasa
		Stolephorus tri	Kata Phasa
		Thryssa dussumieri	Phasa
		Thryssa hamiltoni	Ram Phasa
	Clupeidae	*Gudusia chapra*	Chapila
		Escualosa thoracata	Ischidi
		Sardinella gibbosa	Takia
		Sardinella melanura	Chandana
		Sardinella fembriata	Chandana
		Anodontostoma chacunda	Koiputi
		Dussumieria auta valenciennes	Nailla
		Raconda ruselliana	Fasha
		Tenualosa ilisha	Ilish
		Tenualosa toil	Chandana Ilish
		Hilsha kelee	Garta Ilish
	Pristigasteridae	*Pellona ditchela*	Choka mach
	Chirocentridae	*Chirocentrus dorab*	Korati chala
		Chirocentrus nudus	Korati chala
Cypriniformes	Cyprinidae	*Esomus danricus*	Dainna
		Amblypharyngodon mola	Mola
		Osteobrama cotio	Dela
		Labeo calbasu	kalbaush
		Labeo rohita	Rui
		Labeo bata	Bata
		Cirrhinus cirrhosus	Mrigel
		Puntius sophore	Puti
		Puntius ticto	Tit puti
		Catla catla	Catla
Siluriformes	Siluridae	*Wallago attu*	Boal
		Ompok bimaculatus	Pabda
	Heteropneustidae	*Heteropneustes fossilis*	Shing

	Plotosidae	*Plotosus canius*	Kain magur
	Chacidae	*Chaca chaca*	Chaca
	Pangasidae	*Pangasius hypophthalmus*	Pangash
		Pangasius pangasius	Pangash
	Schilbeidae	*Silonia silondia*	Shillong
Order	**Family**	**Species**	**Local name**
	Bagridae	*Rita rita*	Rita
		Sperata aor	Aire
		Mystus tengara	Tengra
		Mystus gulio	Tengra
	Ariidae	*Osteogeneiosus militaris*	Apuia mach
		Arias gagora	Kata mach
		Arius sona	Kata mach
		Arius thalassinus	Kata mach
		Arius buchanani	Kata mach
		Arius dussumieri	Kata mach
		Arius nenga	Kata mach
		Arius maculatus	Kata mach
Aulopiformes	Harpadontidae	*Harpodon nehereus*	Loitta mach
Cyprinodontiformes	Hemirhamphidae	*Hyporhamphus limbatus*	Kaikha
Syngnathiformes	Syngnathidae	*Hippocampus kuda*	Ghora mach
Synbranchiformes	Synbranchidae	*Monopterus cuchia*	Kuchia
Scorpaeniformes	Platycephalidae	*Platycephalus crocodilus*	Fota mur baila
		Platycephalus scaber	Mur baila
		Rogadius asper	Kata murbaila
Perciformes	Mastacembelidae	*Macrognathus aculeatus*	Bele
		Mastacembelus armatus	Bele
	Stromateidae	*Pampus chinensis*	Rup chanda
		Pampus argenteus	Foli chanda
	Polynemidae	*Polynemus paradiseus*	Taposi, Riksa
		Polynemus indicus	Taposi, Riksa
		Eleutheronema tetradactylum	Tarail
		Polydactylus indicus	Tarail
	Mugilidae	*Rhinomugil corsula*	Bata
		Mugil corsula	Bata
		Mugil cephalus	Bata
		Liza parsia	Pashia
		Liza subviridis	Pashia
	Anabantidae	*Colisa fasciatus*	Kholisha
		Anabas testudineus	Koi
	Eleotridae	*Butis melanostigma*	Kala baila
	Gobiidae	*Pseudapocryptes elongatus*	Chewa
		Pseudapocryptes lanceolatas	Chewa
		Apocryptes bato	Chiring
		Periophthalmus koelreuteri	Dahuk
		Periophthalmodon schlosseri	Dahuk

		Boleopthalmus boddarti	Dahuk
		Glossogobius giuris	Baila
		Parapocryptes botoides	Chiring
		Scartelaos viridis	Chiring
		Stigmatogobius sadanundio	Baila
	Trichiuridae	*Eupleurogrammus muticas*	Suri mach
		Lepturacunthas savale	Suri mach
		Trichiurus lepturus	Suri mach
Order	**Family**	**Species**	**Local name**
	Gobioididae	*Odontamblyopus rubicundus*	Lal chewa
	Uranoscopidae	*Uranoscopus guttatus*	Tara gazar
	Drepanidae	*Drepane longimana*	Pan mach
		Drepane punctata	Pan mach
	Ephippidae	*Ephippus orbis*	Hatir kan
	Pomoadasyidae	*Pomadasys hasta*	Datina
	Lethrinidae	*Lethrinus ornatus*	Choikka
	Platycephalidae	*Platycephalus indicus*	Mur bailla
	Sillaginidae	*Sillaginopsis panijus*	Tulardandi
		Sillago domina	Tulardandi
	Nandidae	*Nandus nandus*	Meni
	Scatophagidae	*Scatophagus argus*	Bishtara
	Lobotidae	*Lobotes surinamensis*	Sagor koi
	Sparidae	*Acanthopagrus berda*	Sada datina
		Argyrops spinifer	Lal datina
	Sciaenidae	*Otolithoides pama*	Poa mach
		Pterotolithus maculatus	Guti poa
		Macrospinosa cuja	Kuju poa
		Johnius coitor	Koitor poa
		Johnius arhentatus	Rupa poa
		Panna microdon	Poa
		Pennahia macrophthalmus	Choka poa
	Carangidae	*Alepes melanoaptera*	Mouri
		Megalaspis cordyla	Kawya
		Selar boops	Salar mach
	Gerreidae	*Pentaprion longimanus*	Jarki
	Menidae	*Mene maculate*	Chan chanda
	Formionidae	*Formio niger*	Kala chanda
	Leiognathidae	*Gazza minuta*	Tak chanda
		Leiognathus fasciatus	Tak chanda
		Leiognathus bindus	Tak chanda
		Secutor ruconius	Tak chanda
		Secutor insidiator	Tak chanda
	Centropomidae	*Lates calcarifer*	Koral, Vetki
	Ambassidae	*Pseudambassis ranga*	Ranga mach
		Chanda nama	Nama chanda
		Chanda ranga	Lal chanda

		Chanda baculis	Kata chanda
		Pseudambassis beculis	Kata chanda
	Serranidae	*Cephalopholis miniatus*	Bol mach
		Epinephelus fasciatus	Bol mach
		Epinephelus tauvina	Bol mach
	Scombridae	*Euthynnus affinis*	Maitta
		Rastrelliger brachysoma	Champa
	Channidae	*Channa striatas*	Shol
		Channa marulius	Gojar
		Channa punctatus	Taki
		Channa orientalis	Gachua
Order	**Family**	**Species**	**Local name**
	Toxotidae	*Toxotes chatareus*	Tiron mach
	Teraponidae	*Terapon jarbua*	Barguni
		Terapon theraps	Barguni
Pleuronectiformes	Bothidae	*Pseudorhombus arsius*	Serbati
		Pseudorhombus elevatus	Serbati
		Pseudorhombus malayanus	Serbati
	Soleidae	*Synaptura pan*	Katal pata
		Synaptura orientalis	Katal pata
	Cynoglossidae	*Cynoglossus bilineatus*	Kukur jib
		Cynoglossus lingua	Kukur jib
		Cynoglossus cynoglossus	Kukur jib
		Cynoglossus versicolor	Kukur jib
Tetraodontiformes	Tetraodontidae	*Chelondon patoca*	Potka mach
		Chelondon fluviatillis	Potka mach

Table 5. List of organisms under Crustacea class in the Sundarbans

Order	Family	Species	Local name
Decapoda	Penaeidae	*Penaeus monodon*	Bagda
		Penaeus indicus	Sada icha
		Penaeus merguiensis	Bagda
		Metapenaeus monoceros	Horinna icha
		Metapenaeus brevicarnis	Hainna Chingri
		Metapenaeus spinulatas	Hainna Chingri
		Parapenaeopsis sculptilis	Godda chingri
		Parapenaeopsis stylifera	Godda chingri
		Parapenaeopsis uncta	Ruda chingri
	Solenoceridae	*Solenocera subnuda*	Chama chingri
	Sergestidae	*Acetes indicus*	Lotia icha
	Palaemonidae	*Macrobrachium rosenbergii*	Golda chingri
		Macrobrachium villosimanus	Dimua icha
		Macrobrachium birmanicus	Shul icha
		Macrobrachium lamerrei	Thenga icha
		Palaemon styliferus	Gura icha
	Portunidae	*Scylla serrate*	Kakra
	Grapsidae	*Sesarma mederi*	Kakra
		Metaplax elegans	Kakra
		Metaplax crenulata	Kakra
	Macrophthalmidae	*Macrophthalmus brevis*	Kakra
	Scyllaridae	*Thenus orientalis*	Lobster

The fisheries resources in Sundarbans are characterized by a very high degree of endemism and diversity. The habitat of Sundarbans supports higher number of fish and Shrimp then other habitats. Among them, most of the fish and Shrimp are commercially important. Seidensticker and Hai (1983) found that over 120 species of fish are indicated to be commonly caught by commercial fishermen in the Sundarbans. Hussain and Acharya (1994) recorded 53 species of pelagic fish belonging to 27 families and 124 species under 49 families of demersal fish in Sundarbans aquatic habitat. Another study discovered that the total number different fish species recorded 172 in Sundarbans (Chandra and Sagar, 2003). In the present study, total 165 fish species were recorded. Among them, teleost were recorded 157 species belonging to 58 families and 8 species of shark and ray were recorded belonging to 4 families respectively. Huge number of shark and ray species can also be found in mangrove environments besides the teleost (Matthes, 1988). In Sundarbans, the highly saline areas are likely to support species such as *Thryssa spp.,Harpodon nehereus*, *Arius spp.,Trichiurus savala*, *Setipinna spp.*, *Lethrinus spp.,Pseudorhombus spp.*, *Pampus spp.*, *Sillago spp.,Sardinella spp.*, *Salar spp*. etc. The moderate saline zones are dominated by *Tenualosa ilisha*, *Pomadasys hasta, Plotosus spp., Polynemus spp., Mugil spp., Liza spp., Coilia spp., Pseudapocryptes spp., Drepane spp., Otolithoides pama, Johnius spp.* etc. The low saline zones are dominated by *Chelondon spp.*, *Cynoglossusspp.*, *Synaptura spp., Epinephelus spp., Glossogobius giuris, Apocryptes bato, Periophthalmus spp., Butis melanostigma, Platycephalus spp.,* etc and diadromous species such as *Pangasius pangasius, Tenualosa ilisha and Lates calcarifer* are available in the low saline zone. The number of recorded fish species in the present study is fearfully less than previous studies due to climate change and anthropogenic reasons. Fish species richness has been reported to be as high as almost 200 species in mangrove-dominated estuaries in Australia and India (Robertson and Blaber, 1992). The Sundarbans mangroves also support many crustacean species of very high commercial values. These include 24 species of Shrimps belonging to five families, seven Crab species under three families and eight species of Lobsters (Hussain and Acharya, 1994; Blower, 1985). Hoq *et al.* (2001) observed that 10 Shrimp species occurred in the major river systems flowing through the Sundarbans. In the present study, 5 species of Prawn belonging to 2 families, 11 species of Shrimp belonging to 3 families were recorded. Besides, only 5 species of Crab belonging to 3 families and 1 species of Lobster belonging to a family were recorded from the study area. The number of crustacean species is less than the previous studies also. Most of these species was not available in the market also. The abundance of fishes is also decreased sharply. Because, fishermen capture a large number of teleosts species by small mesh sized nets that utilize mangrove areas as larvae, juveniles, or adults in rivers. The abundance of fish and Shrimp are gradually reduced by large fishing effort and blocking migration route through nets. Fishing is also done during banned season by some small scaled fishers. Besides, nursery ground and spawning ground of fishes are dramatically shifted and destroyed by climate change and anthropogenic reasons. Freshwater fish species are vividly decreased due to salinity intrusion rate is increased in freshwater zones by climate change. Abundance and distribution of fish species and other crustacean is controlled by water quality and primary productivity in rivers.

11.2 Fishin the Meghna, Laukhati and Galachipa rivers

A total of 61 species under 13 orders and 29 families were recorded from the Meghna river. List of existing fish species with their taxonomic position (order and family name), scientific name, local name and their number are presented in (Table 6). On the contrary, a total of 73 fish species under 11 orders and 33 families were recorded simultaneously in the Laukhati and Galachipa rivers (Table 7).

Table 6 List of fish species available in the Meghna river

Order	Family	Scientific name	Local name
Pleuronectiformes(2)	Soleidae	*Brachirus pan*	Kathalpata
	Cynoglossidae	*Cynoglossus lingua*	Kukurjeeb
Syngnathiformes(1)	Syngnathidae	*Microphis cuncalus*	Kumirer khil
Anguiliformes(2)	Moringuidae	*Moringua raitaborua*	Rata boura
	Ophichthidae	*Pisodonophis boro*	Bamosh
Synbranchiformes(3)	Synbranchidae	*Monopterus cuchia*	Kuchia
	Mastacembelidae	*Mastacebelus armatus*	Baim
		Macrognathus aculeatus	Tara baim
Beloniformes(2)	Belonidae	*Xenentodon cancila*	Kakila
	Hemirhamphidae	*Hyporhampus limbatus*	Ekthuita
Channiformes(1)	Channidae	*Channa punctatus*	Taki
Cypriniformes(16)	Cyprinidae	*Salmostoma acinaces*	Chela
		Esomus danricus	Darkina
		Megarasbora elanga	Along
		Barilius bendelisis	Joiya
		Devario devario	Banspata
		Amblypharyngodonmola	Mola
		Chela cachius	Chep chela

		Puntius sarana	Sarpunti
		Puntius ticto	Tit punti
		Puntius phutunio	Phutani punti
		Puntius sophore	Bhadi punti
		Labeo calbasu	Kalibaus
		Labeo rohita	Rui
		Labeo bata	Bata
		Gibelion catla	Catla
		Cirrhinus mrigala	Mrigal
Siluriformes(15)	Siluridae	*Wallago attu*	Boal
		Ompok pabda	Modhupabda
		Ompok pabo	Pabda
	Schilbeidae	*Silonia silondia*	Shilong
		Ailia coila	Kajuli
		Neotropius atherinoides	Batasi
		Clupisoma garua	Ghaura
	Pangasidae	*Pangasius pangasius*	Pangas
	Bagridae	*Rita rita*	Rita
		Sperata aor	Ayr
		Mystus bleekeri	Gulsha tengra
		Mystus vittatus	Tengra
		Hemibagrus menoda	Ghagla
	Sisoridae	*Nangra ornata*	Gang tengra
Clupeiformes(4)	Clupeidae	*Tenualosa ilisha*	Ilish
		Gudusia chapra	Chapila
	Pristigasteridae	*Corica soborna*	Kachki
		Ilisha megaloptera	Chaukka
Elopiformes (1)	Megalopidae	*Megalopes cyprinoides*	Tarpons
Osteoglossiformes(2)	Notopteridae	*Notopterus notopterus*	Foli
		Chitala chitala	Chitol
Perciformes(11)	Polynemidae	*Polynemou sparadiseus*	Tapasi
	Anabantidae	*Anabas testudineus*	Koi
	Osphronemidae	*Trichogaster lalius*	Lal kholisa
	Centropomidae	*Lates calcarifer*	Koral
	Nandidae	*Nandus nandus*	Vheda
		Nandus meni	Meni
	Gobiidae	*Pseudapocryptes elongatus*	Chewa
		Apocryptes bato	Chiring
		Awaous grammepomus	Bele
	Sciaenidae	*Otolithoides pama*	Poa
	Silaginidae	*Sillaginopsis panijus*	Tulardandi
	Platycephalidae	*Platycephalus indicus*	Chotabele

Table 7 List of fish species available in the Laukhati and Galachipa river

Order	Family	Scientific name	Local name
Pleuronectiformes (4)	Soleidae	*Brachirus pan*	Kathal pata
	Cynoglossidae	*Cynoglossus arel*	Kukur jib
		Cynoglossus lingua	Kukur jib
		Cynoglossus cynoglossus	Kukur jib
Syngnathiformes(1)	Syngnathidae	*Microphis cuncalus*	Kumirer khil
Anguiliformes(2)	Anguillidae	*Anguilla bengalensis*	Banehara
	Moringuidae	*Moringua raitaborua*	Rata boura
Synbranchiformes(5)	Mastacembelidae	*Mastacembelus armatus*	Baim
		Macrognathus pancalus	Guchi
		Macrognathus aculeatus	Tara baim
	Synbranchidae	*Ophisternon bengalense*	Bamosh
		Monopterus cuchia	Kuchia
Beloniformes(4)	Adrianichthyidae	*Oryzias carnaticus*	Bechi
	Adrianichthyidae	*Oryzias dancena*	Bechi
	Belonidae	*Xenentodon cancila*	Kakila
	Hemiramphidae	*Dermogenys pusilla*	Ek thota
Channiformes(1)	Channidae	*Channa punctatus*	Taki
Cypriniformes (19)	Cobitidae	*Lepidocephalichthys guntea*	Gutum
	Cyprinidae	*Megarasbora elanga*	Along
		Labeo bata	Bata
		Devario aequipinnatus	Chebli
		Esomus danricus	Darkina
		Esomus lineatus	Darkina
		Rasbora rasbora	Darkina
		Osteobrama cotio	Dhela
		Catla catla	Catla
		Cirrhinus cirrhosus	Mrigal
		Labeo rohita	Rui

		Labeo calbasu	Kalibaus
		Amblypharyngodon microlepis	Mola
		Chela cachius	Chep chela
		Laubuca laubuca	Chep chela
		Amblypharyngodon mola	Mola
		Puntius sarana	Shorpunti
		Salmophasia bacaila	Chela
		Roho labeo	Rui
Scorpaeniformes(1)		*Chela cachius*	Chep chela
Siluriformes(14)	Siluridae	*Wallago attu*	Boal
		Ompok pabda	Modhupabda
		Ompok pabo	Pabda
	Ariidae	*Osteogeneiosus militaris*	Apuia
	Plotosidae	*Plotosus canius*	Kainmagur
	Schilbeidae	*Silonia silondia*	Shilong
		Ailia coila	Kajuli
		Neotropius atherinoides	Batasi
		Clupisoma garua	Ghaura
	Pangasidae	*Pangasius pangasius*	Pangas
	Bagridae	*Rita rita*	Rita
		Sperata aor	Ayre
		Mystus bleekeri	Gulsha tengra
		Hemibagrus menoda	Ghagla
Clupeiformes(5)	Engraulidae	*Setipinna phasa*	Phasa
	Clupeidae	*Gudusia chapra*	Chapila
		Corica soborna	Kachki
		Tenualosa ilisha	Ilish
		Tenualosa toli	Chandan ilish
Osteoglossiformes(2)	Notopteridae	*Chitala chitala*	Chital
		Notopterus notopterus	Foli
Perciformes(15)	Polynemidae	*Polynemou sparadiseus*	Taposhi
	Ambassidae	*Parambassis ranga*	Ranga Chanda

Anabantidae	*Anabas testudineus*	Koi
Osphronemidae	*Trichogaster lalius*	Lal kholisa
Centropomidae	*Lates calcarifer*	Koral
Nandidae	*Nandus nandus*	Vheda
	Nandus meni	Meni
Gobiidae	*Pseudapocryptes elongatus*	Chewa
	Apocryptes bato	Chiring
	Awaous grammepomus	Bele
Sciaenidae	*Otolithoides pama*	Poa
Silaginidae	*Sillaginopsis panijus*	Tulardandi
Eleotridae	*Butis butis*	Kuli
	Eleotris fusca	Bhut bele
	Trypauchen vagina	Dogri

Hossain *et al.* (2012) gave an account of 293 fresh water fish species including 13 orders and 61 families. Rahman *et al*. (2005) compiled a list of 265 species of freshwater fishes belonging to 154 genera and 55 families from Bangladesh. Hossain *et al*. (2012) documented 53 fish species from the Meghna river estuary. Only 20 species were identified from the catches of different nets reported by Mia *et al*. (2015) from the Meghna River at Ashugonj upazilla, which was one third as compared to the present findings. Mandal *et al*. (2013) recorded 16 species in the Meghna river at Ramgoti Upazilla, which was far less than the present findings. Ali *et al*. (2015) documented 53 species under 9 orders and 26 families from Lohalia river of Patuakhali, which differ to present investigation. Habib *et al*. (2016) found 82 species under 11 orders and 2 classes in Padma river near Rajshahi city which was very close to the present study. Almost similar study was conducted by Gain *et al*. (2015)who recorded 95 finfish species contributing to 14 orders, 45 families and 77 genera of the Passur river in Bangladesh. Yeamin *et al*. (2016) documented 64 species under 11 orders and 30 families during their study in Rupsha river**.** Alam *et al*. (2013) recorded 63 species belongs to 9 orders, 24 families, 51 genera from the upper Halda river, Chittagong, Bangladesh.Galib *et al*. (2013)reported 63 species constituting 9 orders and 23 families, 41 genera of the River Choto Jamuna. Joadder *et al*. (2015) recorded 71 species constituting 10 orders, 26 families and 54 genera in the River Padma. Mohsin *et al*. (2013) found 69 species belonging to 10 orders, 25 families and 47 genera in the Padma river at Rajshahi district. Perciformes was found to be the most diversified order followed by Siluriformes and Cypriniformes**.** Ali *et al*. (2015) also reported similar findings during their study at Lohalia river of Patuakhali. The dominance of these three groups was also found by Yeamin *et al*. (2016), Galib, (2013). In accordance with freshRahman *et al*. (2005), water bodies of Bangladesh, these three groups were the most dominant groups

The most dominant family found in the present study was Cyprinidae. Joadder *et al*. (2015) and Mohsin *et al*. (2013) reported the domination of this family in the River Padma of Rajshahi district and Upper Halda river of Chittagong district respectively. Rahman *et al*. (2005) showed that this family is dominant in the fresh water fishes of Bangladesh. The richest group in terms of fish species composition in the river Meghna was Catfish group which is similar to the findings of Trina *et al*. (2016). Estuary-River was found to be the biggest habitat for the maximum number of fishes that differ with the study of Hossain *et al*. (2012) who recorded the highest number of fresh water fish habitat was river. To evaluate the extinction risk of many species the IUCN adopted Red List categories of animals and plants. The objective of IUCN Red List is to help the international community to try to reduce species extinction through suggesting the importance of conservation issues to the public and policy makers (Alam *et al*., 2013).

In accordance withIUCN (2015), among the threatened fishes Joadder *et al*. (2015) found in the Meghna river 11 species (10.28%) were Vulnerable (VU), 8 species (7.48%) were Endangered (EN) and 2 species (2%) were Critically Endangered (CR). Alam *et al*. (2013) found almost similar result in terms of threatened fish species in the Upper Halda river in which he reported 22 threatened fish species out of 63 identified fish species where 8 species belong to Vulnerable (VU), 11 species belong to Endangered (EN) and 3 species belong to Critically Endangered (CR).

According to the local people and fishers opinion, very rare species as Elong (*Megarasboraelanga*), Kalibaus (*Labeo calbasu*), Shorpunti (*Puntius sarana*), Gozar (*Channa marulius*), Pangas (*Pangasius pangasius*), Muribacha (*Clupisoma garua*), Baghair (*Bagarius bagarius*), Gang tengra (*Gagata cenia*) and Baim(*Mastacembelus armatus*) were available for at least 15-20 years ago. But now these species are facing an extremely high risk of extinction day by day. They also mentioned that this negative trend is due to overfishing, indiscriminate fishing of larvae and juveniles, siltation, salinity intrusion, perturbation of temperature and pollution. The findings clearly represent the declining trends of fish diversity in the study area which warning the gradual declination of fish diversity of Bangladesh.Stoddard *et al.* (2006) similar decline causes of fish diversity of inland water bodies of Bangladesh and recommended to solve them as conservation.

11.3 Fishin the Padma river

A total of 82 species under 15 orders and 35 families were recorded from the Padma river. List of existing fish species with their taxonomic position (order and family name), scientific name, local name and their number are presented in (Table 8).

Table 8. List of fish species available in the Padma river

Order	Family	Scientific name	Local name
Syngnathiformes(1)	Syngnathidae	*Microphis cuncalus*	Kumirer khil
Anguiliformes(2)	Moringuidae	*Moringua raitaborua*	Rata boura
	Ophichthidae	*Pisodonophis cancrivorus*	Bamosh
Synbranchiformes (1)	Synbranchidae	*Monopterus cuchia*Kuchia	
Mugiliformes (1)	Mugilidae	*Rhinomugil corsula*	Mulet
Beloniformes (1)	Belonidae	*Xenentodon cancila* Kakila	
Channiformes (4)	Channidae	*Channa punctatus*	Taki
		Channa orientalis	Gachua
		Channa striata	Gozar
		Channa marulius	Shol
Cypriniformes(16)	Cyprinidae	*Salmostoma acinaces*	Chela
		Esomus danricus	Darkina

		Megarasbora elanga	Along
		Barilius bendelisis	Joiya
		Devario devario	Banspata
		Aspidoparia morar	
		Salmophasia phulo	
		Salmophasia bacaila	
		Amblypharyngodon mola	Mola
		Osteobrama cotio	Dhela
		Chela cachius	Chep chela
		Puntius sarana	Sarpunti
		Puntius ticto	Tit punti
		Puntius phutunio	Phutani punti
		Puntius sophore	Bhadi punti
		Labeo calbasu	Kalibaus
		Labeo rohita	Rui
		Labeo bata	Bata
		Gibelion catla	Catla
		Cirrhinus mrigala	Mrigal
		Cirrhinus reba	
	Cobitidae	*Botia dario*	Rani
		Botia lohachata	Lohachata
		Lepidocephalus guntea	Gutum
Cyprinodontiformes (1)	Aplocheilidae	*Aplocheilus panchax*	Kanpona
Siluriformes(19)	Siluridae	*Wallago attu*	Boal
		Ompok pabda	Modhupabda
		Ompok pabo	Pabda
	Schilbeidae	*Silonia silondia*	Shilong
		Ailia coila	Kajuli
		Neotropius atherinoides	Batasi
		Eutropiichthys vacha	Vacha
		Pseudeutropius artherinoides	
		Clupisoma garua	Ghaura
	Pangasidae	*Pangasius pangasius*	Pangas
	Bagridae	*Rita rita*	Rita
		Sperata aor	Ayr
		Sperata seenghala	Guchi
		Mystus bleekeri	Gulsha tengra
		Mystus vittatus	Tengra
		Hemibagrus menoda	Ghagla
	Sisoridae	*Nangra ornata*	Gang tengra
	Clariidae	*Clarias batrachus*	Magur
	Heteropneustidae	*Heteropneustes fossilis*	Shing
	Clupeidae	*Tenualosa ilisha*	Ilish

Clupeiformes(7)		*Gudusia chapra*	Chapila
		Gonialosa manmina	
	Pristigasteridae	*Corica soborna*	Kachki
		Ilisha megaloptera	Chaukka
	Engraulidae	*Setipinna phasa*	
		Setipinna taty	
Elopiformes (1)	Megalopidae	*Megalopes cyprinoides*	Tarpons
Osteoglossiformes (2)	Notopteridae	*Notopterus notopterus*	Foli
		Chitala chitala	Chitol
Perciformes(16)	Polynemidae	*Polynemou sparadiseus*	Tapasi
	Anabantidae	*Anabas testudineus*	Koi
	Osphronemidae	*Trichogaster lalius*	Lal kholisa
		Trichogaster fasciata	Colisa
	Centropomidae	*Lates calcarifer*	Koral
	Nandidae	*Nandus nandus*	Vheda
		Badis badis	Napit koi
	Gobiidae	*Pseudapocryptes elongatus*	Chewa
		Apocryptes bato	Chiring
		Glossogobius giuris	Bele
	Sciaenidae	*Otolithoides pama*	Poa
	Silaginidae	*Sillaginopsis panijus*	Tulardandi
	Platycephalidae	*Platycephalus indicus*	Chotabele
	Ambassidae	*Chanda nama*	Chanda
		Parambassis ranga	Lal chanda
		Parambassis lala	
Mastacembeliformes (3)	Mastacembelidae	*Mastacembelus pancalus*	Guchi baim
		Mastacembelus armatus	Baim
		Macrognathus aculeatus	Tara baim
Tetraodontiformes (1)	Tetraodontidae	*Tetraodon cutcutia*	Potka

Habib *et al*. (2016) found 82 species under 11 orders and 2 classes in Padma river near Rajshahi city which was very close to the present study. Almost similar study was conducted by Gain *et al*. (2015)who recorded 95 finfish species contributing to 14 orders, 45 families and 77 genera of the Passur river in Bangladesh. Yeamin *et al*. (2016) documented 64 species under 11 orders and 30 families during their study in Rupsha river**.** Alam *et al*. (2013) recorded 63 species belongs to 9 orders, 24 families, 51 genera from the upper Halda river, Chittagong, Bangladesh.Galib *et al*. (2013)reported 63 species constituting 9 orders and 23 families, 41 genera of the River Choto Jamuna. Joadder *et al*. (2015) recorded 71 species constituting 10 orders, 26 families and 54 genera in the River Padma. Mohsin *et al*. (2013) found 69 species belonging to 10 orders, 25 families and 47 genera in the Padma river at Rajshahi district. Perciformes was found to be the most diversified order followed by Siluriformes and Cypriniformes**.** Ali *et al*. (2015) also reported similar findings during their study at Lohalia river of Patuakhali. The dominance of these three groups was also found by Yeamin *et al*. (2016), Galib, (2013). In accordance with freshRahman *et al*. (2005), water bodies of Bangladesh, these three groups were the most dominant groups

The most dominant family found in the present study was Cyprinidae. Joadder *et al*.(2015) and Mohsin *et al*. (2013) reported the domination of this family in the River Padma of Rajshahi district and Upper Halda river of Chittagong district respectively. Rahman *et al*. (2005) showed that this family is dominant in the freshwater fishes of Bangladesh. The richest group in terms of fish species composition in the river Meghna was Catfish group which is similar to the findings of Trina *et al*. (2016). Estuary-River was found to be the biggest habitat for the maximum number of fishes that differ with the study of Hossain *et al*. (2012) who recorded the highest number of freshwater fish habitat was river. In accordance withIUCN (2015), among the threatened fishes Joadder *et al*. (2015) found in the Meghna river 11 species (10.28%) were Vulnerable (VU), 8 species (7.48%) were Endangered (EN) and 2 species (2%) were Critically Endangered (CR). Alam *et al*. (2013) found almost similar result in terms of threatened fish species in the Upper Halda river in which he reported 22 threatened fish species out of 63 identified fish species where 8 species belong to Vulnerable (VU), 11 species belong to Endangered (EN) and 3 species belong to Critically Endangered (CR). The findings clearly represent the declining trends of fish diversity in the study area which warning the gradual declination of fish diversity of Bangladesh.Stoddard *et al.* (2006) similar decline causes of fish diversity of inland water bodies of Bangladesh and recommended to solve them as conservation.

11.4 Fish in Kishoreganj haor

During the study period, different fish species were observed in Chamra bondor. According to the present study, a total of 79 species of fishes belonging to 27 families under 9 order were recorded during the study period from July 2017 to December 2018 in the study area where Cypriniformes was the most dominant family contributing 31 species followed by Anguilliformes (2 species), Synbrachiformes (1 species), Tetraodontiformes (1 species), Beloniformes (2 species), Cyprinodontiformes (1 species), Sliuriformes (21 species), Clupeiformes (4 species) and Perciformes (16 species). Sliuriformes was the second large order containing 21 species in the study area (Table 9 and Figure 6).

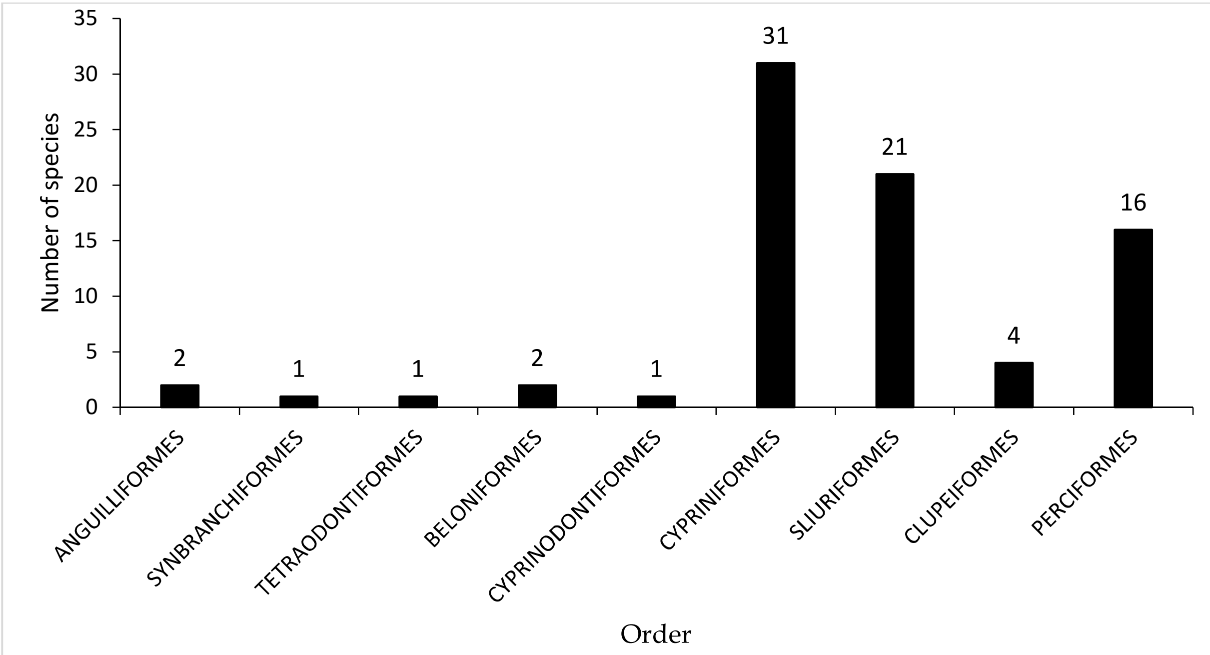

Figure 6: Different groups of fish recorded in Kishoreganj haor

11.4.1 Fish species availability in Kishoreganj haor region

According to the availability of fish species, their present status was ranked into 3 categories where 26 commonly available (CA), 26 moderately available (MA) and 27 rarely available (RA) species in the study area (Figure12.4.1.7). Comparing the present status of fish diversity with past status, it is clearly indicated that the fish species number are declined due to climate change (Figure12.4.1.8). According to the statement of the fishers the rare species will be disappeared from the water body with in few years. Fishers were also acknowledged that fish diversity of the Kishoregonj haor region was declining gradually due to climate change.

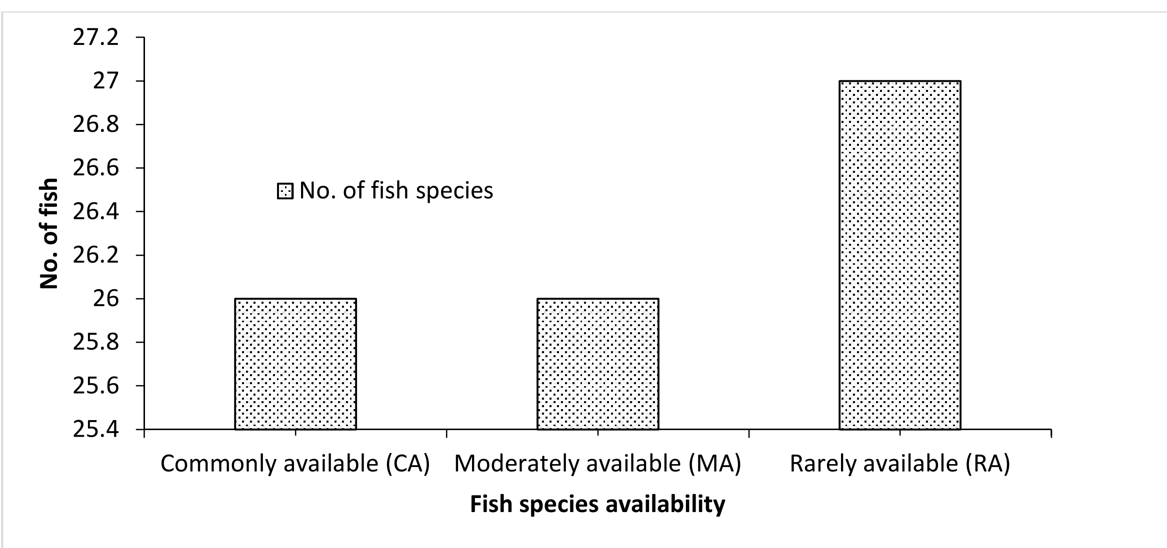

Figure 7: Present status of fish diversity in Kishoreganj haor region during study period

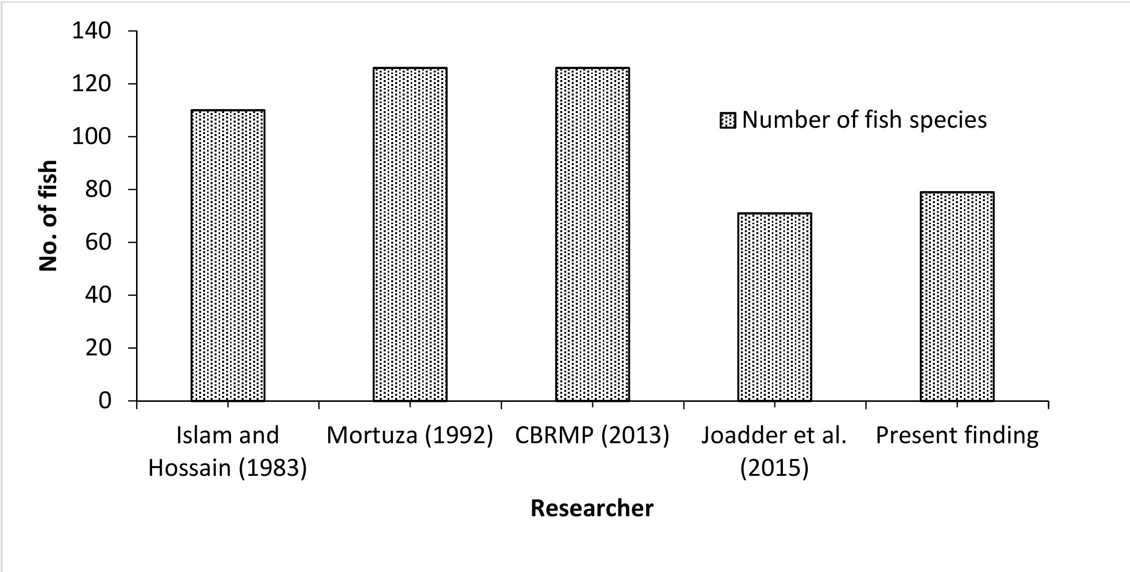

Figure 8: Comparison of present status of fish with past status in Kishoreganj haor

Table 9. Present status of fish diversity in Kishoreganj haor region

Order	**Family**	**Scientific name**	**Local name**	**English name**
Anguilliformes	ANGUILLIDAE	*Anguilla bengalensis*	Bamos, Bau baim	Giant Mottled Eel
	OPHICHTHIDAE	*Pisodonophis boro*	Nol baim.	Rice-paddy Eel
SYNBRANCHIFORMES	SYBRANCHIDAE	*Monopterus cuchia*	Kuiccha	Cuchia/ Gangetic Mudeel
TETRAODONTIFORMES	TETRAODONTIDAE	*Tetraodon cutcutia*	Potka	Pufferfish
BELONIFORMES	BELONIIDAE	*Xenentodon cancila*	Kaikka	Freshwater Garfish
	HEMIRAMPHIDAE	*Hyporamphus limbatus*	Subol kaikka	Congaturi Halfbeak
CYPRINODONTIFORMES	CYPRINODONTIDAE	*Aplocheilus panchax*	Kanipona	Panchax Minnow
CYPRINIFORMES	CYPRINIDAE	*Securicula gora*	Naukka chela	Gora Chela
		Salmostoma phulo	Chela	Finescaled Razorbelly Minnow
		Salmostoma bacalia	Chela	Large Razorbelly Minnow
		Esomus danricus	Darkina	Flying Barb
		Parluciosoma daniconius	Darkina	Blackline Rasbora
		Barilius bendelisis	Nunchora	Hamilton's Barila

		Danio devario	Kash khauri	Devario Danio
		Amblypharyngodon mola	Mola	Pale Carplet
		Osteobrama cotio	Gilachaki	Cotio
		Labeo gonius	Ghonia	Kuria Labeo
		Labeo calbasu	Kalbaush	Black Rohu/Kalbasu
		Labeo rohita	Rou/rui	Rohu
		Labeo angra	Karish, Dirua	Angra Labeo
		Labeo boggut	Ghania	Boggut Labeo
		Cirrhinus cirrhosus	Mrigal	Mrigal Carp
		Puntius sarana	Deshi sarpunti,	Olive Barb
		Barbonymus gonionotus	Thai sarpunti	Silver Barb
		Puntius guganio	Titpunti	Glass Barb
		Puntius phutunio	Titpunti	Pigmy Barb
		Puntius conchonius	Punti	Rosy Barb
		Puntius ticto	Tita punti	Two-spot Barb
		Puntius sophore	Jat punti	Pool Barb
		Puntius terio	Teri punti	Onespot Barb
		Catla catla	Katal	Catla
		Hypophthalmichthys molitrix	Silver carp	Silver Cap
		Cyprinus carpio	Carpu	Common Carp
	BALITORIDAE	*Nemachilus botia*	Gutum	Mottled Loach
		Nemachilus zonalternans	Gutum	River Loach
	COBITIDAE	*Botia dario*	Bou mach	Bengal Loach
		Lepidocephalus guntea	Gutum	Guntea Loach
		Lepidocephalichthys annandalei	Gutum	Annandalei Loach
SLIURIFORMES	CLARIIDAE	*Clarias batrachus*	Magur	Walking Catfish
	SILURIDAE	*Wallago attu*	Boal	Wallago
		Ompok bimaculatus	Pabda	Butter Catfish
		Ompok pabda	Lali paibba	Gulper Catfish
	HETEROPNEUSTIDAE	*Heteropneustes fossilis*	Shingi	Stinging Catfish
	SCHILBEIDAE	*Silonia silondia*	Shilon	Silond Catfish
		Ailia coila	Kajuli	Gangetic Ailia

		Pseudeutropius atherinoides	Batai	Indian Potasi
		Eutropiichthys vacha	Bacha	Batchwa Bacha
		Eutropiichthys murius	Bacha, Muri bacha	Indus Garua
		Clupisoma garua	Ghaura	Gagra
	BAGRIDAE	*Rita rita*	Rita, Rida	Rita
		Aorichthys aor	Ayer	Long-Whiskered Catfish
		Aorichthys seenghala	Kata	Giant River-Catfish
		Hemibagrus menoda	Gang magur	Menoda Catfish
		Mystus cavasius	Gulsha	Gangetic Mystus
		Mystus bleekeri	Gulsha	Day's Mystus
		Mystus tengara	Bajari tengra	Tengara Mystus
		Mystus vittatus	Tengra	Striped Catfish
	SISORIDAE	*Gagata chenia*	Gun mach	Clown Catfish
		Bagarius yarrellii	Bagha ayer	Gangetic Goonch
CLUPEIFORMES	NOTOPTERIDAE	*Chitala chitala*	Chital	Clown Knifefish
		Notopterus notopterus	Foli	Bronze Featherback
	ENGRAULIDAE	*Setipinna phasa*	Bansh pata	Gangetic Hairfin Anchovy
	CLUPEIDAE	*Corica soborna*	Kachki	Ganga River Spart
PERCIFORMES	CHANNIDAE	*Channa striatus*	Shol	Striped Snaked
		Channa punctatus	Taki	Spotted Snakehead
		Channa orientalis	Taki, Telo taki	Walking Snakehead
	MASTACEMBELIDAE	*Macrognathus aral*	Tara baim	One-Stripe Spinyeel
		Mastacembelus armatus	Shal baim	Zig-Zag Eel
		Macrognathus pancalus	Guchi baim, Chikra	Striped Spinyeel
	BELONTIIDAE	*Colisa chuna*	Koiya	Honey

			chata	Gourami
		Colisa fasciata	Khailsha	Giant Gourami
		Colisa lalia	Chata	Dwarf Gourami
	ANABANTIDAE	*Anabas testudineus*	koi	Climbing Perch
	GOBIIDAE	*Glossogobius giuris*	Baila	Tank Goby
		Brachygobius nunus	Bali kora	Bumblebee Goby
	NANDIDAE	*Nandus nandus*	Bheda, meni	Mud Perch
	CICHLIDAE	*Oreochromis niloticus*	Nilotica	Nile Tilapia
	AMBASSIDAE	*Chanda nama*	Chanda	Elongate Glass-perchlet
		Parambassis ranga	Tek chanda	Indian Glassy Fish

11.5 Fisheries resources in the Bay of Bengal, Cox's Bazar

During the study period, different fish species were observed in the fish landing center of Cox's Bazar. According to the present study, a total of 84 species of fishes belonging to 36 families under 13 order were recorded during the study period from May 2017 to August 2018 in the study area where Perciformes was the most dominant family contributing 42 species followed by Clupeiiformes (8 species) and Scombriformes (7 species) (Table 10).

Table10. Present status of fish diversity in the Bay of Bengal

Order	Family	Species	Local name	Common name
Carcharhiniformes	Carcharhinidae	*Scoliodon spp.* (2 species)	Thutte hangor/ hangar	Spadenose shark/Dog fish
		Carcharhinus spp. (5 species)	Hangor	Shark, Dog shark
		Rhizoprionodon acutus	Hangor	Milk shark
	Sphyrnidae	*Sphyrna blochii*	Haturi hangor	Hammerheaded shark
Rajiformes	Rhinobatidae	*Rhinobatos granulatus*	Pitambori	Skate
Anguilliformes	Congridae	*Conger cinereus*	Kamila	Indian conger eel
		Ariosoma anago	Kamila	Silvery Conger
Clupeiformes	Clupeidae	*Tenualosa ilisha*	Ilish	Hilsa shad
		Ilisha filigera	Choukka	Big eye ilisha
		Sardinella frimbiata	Kolombo	Sardine

		Sardinella melanura	Chapila/Takhia	Sardine
	Chirocentridae	*Chirocentrus dorab*	Karati chela	Wolf-herring
	Engraulidae	*Setipinna taty*	Teilla phasa	Hairfin anchovy
		Thryssa mystax	Phasa	Moustached thryssa
		Coilia dussumieri	Pointed tail	Anchovy olua
Myctophiformes	Harpadontidae	*Harpadon nehereus*	Loittya machh	Bombay duck
Siluriformes	Ariidae	*Arius spp.*	Kata machh	Cat fish
Aulopiformes	Synodontidae	*Saurida tumbil*	Tiktiki machh	Lizard fish
Scorpaeniformes	Plaicephalidae	*Platicephalus indicus*	Murbaila	Flat-head fish
Perciformes	Carangidae	*Parastromateus niger*	Hail chanda	Black pomfret
		Scomberoides commersonianus	Chapa kori	Talang queenfish
		Selar boops	Moori	Oxeye scad
		Megalaspis cordyla	Kauwa	Hardtail scad
		Carangoides malabaricus	Malabar moori	Malabar cavalla
	Drepanidae	*Drepane longimana*	Pann machh	Sickle fish
	Ephippidae	*Ephippus orbis*	Spade fish	Hatir kaan
	Gerreidae	*Gerres filamentosus*	Dom machh	Silver biddies
		Pentaprion longimanus	Jagiri	Silver biddies
	Leiognathidae	*Leiognathus brevirostris*	Taka chanda	Pony fish
	Lobotidae	*Lobotes surinamensis*	Samudra koi	Triple tail
	Lutjanidae	*Lutjanus johni*	Ranga choukka	Red snapper
		Lutjanus sanguineus	Ranga choukka	Blood snapper
		Lutjanus malabaricus	Ranga choukka	Malabar red snapper
	Menidae	*Mene maculata*	Tek chanda	Moon fish
	Mullidae	*Upenus sulphureus*	Sonali Bata	Goat fish
		Liza spp.	Bata	Mullet
		Mugil cephalus	Khorul bata	Grey mullet
	Nemipteridae	*Nemipterus spp.*	Lal mach	Threadfin breams, redfish
		Nemipterus japonicus	Rupban	Threadfin bream
	Priacanthidae	*Priacanthus tayenus*	Pari machh	Purple-spotted big eye
	Polinemidae	*Polynemus indicus*	Lakhua	Indian salmon
		Polynemus paradiseus	Tapsi	Paradise threadfin
		Eleutheronema tetradactylum	Thailla	Fourfinger threadfin

	Pomadasyidae	*Pomadasys hasta*	Sada datina	White grunter
		Pomadasys argenteus	Datina	Silver grunter
		Pomadasys maculatus	Guti datina	Blotched grunter
	Siaenidae	*Johnius spp.*	Lalpoa, Rupali poa	Croaker
		Otolithoides argenteus	Bara poa, Lambu	Bronze Croaker
		Pterotolithus maculatus	Gutipoa	Spotted Croaker
		Otolithes ruber	Poa	Tiger toothed croaker
		Argyrosomus amoyensis	Poa	Amoy Croaker
		Dendrophysa russelii	Dhari poa	Goatee croaker
		Panna microdon	Chotta lambu	Panna croaker
		Pennahia anea	Sada poa	Greyfin jewfish
		Protonibea diacanthus	Kala poa	Black spotted croaker
	Theraponidae	*Therapon jarbua*	Barguni	Therapon perch
	Sillaginidae	*Sillago domina*	Hundra baila	Lady fish
	Sphyraenidae	*Sphyraena forsteri*	Dharkuta	Barracuda
	Trichiuridae	*Lepturacanthus savala*	Churi machh	Ribbon fish/Hair tail
		Trichiurus lepturus	Churi machh	Large-headed Ribbon fish
Pleuronectiformes	Psettodidae	*Psettodes erumei*	Samudra serboti	Indian halibut
	Cynoglossidae	*Cynoglossus spp.*	Kukur jeeb	Tongue sole
Scombriformes	Scombridae	*Scomberomorus guttatus*	Maitya/Surma	King Mackerel
		Scomberomorus commerson	Maitya/Surma	Spanish mackerel
		Euthynnus affinis	Bom maitta	Mackerel tuna
		Katsuwonus pelamis	Bom maitta	Striped tuna
		Thunnus obesus	Bom mittya	Big-eye tuna
		Auxis rochei	Bom mittya	Bullet tuna
		Rastrelliger kanagurta	Champa/Ailla	Indian Mackerel
	Stromateidae	*Pampus argenteus*	Fali chanda	Silver Pomfret
		Pampus chinensis	Rup chanda	Chinese Pomfret
Myliobatiformes	Dasyatidae	*Himantura uarnak*	Sapla pata	Stingray
	Dasyatidae	*Dasyatis spp.* (5-6 species)	Haush pata	Stingray
Rhinopristiformes	Rhinidae	*Rhinchobatus djeddensis*	Skate	Pitambori

11.6 Water quality parameters

11.6.1 Water quality parameters in the Sundarbans

In this study, water quality parameters of four rivers were analyzed which represent Sundarbans water bodies and considered to be main rivers of Sundarbans namely Passur, Sibsha, Rupsha and Sela. Water parameters are calculated from three stations in each river. The average values of water quality parameters (temperature, pH, salinity and DO) in each river of the Sundarbans were shown in Figure 11.6.1.9.

The range of pH value was recorded from 7.1 to 8.7 in the rivers of Sundarbans. The range of pH value was found 7.9 to 8.7 in Passur river. In Kopothakho river the range of pH value was recorded from 7.1 to 7.7. In Sibsha and Sela river the value of pH was recorded at range from 7.5 to 8.1 and 7.2 to 8.1, respectively. The highest average value of pH was observed 8.5 in Passur river during monsoon season. The lowest average value of pH was recorded 7.3 in Kopothakho river during winter season (Figure 11.6.1.9A).

The range of temperature was recorded from 25°C to 32.8°C in the rivers of Sundarbans. The range of temperature was found 27°C to 32.8°C in Passur river. The range of temperature was recorded from 25°C to 30.7°C and 25°C to 29.5°C in the Kopothakho and Sela rivers, respectively. In Sibsha river, the temperature was recorded at range from 26°C to 31.5°C. The highest average temperature was observed 32°C in Passur river during summer season. The lowest average temperature was recorded 25.4°C in Kopothakho river during winter season (Figure 9 B).

The range of salinity was recorded from 1.5‰ to 23‰ in the rivers of Sundarbans. The range of salinity was found 3‰ to 23‰ in Kopothakho river. In Sela river, the range of salinity was recorded from 1.5‰ to 7‰. In Sibsa river and Passur river, the salinity was recorded at range from 1.8‰ to 16.8‰ and 1.8‰ to 20.3‰, respectively. The highest average salinity was observed 18.8‰ in Kopothakho river during summer season. The lowest average salinity was recorded 1.6‰ in Sela river during monsoon season (Figure 9 C).

The range of DO value was recorded from 4.3 mg/L to 7.7 mg/L in the rivers of Sundarbans. The range of DO value was found 4.5 mg/L to 7.7 mg/L in Passur river. In Kopothakho river, the range of DO value was recorded from 4.3 mg/L to 5.5 mg/L. In Sibsa river and Sela river, the value of DO was recorded at range from 4.5 mg/L to 5.9 mg/L and 5 mg/L to 7.4 mg/L, respectively. The average highest DO was observed 7.2 mg/L in Sela river during monsoon season. The average lowest DO was 4.4 mg/L found in Kopothakho river during summer season (Figure 9 D).

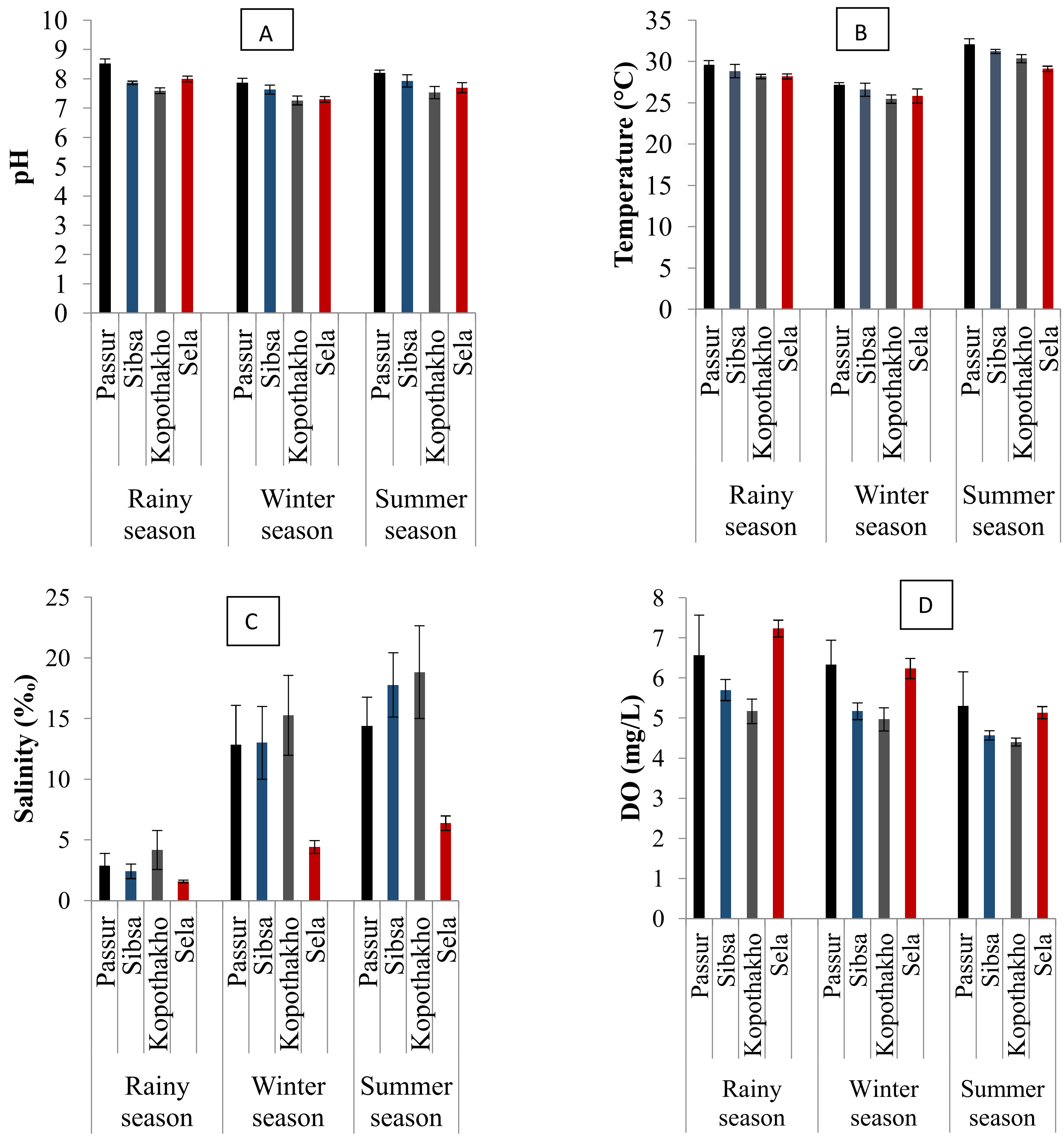

Figure 9: Seasonal variation of water quality parameters assessed in this study from Passur, Sibsa, Kopothakho and Sela river of the Sundarbans: (A) pH; (B) Temperature; C) Salinity; D) DO.

Water quality plays a significant rule in primary production and distribution in rivers which is ultimately related to fish production and distribution. The fish survival and growth can be influenced by the water quality (Likongwe *et al*., 1996). Shaikh and Yeragi (2003) discovered that pH is the most important factor which controls the growth of the green algae. Low and high pH value is very detrimental for the ecosystems of the river, and the recommended pH level of river water is around 7.4. Among the water quality parameters, the highest average water pH of 8.5 was found in Passur river where the lowest average pH was 7.3 recorded in Kopothakho river in the present study. In a previous study, it was discovered that the highest pH of 8.1 was observed at Dhanmari point and the lowest pH of 7.1 was observed at Mongla (Muhibbullah *et al.,* 2005). Rahman *et al.* (2003) observed that the pH of the water of the Sundarbans seasonally varies from 7.0 to 8.4, which is very similar to the present study. In another study, Hoq *et al.* (2006) found that river water of the Sundarbans was characterized by slightly alkaline pH (7.4 to 8.1). The average pH value was slightly increased in Passur river and highest value was observed during rainy season which may be influenced by the local discharges that comprise alkaline effluents from industries and mills situated in the Rupsa-Passur belt. These chemically enriched effluents are diluted with the river water by the rainwater as well as floodwater flowing from upstream regions.

Optimum level of DO is very essential for fish. The level of DO in natural water body depend on the physical, chemical, and bio-chemical activities occurring at surface and subsurface levels of natural water. In a previous study conducted by Hoq *et al.* (2002) found that the maximum DO 7.1 mg/L in the monsoon period and the minimum 4.9 mg/L in the pre-monsoon period in the rivers of Sundarbans. In the present study, the average minimum DO was observed 4.4mg/L in Kopothakho river during summer season which is slightly less than previous study. Salinity was found high in Kopothakho river which is inversely related with DO in water. The oxygen saturation concentration depends on temperature and salinity (Weiss, 1970). According to Boyd and Gross (1999), the DO concentration is highest at 0°C in natural water and decreases with increasing temperature. Moreover, the solubility of oxygen decreases with increasing salinity of water. High temperature and salinity cause the oxygen to be relatively low (Badran, 2001). The highest DO value was 7.2 mg/L found in Sela river where salinity effect was less than other rivers and freshwater flow from the upstream river was high. According to Nair (1985), freshwater flow has contributory role to increase DO in rivers. In addition to the DO concentration depends on the photosynthetic rate and afterward on nutrient concentrations of rivers.

Salinity has a great issue of the rivers in Sundarbans. Because of the relationship between salinity and fish growth seems to be complex. Likongwe *et al*. (1996) observed the performance of juvenile Nile tilapia in different salinity levels and water temperature and showed a better performance in the highest temperatures evaluated, and a decrease from 8 g/L of water salinity. In a previous study, the salinity of the Sundarbans was found steadily increases to reach its maximum in March following the monsoon (Hoq *et al.,* 2006). In the present study, the seasonal variation of salinity was observed and the average maximum salinity was 18.8‰, observed in Kopothakho river during summer season. Other three rivers were also represented high salinity during summer than monsoon and winter season which is similar with previous study. Passur and Sibsa river were found as mesohaline (5-18‰) zone where Kopothakho river was found as polyhaline (18-30‰) zone during summer season. According to Hoq *et al.* (2006) the salinity of water of Passur and Shibsha rivers decline even below 1 ‰ from August to November, which is different from the present study. In this study, the minimum salinity was observed 1.8‰ in both Passur and Sibsa river during monsoon season. The reduction in flow rate has resulted in increase of high saline sea water in rivers of Sundarbans. Ganges river water flow into Bangladesh is remarkably affected by Farakka Barrage in India. The Ganges flow in 1962 was 3700 m^3/s whereas it was 364 m^3/s in 2006 (Islam and Albrecht, 2011). This diversion of Ganges river waters resulted in falling water tables in the southbound rivers of Bangladesh especially in the Sundarbans region. As a result, water from Bay of Bengal enters into the rivers of Sundarbans during rising tide in high rate. After 1975, water flow was drastically reduced with a corresponding increase in salinity of Sundarbans (Islam and Albrecht, 2011).

Water temperature regulates fish body metabolism and other activities. Increased temperature causes stress to fish and other aquatic species. In the present study, the highest average temperature was observed 32°C which is similar with previous study. Hoq *et al*. (2002) found highest and lowest water temperature in the Sundarbans during monsoon and winter seasons, respectively. The temperature of water of the rivers of Sundarbans fluctuated seasonally with air temperature. Water temperature has effects on fish reproduction and distribution. The water temperature has considerable effect on phytoplankton population density (Ishikawa and Taniguchi, 1994; Blanco, 1995). Spatial and tidal uniformity in surface water temperature of the study area has the least probability to affect the plankton community. Nutrient concentrations (nitrate, phosphate, and silicate) of aquatic system may be influenced when temperature rises as it affects the photosynthesis rate (Tait, 1981).

11.7 Changes in weather and climate in the Sundarbans region

From the majority of observations in the Sundarbans, it was discrete that increased air temperature (17.3% of records of the weather and climate change observations), changes in weather patterns/seasonality (15.1% of records of the weather and climate change observations), increased thunder storm (17.3% of records of the weather and climate change observations) and increased extreme weather events (17.3% of records of the weather and climate change observations) are the most frequently reported. These changes have adverse effects on fishers and their communities. Some previous studies suggest the changes included in these subcategories can have a variety of adverse effects on the coastal environment (Harley *et al.*, 2006), local economy (Allison *et al.*, 2009), society and culture (Adger *et al.*, 2005). The monthly maximum mean average temperature was gradually increased due to climate change recorded by Mongla station (1989-2016) (Figure 11.7.10).

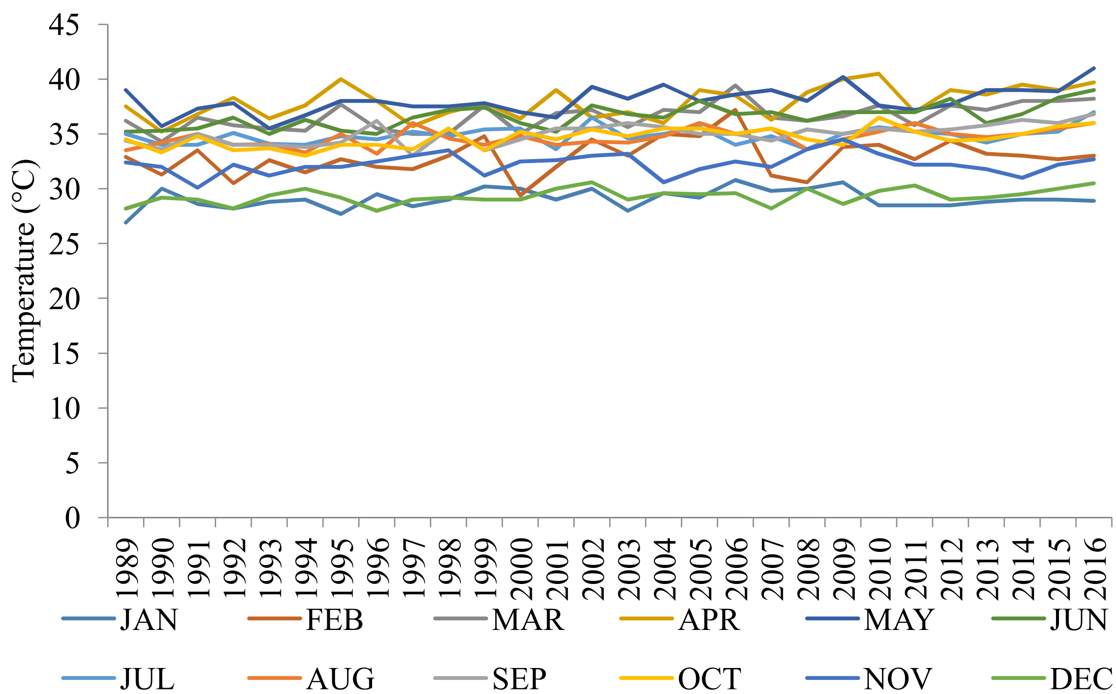

Figure 10: The monthly maximum average temperature of Sundarbans recorded by Mongla station (1989-2016) (Rahman, 2017).

Fishers have got heat stock and dehydration problem during fishing by high temperature. Unfavorable environmental condition in communities is created and ground water levels are gradually moved down. Increased air temperature also created northwester disaster in the study area where many physical structures of fisher communities were destroyed during pre-monsoon. Terrestrial resources and ecosystems of Sundarbans were devastated by cyclones or hurricanes in previous years. Understanding, reading and recording of weather is crucially important for fishers' safety and is of particular concern in the Sundarbans where weather conditions were going to extreme day by day. More unpredictable storms endanger fishers at sea and force changes in seasonal fishing schedules (Fisher, 2011; Turunen *et al.*, 2011), which may, in turn, affect catch availability and the local economy. Fishers were also reported decreases, increases and/ or changes in the duration and timing of rainfall (15.1% of records of the weather and climate change observations) occurred dramatically in Sundarbans where changes in rainfall are the most commonly reported type of observation by fisher communities. The yearly average rainfall was gradually decreased during monsoon in the Sundarbans recorded by Mongla station (1991-2013) (Figure 11.7.11). Water quality parameters were significantly regulated by rainfall in Sundarbans. Therefore, fish population abundance, diversity and distribution might be affected by shifting in rainfall. Some previous Research suggests that shifts in rainfall are important to monitor because many fishes and shellfish depend on seasonal fluxes of precipitation during monsoon that can generate major nutrient transport from freshwater rivers to marine and estuarine environments (Doney *et al.*, 2012).

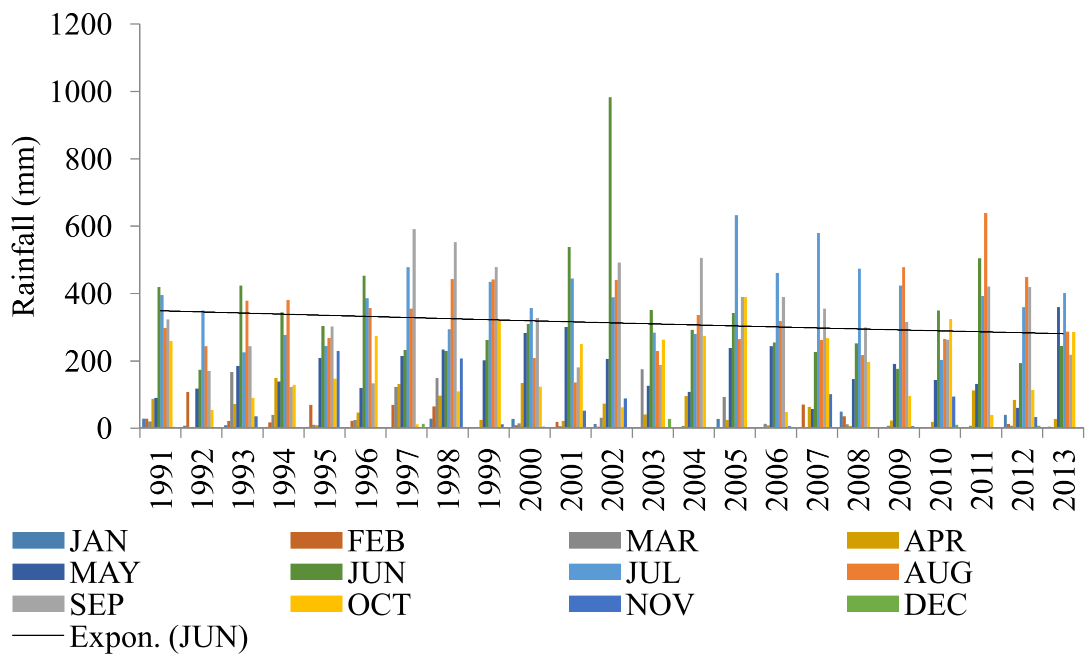

Figure 11: The yearly average rainfall of Sundarbans recorded by Mongla station (1991-2013). (Source: climate.barcapps.gov.bd)

Weather predictability was reduced by changes in wind direction and intensity (4.1% of records of the weather and climate change observations) in Sundarbans which was observed by fishers. Different wind directions are generally associated with specific weather patterns (e.g., rain, storms) that are well known to subsistence fishers based on their long-term knowledge of particular areas (Bunce *et al.*, 2010; King *et al.,* 2008). Unpredictable winds can hinder fishers' ability to read signs of incoming storms, which critically affects ocean navigation and safety, particularly given the small vessels typically used by subsistence fishers (Glaeser and Glaeser, 2010; Grant and Berkes, 2004). Increases in rivers water temperature (10.1% of records of the weather and climate change observations) were also noted by fishers in several communities. The rise in water temperatures is especially relevant for fishers because of the expected changes in fish distribution and abundance (Cheung *et al.*, 2013; Perry, 2011; Weatherdon *at el.,* 2016).

11.8 Water quality parameters of the Meghna, Galachipa and Laukhati rivers

The water quality parameters were recorded regularly during the study period. The parameters are shown in Figure 11.8.12.In the present study the highest pH value (7.2± 0.85) was recorded in the Meghna river whereas the lowest pH values 6.8±0.59 and 7.1±0.15 was recorded in Laukhati and Galachipa river, respectively during monsoon. During post-monsoon, maximum pH, 8.3±0.59 and 8.03± 0.50 was recorded in the Meghna river and Galachipa river, respectively; whereas, the minimum pH (7.8±0.5) was recorded in Laukhati river (Figure 11.8.12 A). The recorded water temperature varied from 25.53±0.60 ^{o}C to 30.5±0.90 °C in the study area. Highest water temperature was recorded as 30.5±0.90 °C in the Meghna river whereas the minimum temperature was recorded as 27.1±1.05 °C at Galachipa and 27.4±0.6 °C at Laukhati river during monsoon. In post-monsoon, the maximum temperature was recorded as 26.00±1.10°C at Galachipa river while the minimum temperature (25.53±0.60 °C) was recorded in Meghna river and 25.3±1.1 °C was at Laukhati river (Figure 11.8.12B). Surface water temperature was 21-30 ºC lower than that of the air temperature.The concentration of DO ranged from 5.4-6.37 mg/L in different locations of the study area. During monsoon, maximum DO was recorded as 6.37±1.11 mg/L in the Meghna river and the minimum DO was 6.33±0.51 mg/L at Galachipa river and 6.33±0.36 mg/L at Laukhaki river. During the post-monsoon, the highest DO was recorded as 5.63± 0.33mg/L at Galachipa and Laukhati river and the lowest value 5.4±0.50 mg/L in the Meghna river (Figure 11D). Highest DO concentration was recorded during monsoon period because of highest occurrence of the phytoplankton density. During the monsoon, 0.10±0.10 ppt. 0.22±0.11 ppt. and 0.10± 0.11 ppt. salinity was recorded in the Meghna river, Galachipa river, and Laukhati river, respectively. During post-monsoon, maximum salinity, 1.2±0.15 ppt. and 0.23± 0.13 ppt. was recorded in Laukhati and Galachipa river, respectively; whereas, minimum salinity (0.13± 0.06 ppt.) was recorded in the Meghna river (Figure 11.8.12C).

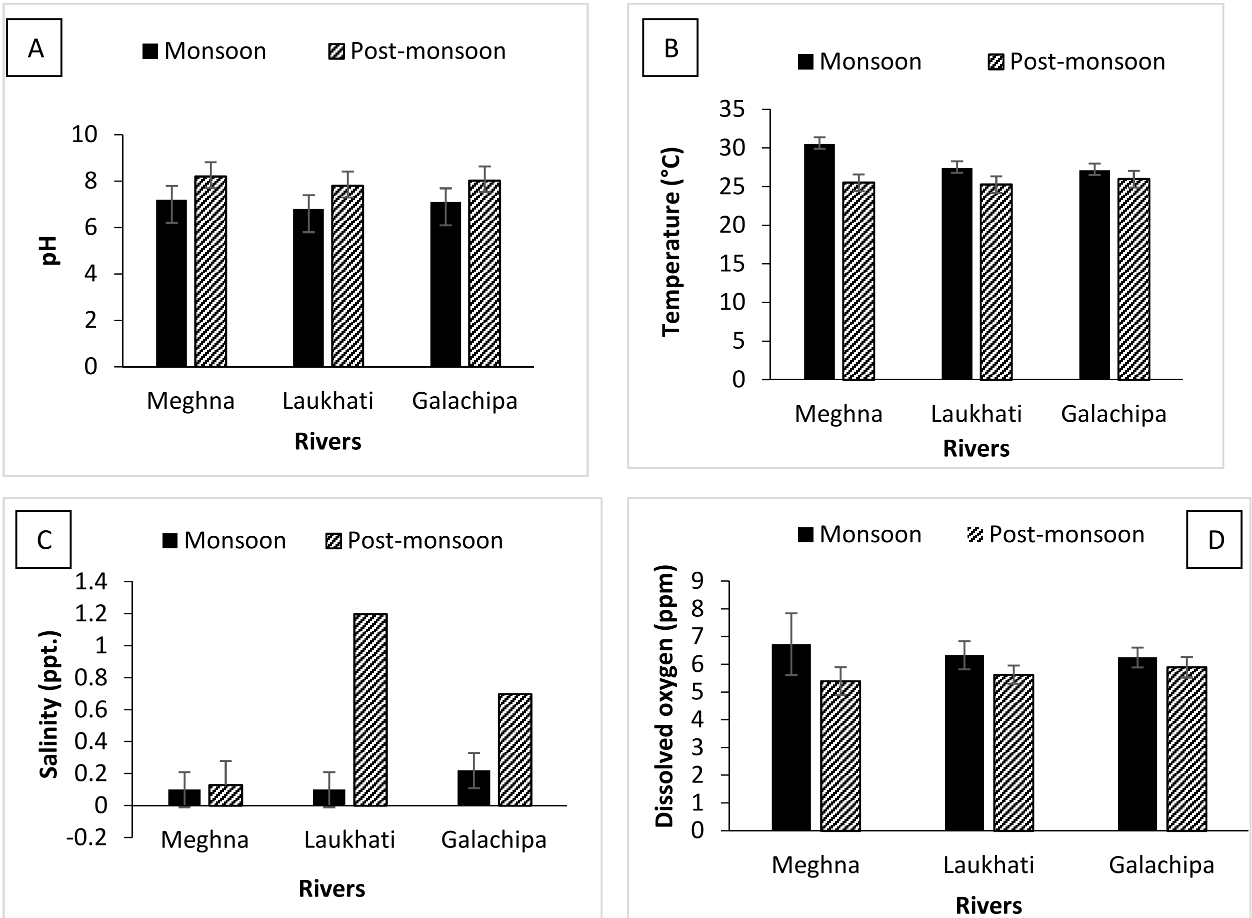

Figure 12: Graphs showing the water quality parameters during study period in the Meghna, Laukhati and galachipa rivers; A) pH; B) Water temperature; C) Salinity and D) Dissolved oxygen

Temperature is known as a critical quality parameter, since it directly influences the amount of dissolved oxygen that is available to aquatic organisms. Temperature affects the distribution, health, and survival of aquatic organisms. While temperature changes can cause mortality, it can also cause sub-lethal effects by altering the physiology of aquatic organisms (Chapman *et al.*, 1996). Temperatures outside of an acceptable limit affect the ability of aquatic organisms to grow, reproduce, escape predators, and compete for their habitat. The fluctuation in river water temperature usually depends on the season, geographic location, sampling time and temperature of effluents entering the stream. Theoptimum temperature range (22-31°C) for the survival and best growth of aquatic organisms in subtropical estuaries. In the recent study, highest water temperature (30.5°C) was in the Meghna river, (27.1°C) at Galachipa river and (27.4°C) at Laukhati river. Surface water temperature was (1-3) ºC lower than that of the air temperature in the study. This observation was more or less similar with the works of Mahmood and Khan (1976); Elias (1983), Mahmood (1990); Chapman (1956); Zafar (1995); Noori (1999) and Martin *et al*. (2008).

Dissolved oxygen is another essential quality for the aquatic organisms. It is the most important factor for all living organisms on the earth. It is also an ecological factor that decides environmental health of water bodies and supports a well-balanced aquatic living organisms (George *et al*., 2012). In the deficiency of suitable range of oxygen in the water body organism can't grow properly even they can die. It can vary with the day time, generally in the time of morning, oxygenis low but it becomes high at mid time of a day because photosynthesis is occurred and produce more oxygen by the help of sun light. Adequate DO is necessary for good water quality, survival of aquatic organism and decomposition of waste by microorganism (Dara, 2002). Maximum DO value was found to be 6.33 to 6.37 mg/L in the rivers which is standard according to Pandey (1997).

Unlike other coastal districts salinity intrusion in the rivers are not so severe. Local people reported that the status salinity intrusion of the rivers is reducing in recent years. Sea level rise, change of river flow direction, reduced upstream flow which increases the rate of salinity intrusion. The impacts of salinity intrusion are decrease soil fertility due to application of higher doze of zinc fertilizer in the agricultural land, decrease fresh water fishes, reduce agriculture production, hamper irrigation of boro crops during dry season months. Salinity is also a major important parameter for the marine fish species but it is perilous for the freshwater species. Too much range of salinity in the fresh water may harm to fertilize egg even can occur the migration. Consequently, total fish production can be reduced. Therefore, the salinity of the sampling rivers was carefully investigated. According to Shridher *et al*. (2006), salinity acts as a limiting parameter that hugely influences the dispersal of plankton community**.** Excessively high or low salinity also prompt organisms to migrate in order to escape unfavorable environmental conditions. Perumal *et al*. (2009) also mentioned that changes in salinity can also contribute indirectly to food shortages and thereby impact the zooplankton abundance. In my present study, during monsoon, only 0.10 ppt. salinity was recorded in the Meghna river near boro station fish landing Centre while the salinity of Galachipa river was 0.22 ppt. During post-monsoon, maximum salinity was 0.23 ppt. at Galachipa river and minimum was 0.13 ppt. in the Meghna river and 1.2 ppt. was at Laukhati river. The salinity in the Meghna river has found recently which was not at before. According to the fishermen's opinion, this may be the reason of intrusion the sea water during flood time.

pH is commonly known as the controlling variable in water since many properties, processes and reaction are pH dependent **.** The pH of a water body is very important in determination of water quality since it affects other chemical reactions such as solubility and metal toxicity (Fakayode, 2005). The pH was found to be 7.8 to 8.3 in present study. According toMillero (1986) high pH causes zooplankton abundance reduction and Ivanova and Kazantseva(2006) mentioned while low alkaline condition contributes high primary production that favors the occurrence and diversity of zooplankton. The pH recorded in the present study fall with the FEPA (1991) and Pandey (1997) standard range of 6.0-9.0. It was also similar to the findings of Inuwa (2007); Mustapha (2008).

11.9 Observation of rainfall in the study area of Chandpur and Patuakhali

Rainfall is an important factor which influences the environment. The frequency of heavy rainfall over the study area and the perception level about heavy rainfall is changing day by day in the study area. This has been showed in the Figure 13.

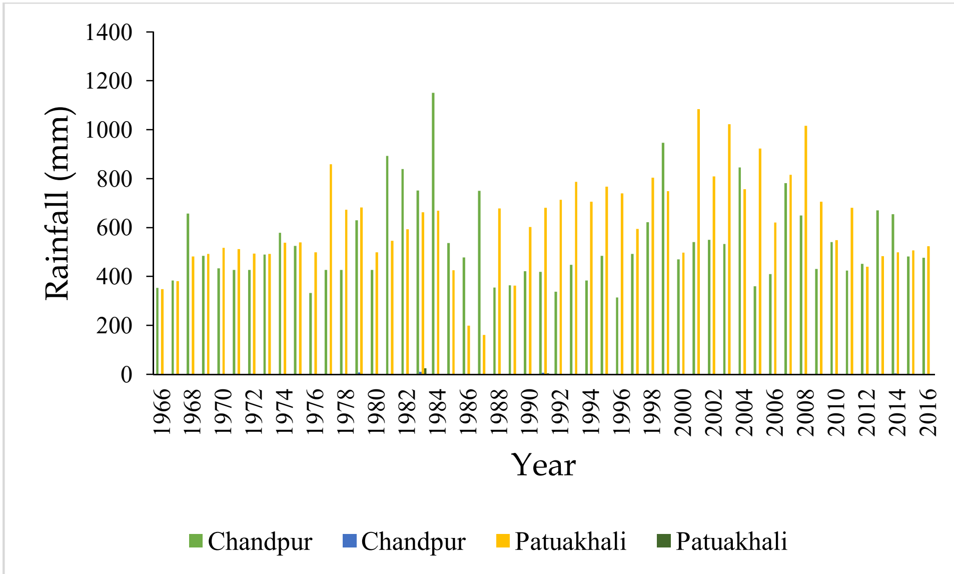

Figure 13: Annual maximum and minimum rainfall in Chandpur and Patuakhali (Source- IUCN, 2017)

11.10 Observation of temperature in the study area of Chandpur and Patuakhali

Temperature is an essential climatic parameter. It affects evaporation from open water. At present the most concerning issue is rising temperature. This rising temperature is as threatened as dangerous to the living organisms on the earth. Using the trend line equation, this study found changes over the period of 41 years (1965-2016), annual maximum and minimum temperature has increased by 1.4°c and 1.45°c respectively in these area (Figure 14).

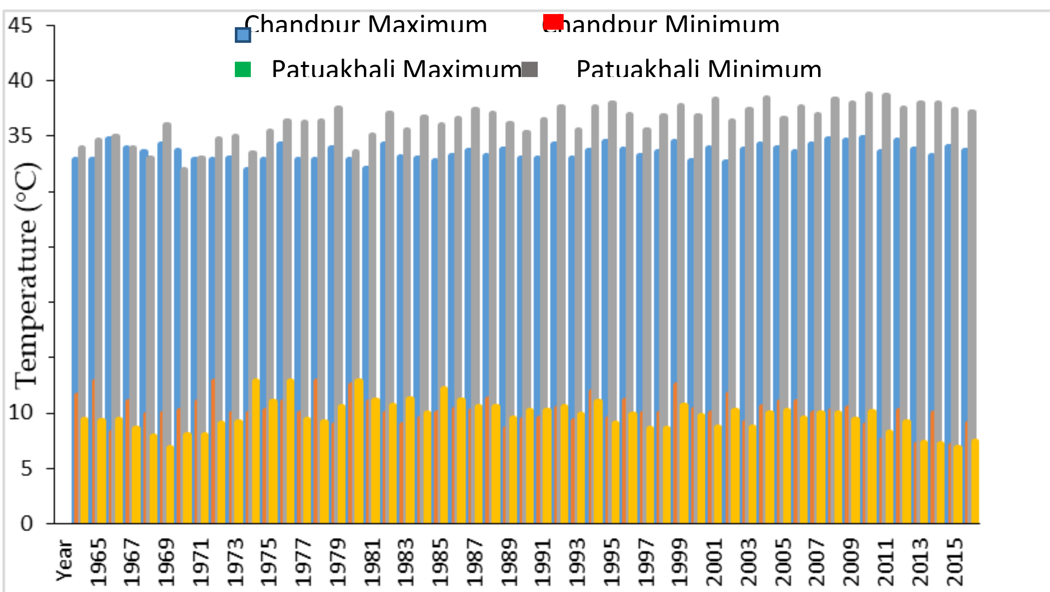

Figure 14: Annual maximum and minimum temperature in Chandpur and Patuakhali (Source- IUCN, 2017)

11.11 Water quality parameter of the Padma river

The water quality parameters such as temperature, pH and DO were monitored monthly in the Padma river during the study period. The temperature of water was found to vary from 28.7°C to 32.3°C in the study area (Table 11). The temperature was high in the pre-monsoon period. The hydrogen ion concentration (pH), DO and salinity of water as recorded in the study area was in the range of 7.8±0.26 to 8.9±0.41, 7.8±0.26 to 8.9±0.41 ppm and 0.10±0.01 to 0.15±0.01, respectively.

Table 11. Water quality parameters during study period in the Padma river at Louhajang, Munshiganj

Parameters	Pre-monsoon	Monsoon	Post-monsoon
Temperatures	32.3±0.52	28.7±0.66	30.4±.65
Dissolved oxygen (DO)	7.8±0.26	8.9±0.41	8.1±0.30
pH	8.0±0.25	8.2±0.15	7.7±0.25
Salinity	0.15±0.01	0.10±0.01	0.10±0.01

Temperature is a critical water quality parameter, since it directly influences the amount of dissolved oxygen that is available to aquatic organisms (Ahmed et al., 2003). Temperature affects the distribution, health, and survival of aquatic organisms. While temperature changes can cause mortality, it can also cause sub-lethal effects by altering the physiology of aquatic organisms (Collins et al., 2008). Temperatures outside of an acceptable limit affect the ability of aquatic organisms to grow, reproduce, escape predators, and compete for their habitat. The fluctuation in river water temperature usually depends on the season, geographic location, sampling time and temperature of effluents entering the stream (ADB, 1994). The pH of a water body is very important in determination of water quality since it affects other chemical reactions such as solubility and metal toxicity (Dara, 2002). The pH was found 8.0 to 8.2 in the present study. Adequate dissolve oxygen is necessary for good water quality, survival of aquatic organism and decomposition of waste by microorganism (Chowdhury and Raknuzzaman 2005). Maximum dissolve oxygen value was found 6.7 to 6.9 mg/l. The rise in temperature in the river water can be correlated with increase in carbon dioxide levels (Shafi et al., 1978). Salinity is also a major important parameter for the marine fish species but it is perilous for the freshwater species. Too much range of salinity in the fresh water may harm to fertilize egg even can occur the migration. Consequently, total fish production can be reduced. Therefore, the salinity of the sampling rivers was carefully investigated. According to Shridher *et al*. (2006), salinity acts as a limiting parameter that hugely influences the dispersal of plankton community**.** Excessively high or low salinity also prompt organisms to migrate in order to escape unfavorable environmental conditions. Perumal *et al*. (2009) also mentioned that changes in salinity can also contribute indirectly to food shortages and thereby impact the zooplankton abundance. In my present study, during monsoon, only 0.10 ppt, salinity was recorded in the Padma river at Louhajang sadar, Munshiganj. During post-monsoon, maximum salinity was 0.20 ppt and the same place.

11.12 Water quality parameters of the Kishoreganj haor region

The water quality parameters such as temperature, pH and DO were monitored monthly in Kishoreganj haor region during the study period. The temperature of water was found to vary from 28.77°C to 33.3°C respectively in the study area (Table 12). The temperature was high in the pre-monsoon period.

The hydrogen ion concentration (pH) of water as recorded in the study area was in the range of 7.9 – 8.3, DO ranged from 7.3 to 8.5 mg/l and salinity was 0 in the study area.

Table 12. Water quality parameters during study period in the Kishoreganj haor region

Parameters	**Pre-monsoon**	**Monsoon**	**Post-monsoon**
Temperatures	33.3±0.52	28.77±0.66	29.4±.55
Dissolved oxygen (DO)	7.3±0.06	8.5±0.14	7.8±0.20
pH	8.3±0.20	8.0±0.15	7.9±0.20
Salinity	0	0	0

Temperature is an essential climatic parameter. It affects evaporation from open water. In the Figure 11 showed the annual maximum and minimum temperature respectively at Kishoreganj haor region. Using the trend line equation, this study found changes over the period of 36 years (1981-2017), annual maximum and minimum temperature has increased by 1.36°C and 1.59°C respectively in Kishoreganj haor region (Figure 15).

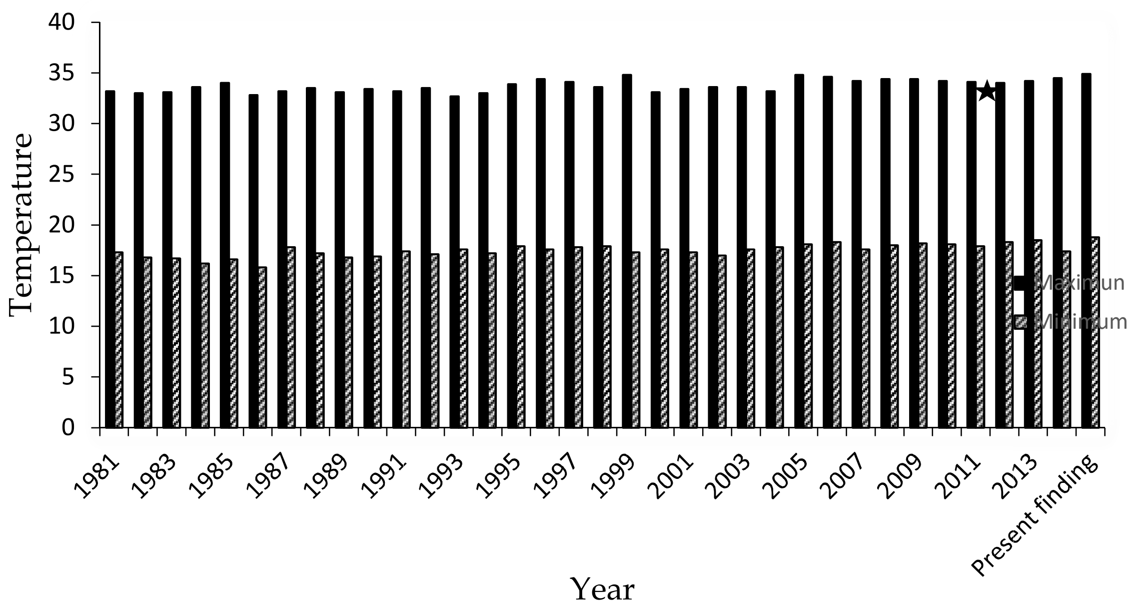

Figure 15: Comparison of annual maximum and minimum temperature in the Kishoreganj haor region. Source: IUCN, 2015 and Present finding

Water is an essential element for fisheries resources and primary productivity. It is one of the most important elements that directly influence aquatic organisms. The fish survival and growth is influenced by the water quality (Likongwe *et al*., 1996). Increased temperature affects the breeding season of the fishes. High temperatures can affect fish population by altering physiological functions such as thermal tolerance, growth, metabolism, food consumption, reproductive success (Fry, 1971a). In the present study area, the temperature range was 28.77°C to 33.3°C and annual maximum and minimum temperature has increased by 1.36°C and 1.59°C respectively in Kishoreganj haor region. Rahaman *et al.* (2016) reported that annual maximum and minimum temperature has increased by 1.4°C and 1.45°C respectively in the Tanguar haor region which was similar to the present finding. Adeniji and Ovie,

(1982) suggested optimum temperature range (22-31°C) for the survival and best growth of aquatic organisms. The present findings indicate that temperature is higher than optimum range.

Optimum level of DO is very essential for fish and other organisms. The level of DO in natural water body depend on the physical, chemical, and bio-chemical activities occurring at surface and subsurface levels of natural water. In the present study area, dissolved oxygen (DO) range was 7.3 to 8.5 mg/l respectively. Islam *et al.* (2014) found the DO range between 4.6 – 5.6mg/l in Hakaluki haor which is slightly less than present study. According to Lagler (1972) DO content less than 3mg/l is harmful to fishes. DO below 5.0 mg/l stresses aquatic life, below 1-2 mg/l can result in massive fish kills.

The pH is an important factor as measure of water quality. Shaikh and Yeragi (2003) discovered that pH is the most important factor which controls the growth of the green algae. Low and high pH value is very detrimental for the ecosystems of the haor, and the recommended pH level is 6.5 to 9.0 for aquatic organisms. Among the water quality parameters, the water pH range was 7.9 to 8.3 in the present study. Islam *et al.* (2014) reported that pH values varied from 5.9 – 7.1 in Hakaluki haor which was slightly less than present study. Rahman *et al.* (2018) found pH ranged 5.8-6.3 in different haor region. Motwani *et al*. (1956) and Trevedi and Raj (1992) reported that 6.8 to 9.0 as the optimum pH range for the aquatic life in water bodies. The standard value of pH for fisheries lies between 6.5- 8.5 (ECR, 1997) which was similar to the present study.

Climate change may alter the water quality parameters in many ways. In the present study, water quality of Kishoreganj haor region decline gradually due to climate change and human interventions. It has considerable effect on phytoplankton population density (Blanco, 1995). Any alteration of water quality parameters has the least probability to affect the plankton community. Nutrient concentrations of aquatic system may be influenced when temperature rises as it affects the photosynthesis rate (Tait, 1981). Species abundance and primary productivity mainly depend on water quality parameters. Increased temperature causes stress to fish and other aquatic animals. The present research findings clearly indicate that the water temperature rising day by day and it has negative impacts on fisheries resources and primary productivity in Kishoreganj haor region.

11.13 Plankton Abundance

The abundance of different group of phytoplankton and zooplankton in different station of Sundarbans mangrove forest in three seasons has been described in the following sectors.

11.13.1 Plankton abundance in Passur river

The minimum and maximum abundance of phytoplankton cells were recorded at 5833 individuals/l and 6790 individuals/l in pre-monsoon, 4665 individuals/l and 5552 individuals/l in monsoon and 6008 individuals/l and 7236 individuals/l in post-monsoon, respectively from Passur river. The minimum and maximum abundance of zooplankton cells were recorded at 2032 individuals/l and 2355 individuals/l in pre-monsoon, 1768 individuals/l and 2279 individuals/l in monsoon and 2290 individuals/l and 2944 individuals/l in post-monsoon, respectively from Passur river (Table 13).

Table 13. Phytoplankton and zooplankton abundance (individuals/l) in different season in the Passur river system

Sampling area	Station*	Pre-monsoon		Monsoon		Post-monsoon	
		Phyto-plankton	Zoo-plankton	Phyto-plankton	Zoo-plankton	Phyto-plankton	Zoo-plankton
22°27′56″N 89°35′21″E	A1	6790	2118	4665	1933	7236	2743
22°21′08″N 89°38′03″E	A2	5833	2355	5038	2279	6389	2944
22°17′55″N 89°36′48″E	A3	6266	2032	5552	1768	6008	2290

* A1, A2 and A3 are three different locations in the Passur river system.

11.13.2 Plankton abundance in Sibsa river

The minimum and maximum abundance of phytoplankton cells were recorded at 2822 individuals/l and 4006 individuals/l in pre-monsoon, 3050 individuals/l and 4260 individuals/l in monsoon and 3980 individuals/l and 5515 individuals/l in post-monsoon, respectively from Sibsa river. The minimum and maximum abundance of zooplankton cells were recorded at 1522 individuals/l and 2073 individuals/l in pre-monsoon, 1154 individuals/l and 1645 individuals/l in monsoon and 2280 individuals/l and 2662 individuals/l in post-monsoon, respectively from Sibsa river (Table 14).

Table 14. Phytoplankton and zooplankton abundance (individuals/l) in different season intheSibsa river system

Sampling area	Station*	Pre-monsoon		Monsoon		Post-monsoon	
		Phyto-plankton	Zoo-plankton	Phyto-plankton	Zoo-plankton	Phyto-plankton	Zoo-plankton
22°34′25″N 89°23′59″E	B1	3017	1835	3855	1645	4688	2568
22°30′52″N 89°24′45″E	B2	2822	2073	3050	1154	3980	2280
22°27′14″N 89°25′30″E	B3	4006	1522	4260	1390	5515	2662

* B1, B2 and B3 are three different locations in the Sibsa river system.

11.13.3 Plankton abundance in Kopothakho river

The minimum and maximum abundance of phytoplankton cells were recorded at 642 individuals/l and 650 individuals/l in pre-monsoon, 325 individuals/l and 421 individuals/l in monsoon and 436 individuals/l and 885 individuals/l in post-monsoon, respectively from Kopothakho river. The minimum and maximum abundance of zooplankton cells were recorded at 221 individuals/l and 392 individuals/l in pre-monsoon, 108 individuals/l and 204 individuals/l in monsoon and 298 individuals/l and 468 individuals/l in post-monsoon, respectively from Kopothakho river (Table 15).

Table 15. Phytoplankton and zooplankton abundance (individuals/l) in different season in theKopothakho river system

Sampling area	Station*	Pre-monsoon		Monsoon		Post-monsoon	
		Phyto-plankton	Zoo-plankton	Phyto-plankton	Zoo-plankton	Phyto-plankton	Zoo-plankton
22°11′02″N 89°19′06″E	C1	642	257	344	204	436	336
22°14′35″N 89°18′14″E	C2	644	221	421	108	476	298
22°17′01″N 89°19′06″E	C3	650	392	325	132	885	468

*** C1, C2 and C3 are three different locations in the Kopothakho river system**

11.13.4 Plankton abundance in Sela river

The minimum and maximum abundance of phytoplankton cells were recorded at 3665 individuals/l and 4187 individuals/l in pre-monsoon, 1565 individuals/l and 2135 individuals/l in monsoon and 2718 individuals/l and 3452 individuals/l in post-monsoon, respectively from Sela river. The minimum and maximum abundance of zooplankton cells were recorded at 882 individuals/l and 1644 individuals/l in pre-monsoon, 932 individuals/l and 1154 individuals/l in monsoon and 2271 individuals/l and 2832 individuals/l in post-monsoon, respectively from Sela river (Table 16).

Table 16. Phytoplankton and zooplankton abundance (individuals/l) in different season in theSela river system

Sampling area	Station*	Pre-monsoon		Monsoon		Post-monsoon	
		Phyto-plankton	Zoo-plankton	Phyto-plankton	Zoo-plankton	Phyto-plankton	Zoo-plankton
22°21′57″N 89°39′59″E	D1	4187	1644	1565	1154	3452	2521
22°21′24″N 89°40′14″E	D2	4090	882	2135	1068	3131	2271
22°20′09″N 89°40′39″E	D3	3665	1008	2088	932	2718	2832

* D1, D2 and D3 are three different locations in the Sela river system

11.13.5 Qualitatively analysis of plankton in the rivers

Among the collected sample 29 species of phytoplankton and 18 species of zooplankton were identified (Table 17). Bacillariophyceae was represented by 15 species which is the highest number. Cyanophyceae and Chlorophyceae were represented by 5 and 3 species, respectively. Two species was recorded from both Zygnematophyceae and Euglenophyceae, respectively. Xanthophyceae was represented by one species. Occurrence of species and number of individuals per liter was highest in the Passur river during both pre-monsoon and post-monsoon. Lowest number of individuals per liter was found in Kopothakho river in every season. *Chaetoceros socialis* and *Centritractus belanophorus* were found in only Passur river. *Uronema* sp. was found in both Passur and Sela river. *Rhizosolenia sp*. was only found in

Kopothakho river. However, *Oocystis pusilla*, *Coscinodiscus excentricus, Coscinodiscus lineatus, Navicula brekkeansis, Microcustis aeruginosa, Microcustis elongate* and *Microcustis argentea* occurred abundantly in every sampling site. *Cyclotella comta, Thalassionemanitzschioides, Gonatozygon sp.* and *Lioloma delicatula* were common in the rivers. Among zooplankton, Maxillopoda was represented by 11 species which is the highest number. Branchiopoda and Malacostraca were represented by 3 and 2 species, respectively. Only one species was recorded from both Crustacea and Monogononta, respectively. Among the species, *Mesocyclops sp., Bosmina sp., Praunus sp., Diaptomus sp., Scylla sereta* (Crab larvae), *Pseudocandona sp., Brachionus sp., Daphnia sp., Acartia sp., Paracalanus sp., Pseudocalanus sp.* and *Paracartia sp.* were common species in every rivers. Most dominant species were *Mesocyclops sp., Bosmina sp., Praunus sp., Diaptomus sp., Daphnia sp.,* and *Brachionus sp.* in the rivers. *Lucifer sp.* was only recorded in Sibsa and Kopothakho river. *Mysidella* sp was not recorded in Sela river.

Table 17. List of phytoplankton and zooplankton in the Sundarbans

Phytoplankton		**Zooplankton**	
Class	**Species**	**Class**	**Species**
Chlorophyceae	*Oocystis pusilla*	**Malacostraca**	*Lucifer sp.*
	Uronema sp.		*Scylla sereta* (Crab larvae)
	Echinosphaerella limnetica	**Crustacea**	*Pseudocandona sp.*
Euglenophyceae	*Astasia cylindrica*	**Monogononta**	*Brachionus sp*
	Euglena spathirhyncha		
Bacillariophyceae	*Bacteriastrum delicatulum*	**Maxillopoda**	*Acartia sp.*
	Chaetoceros pendulus		*Mesocyclops sp.*
	Chaetoceros socialis		*Centropages sp.*
	Coscinodiscus excentricus		*Mysidella* sp
	Coscinodiscus lineatus		*Diaptomus* sp.
	Coscinodiscus granii		*Calanus sp.*
	Coscinodiscus marginatus		*Cyclops* sp.
	Coscinodiscus jonesianus		*Oithona sp.*
	Cyclotella comta		*Paracalanus sp.*
	Navicula brekkaensis		*Pseudocalanus sp.*
	Thalassionema nitzschioides		*Paracartia sp.*
	Lioloma delicatula		
	Skeletonema costatum		
	Nitzschia acicularis		
	Nitzschia sigma		
Cyanophyceae	*Microcustis aeruginosa*	**Branchiopoda**	*Bosmina sp.*
	Microcustis elongate		*Praunus sp.*
	Microcustis argentea		*Daphnia sp*
	Gloeotrichia pisum		
	Chroococcus dispersus		
Zygnematophyceae	*Gonatozygon aculeatum*		
	Gonatozygon brebissonii		
Rhizosoleniaceae	*Rhizosolenia sp*		
Xanthophyceae	*Centritractus belanophorus*		

Mangroves are of extremely higher primary and secondary productivity than other wetland habitat types (Clough, 1992; Primavera, 1996). Phytoplankton and zooplankton plays an important role in the water of Sundarbans ecosystem as primary and secondary producer and is a significant source of food for the fish and other crustacean. It is the main occasion for typically higher biomass and standing stocks of Sundarbans fisheries. In a previous study, total 34 species of phytoplankton have been recorded belonging to the families Volvocaceae, Palmelaceae, Ulvaceae, Cladephoraceae, Zygnemaceae, and Codiaceae, the Division Chlorophyta is represented by nine species under six genera; division Cyanophyta is represented by 16 species under 9 genera belonging to the families Chroococcaceae, Oscillatoriaceae, Nostocaceae, and Rivulariaceae; Bacillariophyta is represented by 16 genera and 35 species and the Euglenophyta is represented by two genera and two species (Hussain and Acharya, 1994). In the present study, 29 species of phytoplankton were recoded from the rivers of Sundarbans. *Coscinodicus spp.* and *Microcystis spp.* were found the dominant and common species in Sundarbans. Bacillariophyceae was represented by highest number of genera and species. Other recorded common species were *Cyclotella comta, Thalassionemanitzschioides, Gonatozygon sp. Lioloma delicatula Gloeotrichia pisum, Cyclotella sp,* and *Chroococcus disperses.* Only *Rhizosolenia sp.* was recorded in Kopothakho river where salinity was high (23‰) during pre-monsoon. Islam and Aziz (1975) have reported *Coscinodicus granii* and *Rhizosolenia imbricate* in the northern-estern Bay of Bangel, Bangladesh. These are marine phytoplankton which was also recorded from Kopothakho river due to high saline environment during high tide in pre-monsoon. Another study conducted by Mamun *et al.* (2009) have recorded that *Echinosphaerella limnetica* and *Treubaria setgerum* was found in Sela river and Pasur –Sibsa river system respectively, where these two species are considered as rare species. In present study, these two species was not found in Sela, Sibsa and Passur river. Most of the freshwater phytoplankton diversity and abundance in the rivers of Sundarbans was dramatically reduced due to increased salinity intrusion and decreased freshwater flows from upstream. The Sundarbans of Bangladesh are tremendously rich in zooplankton production. Thirteen major taxa of zooplankton namely, Copepods, Amphipods, Mysids, Acetes, Chaetognaths, Polychaetes, Lucifers, Hydromedusae, Shrimp larvae, fin fish larvae, Crab larvae, Squilla, and horse-shoe Crab larvae were found to occur in this region (Islam and Hoque, 2004). Another study conveyed by Mamun *et al.* (2009) have recorded total of 11 genera of different group of zooplankton from the rivers of Sundarbans. In the present study, 18 species of zooplankton were found in different rivers of Sundarbans. Maxillopoda was represented by highest number of genera and species. Most dominant species were *Mesocyclops sp., Bosmina sp., Praunus sp., Diaptomus sp., Daphnia sp.,* and *Brachionus sp.* in the rivers during post-monsoon. The abundance of zooplankton was high in Passure river followed by Sibsa, Sela and Kopothakho river, respectively. Monsoon season represented the lowest number of zooplankton. The concentration of zooplankton was several times higher during post-monsoon than other season. The abundance of zooplankton was very less in Kopothakho river than other three rivers where the average salinity and DO was recorded 18.8‰ and 4.4 mg/l. Salinity has negative correlation and DO has positive correlation with abundance of zooplankton (Bir *et al.,* 2015). The distribution and abundance of plankton in the Sundarbans are greatly influenced by the ecological characteristics, particularly the mixing of saline and freshwater, the amount of nutrients in water and the silt carried by rivers. The physio-chemical parameters of water have positive or negative correlation with the abundance, diversity and distribution of plankton. The average DO was high in both rivers and salinity was low (<5‰) and moderate (<13‰) respectively in Sela and Passur river during post-monsoon season. That's the main reason for high abundance of zooplankton during post-monsoon.

11.13.6 Plankton in the Meghna, Laukhati and Galachipa rivers

A total of 7 groups including 41 genera were of Phytoplankton and 4 groups including 31 genera of zooplankton recorded in the Meghna river. Phytoplankton was belonged to Bacillariophyceae, Dinophyceae, Cyanophyceae, Dinophyceae, Chlorophyceae, Myxophyceae, Euglenophyceae (Table 18) while zooplankton including, Rotifera, Copepoda, Cladocera and Ostracoda were found in the Meghna river (Table 19).

The highest and lowest number of phytoplankton was recorded from groups Chlorophyceae (12) and Euglenophyceae (1) whereas the number of zooplankton groups, Rotifera (9) and Cladocera (4), respectively in the Meghna river (Table 18 and 19). On the contrary, the maximum and minimum number of phytoplankton groups were recorded from groups Bacillariophyceae (13) and Xanthophyceae (2), while the maximum and minimum number of zooplankton groups were recorded from Rotifera (9) and Ostracoda (1), respectively in the Galachipa river (Table 23) and phytoplankton (12) and zooplankton (7) were recorded at Laukhati river (Table 20 and Table 21) during monsoon.During post-monsoon, the highest and lowest number of phytoplankton were recorded from the groups Chlorophyceae (12) and Xanthophyceae (1) whereas the number of zooplankton were recorded from groups Rotifera (6) and Cladocera (1), respectively in the Meghna river (Table 18 and Table 19). On the contrary, the maximum and minimum number of phytoplankton were recorded from groups Chlorophyceae (11) and Xanthophyceae (1)whereas number of zooplankton group were Rotifera (6) and Copepoda (3) respectively, at Galachipa river (Table 22 and Table 23) and the maximum and minimum phytoplankton were recorded from group Cholophyceae (2) and Myxophyceae (1) whereas the zooplankton were recorded from groups Rotifera (3) and Cladocera (2), respectivelyat Laukhati river (Table 20 and Table 21).

Table 18. List of phytoplankton collected from the Meghna river

Groups	Genus	
	Monsoon	Post-monsoon
Bacillariophyceae	*Amphora, Tabellaria , Cyclotella, Coscinodesmus, Stphanodesmus, Ditoma, Fragilaria, Melosira, Navicula, Nitzchia Asterionella, Polycistis*	*Tabellaria, Nitzchia, Ditoma, Anomoeoneis, Gomphonema Polycistis*
Cholorophyceae	*Ankistrodesmus, Eudorina, Spirogyra, Crucigenia, Chlamydomonas, Ceratium, Closterium, Volvox, Scenedesmus, Gonatozygon, Microspora, Pleodarina*	*Spirogyra, Pediastrum, Microspora, Synedra, Ulothrix, Oedogonium, Closterium, Zygenema, Ceratum, Scenedesmus, Volvox, Genecularia,*
Cyanophyceae	*Spirulina, Scenedesmus Nostoc, Oscillatoras*	*Microcystis,Polycistis, Spirulina, Anabaena*
Dinophyceae	*Ulothrix, Protoccocus*	*Ulothrix*
Euglenopyceae	*Tribonema*	
Myxophyceae	*Tetrapedia, Coelosphaerium, Merismopedia, Oedogonium, Aphanocapsa*	*Coelosphaerium, Oedogonium, Aphanocapsa*
Xanthophyceae	*Trachelomonus, Euglena*	*Euglena*

Table 19. List of zooplankton collected from the Meghna river

Groups	Genus	
	Monsoon	Post-monsoon
Rotifera	*Trichocera, Brachionus, Atrochus,Brachionus,Cephalodella, Lophocaris, Rotaria, Trichocerca, Lacane*	*Trichocera,Cephalodella, Lophocaris, Rotaria, Trichocerca, Phinoglena*
Copepoda	*Nauplius, Diaptomus, Cyclops, Eucyclops*	*Eucyclops, Mesocyclops, Phyllodiaptomus*
Cladocera	*Daphnia, Diaphanosoma, Chydo, Chydorus*	*Macrocyclops. Moina, Daphnia, Alona*
Ostracoda		*Cypridopsis*

Table 20. List of phytoplankton collected from the Laukhati river

Groups	Genus	
	Monsoon	Post-monsoon
Bacillariophyce	*Nitzchia , Asterionella, Polycistis*	*Ditoma,nitzchia*
Cholorophyceae	*Closterium, Volvox, Spirogyra*	*Spirogyra, Volvox*
Cyanophyceae	*Spirulina, Scenedesmus, Nostoc*	*Anabaena, Spirogyra*
Euglenopyceae	*Tribonema*	
Myxophyceae	*Tetrapedia, Coelosphaerium*	*Tetrapedia,*

Table 21. List of zooplankton collected from the Laukhati river

Groups	Genus	
	Monsoon	Post-monsoon
Rotifera	*Brachionus, Atrochus,Brachionus*	*Lophocaris, Rotaria, Trichocerca*
Copepoda	*Diaptomus, Cyclops*	*Cyclops,Eucyclops*
Cladocera	*Daphnia, Diaphanosoma*	*Daphnia, Moina*

Table 22. List of phytoplankton collected the Galachipa river

Groups	Genus	
	Monsoon	Post-monsoon
Bacillariophyceae	*Amphora , Tabellaria , Cyclotella, Coscinodesmus, Stphanodesmus, Ditoma, Fragilaria, Melosira, Navicula, Nitzchia , Asterionella, Polycistis, Synedra*	*Tabellaria, Nitzchia,Ditoma, Anomoeoneis,Gomphonema*
Cholorophyceae	*Genecularia, Scenedesmus, Volvox, Mougeotia, Zygenema, Pediastrum*	*Spirogyra, Pediastrum, Microspora,Synedra, Ulothrix, Oedogonium, Closterium, Zygenema, Ceratum, Scenedesmus , Volvox*
Cyanophyceae	*Spirulina, Scenedesmus, Nostoc, Oscillatoras*	*Microcystis, Polycistis, Spirulina, Anabaena*
Dinophyceae	*Ulothrix, Protoccocus*	*Ulothrix*
Euglenopyceae	*Tribonema*	
Myxophyceae	*Tetrapedia, Coelosphaerium, Merismopedia, Oedogonium, Aphanocapsa*	*Coelosphaerium, Oedogonium, Aphanocapsa, Merismopedia*
Xanthophyceae	*Trachelomonus, Euglena*	*Euglena*

Table 23. List of zooplankton collected from the Galachipa river

Groups	Genus	
	Monsoon	Post-monsoon
Rotifera	*Trichocera, Brachionus, Atrochus, Brachionus, Cephalodella, Lophocaris, Rotaria, Trichocerca, Lacane*	*Trichocera, Cephalodella, Lophocaris, Rotaria, Trichocerca, Phinoglena*
Copepoda	*Nauplius, Diaptomus, Cyclops, Eucyclops*	*Eucyclops, Mesocyclops, Phyllodiaptomus*
Cladocera	*Daphnia, Diaphanosoma, Chydo, Chydorus*	*Macrocyclops. Moina, Daphnia, Alona*

Primary productivity is a term used to describe the rate at which plants and other photosynthetic organisms produce organic compounds in an ecosystem. Phytoplankton and zooplankton are used as food for the fish. So its necessity in the aquatic ecosystem is too much.It is essential to use the vast knowledge accumulated on the ecology of phytoplankton and zooplankton communities in the rivers for the ecosystem management aimed at improving the water quality and conservation of natural biological diversity in the ecosystems.

According toMonjurul *et al*. (2017), a total 41 genera of 6 groups of phytoplankton and 31 genera of 4 zooplankton groups were identified in the Meghna river.Arauzo (2003) studied that during phytoplankton blooms in the stratification periods high un-ionized ammonia content values, due to an intense photosynthetic activity and high related pH lead to a decrease in zooplankton and thus to collapse of the treatment process efficiency.According toHonggang (2012), a total of 37 major zooplankton taxonomic group were identified of which 32 and 23 were recorded during monsoon and post-monsoon season in the Meghna river. In accordance with Shah (1997), a total of 27 genera of phytoplankton belong to Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae in Galachipa river. Ivanova *et al.* (2006) found that a total 11 genera of zooplankton such as Rotifera (5 genera), Crustacea (1 genus), Cladocera (3 genera) and Copepoda (2 genera) in the Laukhati river of Patuakhali district.

In the present study, phytoplankton and zooplankton families with genus composition were observed during the study period. A total 41 genera of 7 groups of phytoplankton and 31 genera of 4 zooplankton groups were identified. This finding is similar to the, Monjurul *et al*. (2017). The highest number of genera was found in the family Cholorophyceae followed by the family Dinophyceae and the lowest in Euglenophyceae among the recorded seven phytoplankton family. Copepods and cladocera were found to be the biggest family in terms of genera among recorded four zooplankton family.

11.13.7 Plankton in the Padma river

A total of 7 groups including 41 genera were of Phytoplankton and 4 groups including 31 genera of zooplankton recorded. Phytoplankton belonged to Bacillariophyceae, Dinophyceae, Cyanophyceae, Dinophyceae, Chlorophyceae, Myxophyceae, Euglenophyceae (Table 24) while zooplankton including, Rotifera, Copepoda, Cladocera and Ostracoda (Table 25). The highest and lowest number of phytoplankton was recorded from groups Chlorophyceae (12) and Euglenophyceae (1) whereas the number of zooplankton groups, Rotifera (9) and Cladocera (4), respectively in the Padma river (Table 24 and Table 25).

Table 24. List of phytoplankton collected from the Padma river

Group	Genus
Bacillariophyceae	*Amphora, Anomoeoneis, Asterionella, Bacillaria, Coscinodiscus, Cyclotella, Diatoma, Fragillaria, Gomphonema, Gyrosigma, Melosira, Navicula, Nitzschia, Pleorosigma, Rhizosolenia, Surirella, Synedra, Tabellaria, Triceratium*
Chlorophyceae	*Actinastrus, Ankistrodesmus, Botryococcus, Chlorella, Closterium, Coelastrum, Micractinium, Microspora, Muogeotia, Oedogonium, Oocystis, Palmella, Pediastrum, Pleorococcus, Scenedesmus, Selenestrum, Spirogyra, Staurastrum, Stichococcus, Synedra, Tetraedron, Ulothrix, Uroglena, Volvox, Zygnema*
Cyanophyceae	*Anabaena, Aphanizomenon, Aphanocapsa, Chroococcus, Gomphosphaeria, Merismopedium, Microcystis, Nostoc, Oscillatoria, Polycistis, Spirulina*

Euglenophyceae	*Euglena, Phacus*
Xanthophyceae	*Botrydium, Tribonema*
Dinophyceae	*Ceratium*

Table 25. List of zooplankton collected from the Padma river

Group	Genus
Rotifera	*Anuraeopsis, Asplanchna, Brachionus, Filinia, Hexarthra, Keratella, Polyarthra, Trichocerca*
Copepoda	*Cyclops, Diaptomus, Laptodora, Mesocyclops, Naupleus*
Cladocera	*Bosmina, Diaphanosoma, Daphnia, Moina, Sida*

11.13.8 Plankton in Kishoreganj haor region

In the present study, a total of 23 species of phytoplankton were identified under 4 group. A total 8 species of Bacillariaophyceae, 9 species of Chlorophyceae, 3 species of Cyanophyceae and 3 species of Euglenophyceae group were listed from the study area (Table 26). Bacillariaophyceae is the most common group in the study area. Bacillariaophyceae group consisted of 8 species including *Navicula* sp*., Gyrosigma* sp*., Nitzschia* sp*., Synedra* sp*., Cyclotella* sp*., Bacillaria* sp*., Rhizosolenia* sp*.* and *Chaetoceros* sp*.* The species abundance was higher in wet season than dry season. Only 8 species was found in wet season and 5 species was found in dry season including *Navicula* sp*., Gyrosigma* sp*., Nitzschia* sp*., Synedra* sp*.* and *Bacillaria* sp*.* Chlorophyceae is the dominant group in the study area. Total 9 species was found under Chlorophyceae group including *Spirogyra* sp*., Ulothrix* sp*., Volvox* sp*., Spirulina* sp*., Chlorella* sp*., Coleochaete* sp*., Microspora* sp*., Melosira* sp*.* and *Cosmarium* sp. Species richness is higher in wet season than dry season. Only 3 species were found in dry season including *Spirogyra* sp*., Ulothrix* sp*., Volvox* sp*.* Only 3 species (*Oscillatoria* sp., *Anabaeca* sp., *and Microcystis* sp.) were found in wet season and 1 species (*Oscillatoria* sp.) was found in dry season in the study area. A total 3 species (*Euglena* sp., *Phacus* sp. and *Trachelomonas* sp.) under Euglenophyceae group were found in the study area. But in the dry season, 2 species were listed from the study area.

In the study area, a total 3 groups of zooplankton were identified, i.e. Rotifera, Cladocera and Copepoda in Kishoreganj haor region. A total 5 known species of Rotifera, 4 species of Copepoda and 4 species of Cladocera were identified during the study period in Kishoreganj haor region (Table 11.13.8.26). Rotifera was the most common and dominant group in the study area. A total 5 species of rotifera found in wet season consists of *Brachionus* sp., *Keratella* sp., *Filinia* sp., *Asplanchna* sp., and *Polyarthra* sp. But in dry season, only 2 species of rotifera were found during the study period. These are *Brachionus* sp., *Keratella* sp. A total 4 species of Cladocera were found in Kishoreganj haor region on wet season. These were *Moina* sp., *Daphnia* sp., *Bosmina* sp. and *Diaphanosoma* sp. In wet season, the Cladocera Zooplankton abundance was low in dry season. Only 2 species were found these were *Moina* sp., *Daphnia* sp. Copepoda was also common group in the study area. A total 4 species of Copepoda were found in the study period. This group composed of *Cyclops* sp., *Diaptomus* sp., *Macrocyclops* sp., and *Mesocyclops* sp. In wet season, species abundance was higher than dry season. Only 2 species (*Cyclops* sp. and *Diaptomus* sp.) of Copepoda were found during the study period.

Table 26. A list of plankton from Kishoreganj during study period

Plankton	Group	Wet season	Dry season
		Genera/species	**Genera/species**
Phytoplankton	Bacillariaophyceae	*Navicula* sp. *Gyrosigma* sp. *Nitzschia* sp. *Synedra* sp. *Cyclotella* sp. *Bacillaria* sp. *Rhizosolenia* sp. *Chaetoceros* sp.	*Navicula* sp. *Gyrosigma* sp. *Nitzschia* sp. *Synedra* sp. *Bacillaria* sp.
	Chlorophyceae	*Spirogyra* sp. *Ulothrix* sp. *Volvox* sp. *Spirulina* sp. *Chlorella* sp. *Coleochaete* sp. *Microspora* sp. *Melosira* sp. *Cosmarium* sp.	*Spirogyra* sp. *Ulothrix* sp. *Volvox* sp.
	Cyanophyceae	*Oscillatoria* sp. *Anabaeca* sp. *Microcystis* sp.	*Oscillatoria* sp.
	Euglenophyceae	*Euglena* sp. *Phacus* sp. *Trachelomonas* sp.	*Euglena* sp. *Phacus* sp.
Zooplankton	Rotifera	*Brachionus* sp. *Keratella* sp. *Filinia* sp. *Asplanchna* sp. *Polyarthra* sp.	*Brachionus* sp. *Keratella* sp.
	Cladocera	*Moina* sp. *Daphnia* sp. *Bosmina* sp. *Diaphanosoma* sp.	*Moina* sp. *Daphnia* sp.
	Copepoda	*Cyclops* sp. *Diaptomus* sp. *Macrocyclops* sp. *Mesocyclops* sp.	*Cyclops* sp. *Diaptomus* sp.

Source: **Study period, 2017-2018.**

Plankton plays an important role in the water of haor ecosystem as primary producer and it is an important source of food for the fish. Plankton growth, biomass and productivity are influenced by a myriad of related and unrelated factors. Nutrients, light and water temperature are often of prime importance. Phytoplankton and zooplankton abundance varies from one water system to another. Phytoplankton is an important primary producer and constitutes the basis of nutrient cycle of an ecosystem (Singh *et al.,* 2013). There are a number of reports that algal assemblage could be used as organism indicative of water quality (Mohapatra *et al.,* 2012). In the present study, a total 23 phytoplnakton genera under 4 groups was identified. Bacillariophyceae, Chlorophyceae were the dominant and common group in the present study area. Other recorded common genus were *Navicula* sp., *Gyrosigma* sp., *Nitzschia* sp., *Synedra* sp., *Cyclotella* sp., *Bacillaria* sp., *Rhizosolenia* sp., *Spirogyra* sp., *Ulothrix* sp., *Volvox* sp., and *Euglena* sp. Azher *et al.* (2006) listed 60 genera of phytoplankton in Kishoreganj haor region where Chlorophyceae was the most dominant group of phytoplankton respectively. Ahsan *et al*. (2012) listed a total 19 taxa (32.76%) of phytoplankton where Chlorophyceae (7 taxa) was the most dominant group in the Meghna river. This result is quite similar to the present study. In Kishoreganj haor region,*Nitzschia* sp., *Synedra* sp., and *Oscillatoria* sp. were found in wet and dry seasons. These species indicate the pollution of water in the study area (Singh *et al.,* 2013). In addition, *Microcystis* sp., and *Euglena* sp. were also found in the study area which indicate the eutrophic condition in the water body (Singh *et al.,* 2013). However, the condition is quiet contradictory under both polluted and unpolluted water bodies while unpolluted water bodies supports great deal of algal diversity, polluted water support just a few tolerant organisms with one or two being the dominant form (Rai *et al.,* 2008).

Zooplanktons are minute aquatic organisms that are non-motile or are very weak swimmers. Although zooplankton do not depend directly on nutrients to survive, and are affected by the quantity and quality of algae, bacteria and detritus in a reservoir, its trophic state may influence the richness, structure, body size and productivity of this community. They play important role in food web by linking primary producers and higher trophic levels (Xu *et al.,* 2001). In the present study, a total 12 zooplankton genera under 3 groups were identified. Rotifera (*Brachionus* sp., *Keratella* sp., *Filinia* sp., *Asplanchna* sp., and *Polyarthra* sp.) was the dominant group in the present study area. Rotifera was represented by highest number of genera and species. Other recorded common species were *Brachionus* sp., *Keratella* sp., *Moina* sp., *Daphnia* sp., *Bosmina* sp., and *Cyclops* sp. in the present study area under group. Ahmed *et al.* (2003) was also found also quite similar results mentioned 13 zooplankton genera in the Meghna river. Azher *et al.* (2006) listed 15 genera (*Daphnia* sp., *Ceriodaphnia* sp., *Diaphanosoma* sp., *Bosmina* sp., *Moina* sp., *Cyclops* sp., *Diaptomus* sp., *Brachionus* sp., *Keratella* sp., *Filinia* sp., *Tiichocera* sp., *Filinia* sp., *Lecane* sp., *Lecane* sp. *and Polyarthra* sp.) of zooplankton in Kishoreganj haor region where Copepoda was the most dominant group of zooplankton. In the present study, *Moina* sp. and *Cyclops* sp. were also found in both dry and wet season which indicate the pollution of water body in the Kishoreganj haor region (Jha and Barat, 2003).The variation of species number and differences of total zooplankton in two geographical locations were `acceptable as they may be influenced by environmental factors of the water bodies. The distribution and abundance of plankton in Kishoreganj haor region are greatly influenced by the ecological characteristics. The physio-chemical parameters of water have positive or negative correlation with the abundance, diversity and distribution of plankton. In Kishoreganj haor region, plankton diversity and abundance are dramatically reduce by temperature rising and changing water quality parameters.

11.3.9 Plankton abundance in the Bay of Bengal

Among the collected sample of the Bay of Bengal, 32 species of phytoplankton and 23 species of zooplankton were identified (Table 27). Bacillariophyceae was represented by 20 species which is the highest number. Among zooplankton, Maxillopoda was represented by 14 species which is the highest number.

Table 27. List of phytoplankton and zooplankton in the Bay of Bengals

Phytoplankton		Zooplankton	
Class	**Species**	**Class**	**Species**
Chlorophyceae	*Oocystis pusilla* *Uronema sp.* *Echinosphaerella limnetica*	**Malacostraca**	*Mesopodopsis sp.* *Scylla sereta* (Crab larvae)
		Crustacea	*Penaeus indicus* *Acetes spp.* *Metapenaeus spp.*
Euglenophyceae	*Euglena spathirhyncha*	**Monogononta**	*Brachionus sp*
Bacillariophyceae	*Actinocyclusspp.* *Asteromphalus spp.* *Bacteriastrum comosum* *Bacteriastrum delicatulum* *Cerataulina spp.* *Chaetoceros spp.* *Coscinodiscus excentricus* *Coscinodiscus lineatus* *Coscinodiscus granii* *Coscinodiscus marginatus* *Coscinodiscus jonesianus* *Cyclotella comta* *Dactyliosolen spp.* *Ethmodiscusspp.* *Hemiaulus spp.* *Navicula spp.* *Nitzschiaspp.* *Pseudosolenia sp.* *Rhizosolenia spp.* *Thalassionema spp.*	**Maxillopoda**	*Acartia sp.* *Candacia catula* *Paracandacia sp.* *Mesocyclops sp.* *Calanopia minor* *Centropages sp.* *Mysidella* sp *Diaptomus* sp. *Calanus sp.* *Cyclops* sp. *Oithona sp.* *Paracalanus sp.* *Pseudocalanus sp.* *Paracartia sp.*
Cyanophyceae	*Calothrix crustacea* *Chroococcus dispersus* *Gloeotrichia pisum* *Microcustis spp.*	**Branchiopoda**	*Bosmina sp.* *Praunus sp.* *Daphnia sp*
Zygnematophyceae	*Gonatozygon aculeatum* *Gonatozygon brebissonii*		
Rhizosoleniaceae	*Rhizosolenia sp*		
Xanthophyceae	*Centritractus belanophorus*		

11.14 Livelihood of fishers in climate hotspot zones

11.14.1 Observations by fishers of changes in weather and climate in the Sundarbans region

Under this observation eight sub-categories were taken to evaluate the changes in weather and climate in the Sundarbans region (Figure 16). Hundred percent fishers agreed that increased air temperature, increased thunder storm and increased extreme weather events are the most frequently occurred. All three of these subcategories are reported more frequently in the Sundarbans zone considered as extremely high events (rank-5). Besides, changes in rainfall patterns and changes in weather patterns/seasonality are also often observed in this area frequently by fishers. Decreased rainfall and changes in weather patterns/seasonality in Sundarbans were agreed by 87.4% and 87.3% fishers, respectively. It is also considered as extremely high events (rank-5). Water temperature also increases due to increased air temperature and 58.6% fishers agreed with it.

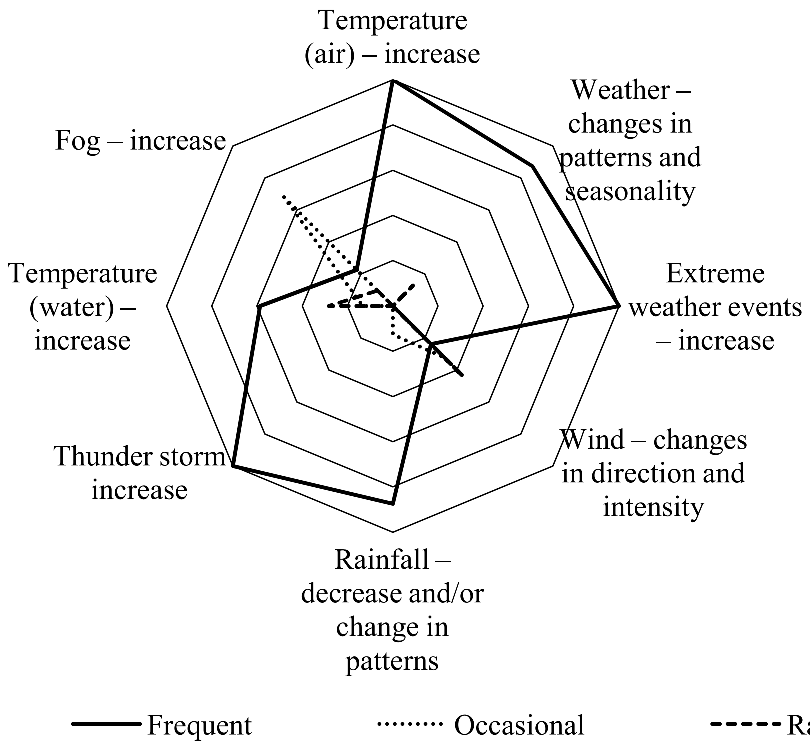

Figure 16: Observations by fishers of changes in weather and climate in the Sundarbans region by frequency and rank

Water temperature is an important sub-category in fisheries sector and it was also considered as moderately high events (rank-3). On the other hand, many fishers didn't able to provide information about wind direction and intensity changes. The direction and intensity changes of wind were accepted by 44% fishers and it ranked as occasional event (rank-2). Fog is another important sub-category during winter season in the study area which is also influenced by climate change. Fog is considered as occasional event (rank-2) also and 68% fishers admitted it (Figure 16).

11.14.2 Observations by fishers of changes in the physical components of the environment in the Sundarbans region

Under this observation seven sub-categories were taken to evaluate the impacts due to climate change on physical components in environment of fishers (Figure 17). Increased soil erosion is occurred occasionally in environment of most of the fisher communities and 57.1% fishers explicit that. Increased soil erosion is deliberated as rare event (rank-1) in most of the area of fishers´ communities. Soil erosion mainly depends on the upstream river water flow. But river freshwater flows were gradually decreased, and it was disclosed by 100% fishers. Therefore, decreased river freshwater flow is apprehended as extremely high event (rank-5).

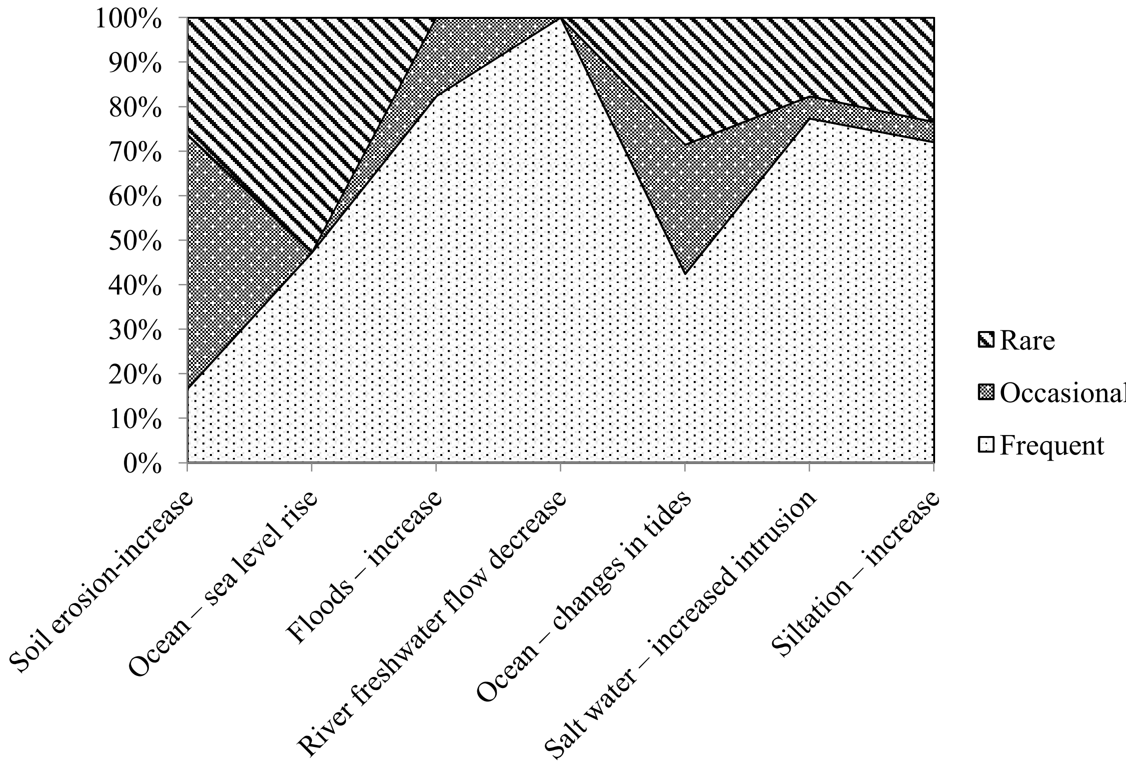

Figure 17: Observations by fishers of changes in the physical components of the environmentof fishers' community in the Sundarbans region by frequency and rank

Decreased upstream freshwater flow were the main reason to introduced high rate saline water in these area. In this study, it was found that the rate of saline water intrusion was gradually increased. The saline water intrusion was agreed by 77.3% fishers. Therefore, salt water intrusion is considered as high event (rank-4). The others reasons of salt water intrusion were sea level rising and ocean tidal effects. The sea level rising was admitted by 57.8% fishers and it is deliberated as moderately high event (rank-3). On the other hand, ocean tidal effects were frequent problem to 42.4% fishers in their communities. Therefore, it is apprehended as moderately high event (rank-3). Siltation is another serious problem which mainly occurred due to low rate of freshwater flow from upstream. Siltation problem was agreed by 72% fishers and it is considered as high event (rank-4). Flood is also increased by high rate of siltation in rivers and rivers mouth. Flood problem was faced by 82.3% fishers frequently in their communities. Therefore, increased flood is deliberated as extremely high event (rank-5) in present time (Figure 17).

11.14.3 Impacts of climate change on well-being of fishers (women and children) in the Sundarbans region

Under this observation, 15 sub-categories were taken to evaluate the impacts of climate change on social well-being of fishers specially women and children (Figure 18). All fisher communities were located more or less in unfavorable environment which is created by climate change. But this unfavorable environmental condition was frequently faced by 66.1% fishers. Unfavorable environmental condition is considered as high event (rank-4). To live in the unfavorable environment, social well-being of fishers were affected by several problems namely disease, lack of drinking water, malnutrition, sanitary problem, electricity, lack of food and cloths and lack of proper treatment etc. Among them disease is rapidly occurred and considered as the serious problem. Disease is frequently expanded in their communities and 87.3% fishers´ are agreed with this problem. Disease is considered as extremely high event (rank-5). Besides, proper treatment is rarely got by fishers and 67% fishers agreed that. Only 11.3% fishers are able to get proper treatment and it is deliberated as rare event. Disease was rapidly happened due to lack of drinking water, sanitary, malnutrition problems etc. Most of the fishers didn't have facilities to get pure drinking water that's why 91.2 % fisher families were frequently suffering this serious problem. Lack of drinking water is apprehended as extremely high event (rank-5). Another major issue is the sanitary problem in the study area. This problem is frequently faced by 63.6% fisher families.Sanitary problem is considered as high event (rank-4). Malnutrition problem is also influence the occurrence of disease. Most of the children and women didn't get proper nutrition. Malnutrition problem is suffered by 77.4% fisher families. Therefore, it is considered as high event (rank-4). Education qualification of fisher families is very less in the study area. Education facilities are frequently got by only 22.7% fishers' family. Illiterate and primary level dropped fisher families are 70.7% and 13.6%, respectively. These illiterate fisher communities didn't aware of the disadvantage of early marriage. High rate of early marriage was occurred in the study area. Before 18 years old, 82.3% women forcefully got married. Early marriage is discriminated as extremely high event (rank-5) in the study area.

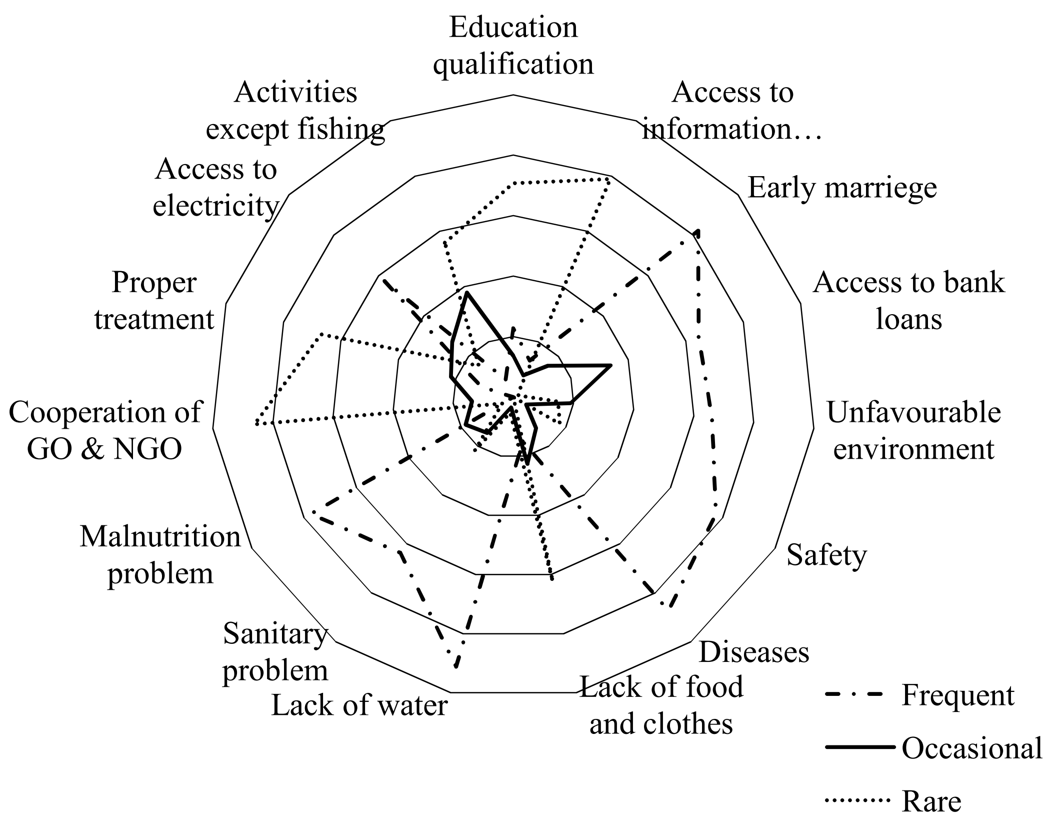

Figure 18: Observations by fishers of changesof well-being of fishers (especially women and children**)** in fishers' community by frequency and rank

Due to lack of educational qualification, most of the fishers didn't move to any other activities from fishing and 55.8% fishers admitted that. Only 6.4% fishers were got the chance to move other activities from fishing. During banned seasons, some other activities related to fisheries such as making nets and traps, making and repairing boats have done by 37.8% fishers. But most of the fishers (64.4%) who didn't have facilities to do any other activities during banned seasons, they took loan frequently from Mohajan, agencies and banks to maintain their livelihood. Any kinds of help from Govt. and NGOs didn't reach to 86.2% fishers in the study areas. Therefore, information and training was not accessed by 78.9% fishers to become well in their profession. Although, Govt. was take proper step to ensure electricity and safety in most of the study area. Electricity and safety facilities from Govt. are enjoying 57.4% and 77.4% fishers, respectively (Figure 18).

11.14.4 Observations by fishers of changes in fisheries resources in the Sundarbans region

Under this observation, 11 sub-categories were taken to evaluate the impacts of climate change on fisheries in the study area (Figure 19).

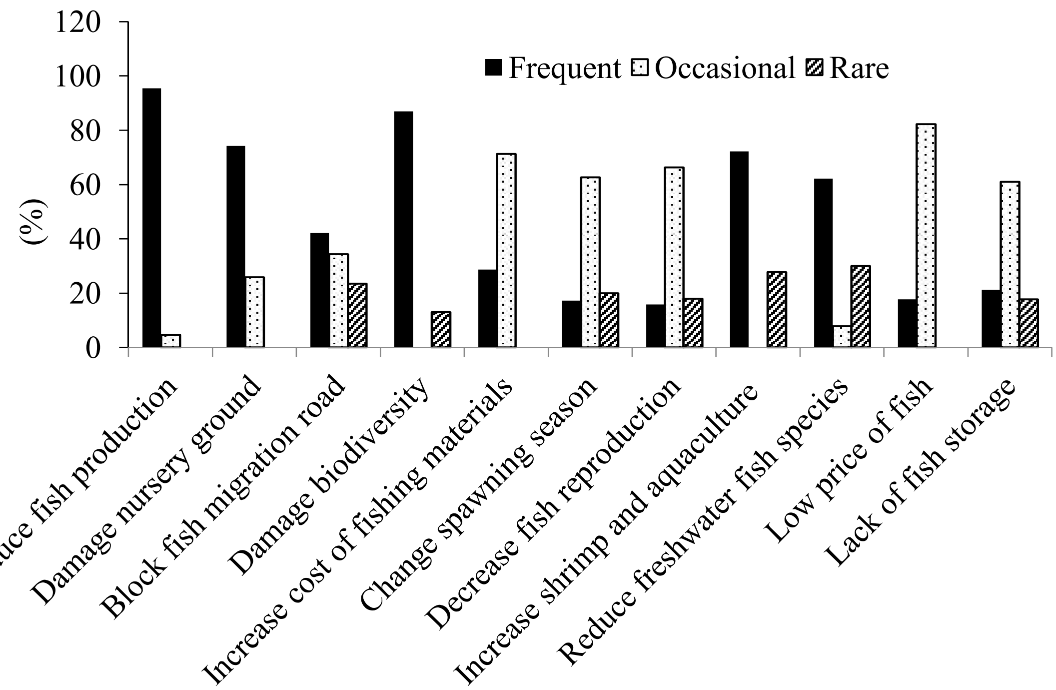

Figure 19: Observations by fishers of changesin fisheries of the Sundarbans region by frequency and rank.

Fish production is immensely reduced in the rivers of the Sundarbans and 95.4% fishers admitted it. Most of the fishers didn't get enough fish like they captured before. Besides, some of the species of the Sundarbans are not available in rivers. Fish biodiversity is also hampered. At 87% of records of fishers´ opinion, fish biodiversity is also damaged. Among them, freshwater fish species are mainly damaged than others. The biodiversity, abundance and production of most of the freshwater species are greatly reduced and 62.2% fishers agreed that. Fish production in the Sundarbans is reduced due to the destruction of nursery ground, changing spawning season, blocked fish migration route etc. In accordance with 74.2% of records of fishers´, nursery ground is gradually damaged in rivers of the Sundarbans. Rivers are used as migration route for migratory fish species. But in accordance with the counsel of 42.1% fishers´, these migration routes are blocked with small mesh sized nets. In case of few fishes, spawning seasons are also slightly changed which is confirmed by only 17.3% fishers. But according to most of the fishers (62.7%) spawning seasons are changed occasionally. Besides, fish reproduction is decreased occasionally due to destruction of spawning ground and unfavorable water quality. Therefore, peoples constructed lots of polder in most of the study area to expand Shrimp and aquaculture. Shrimp and aquaculture is increased near of communities of 72.2% fishers. On the other hand, fish storage was not enough in local areas. Fishing materials cost is increased occasionally in a year. But fish price in market was good according to most of the fishers (82.3%). Sometimes, fish price is reduced in local market in the study areas (Figure 19).

Fishers' observations of changes in the physical components of the environment are frequently occurred in the study area. Fishers most often report three linked phenomena in the physical environment category: decreased river freshwater flow (22.9% of records of the physical environment observations), increased salt water intrusion (17.7% of records of the physical environment observations) and increased siltation (16.5% of records of the weather and climate change observations). Salt water intrusion was the crucial problem occurred frequently in study area. Fishers relate increased salt water intrusion and siltation to decreased freshwater flow, but also to concurrent phenomena such as higher tides (9.7% of records of the physical environment observations), more frequent storm surges and increased sea level rise (10.8% of records of the physical environment observations) in Sundarbans. According to Wahid *et al.* (2007) the freshwater flow has declined almost by 60% since 1973 due to the construction of the Farakka Barrage on the Ganges in India has silted up most of its distributaries in Bangladesh and impacted the carrying capacities of rivers in Sundarbans. As a result the dry season as well as the wet season flow of freshwater in many of these rivers is reduced.Soil erosion (3.4% of records of the physical environment observations) also took place due to sea level rise, floods (18.8% of records of the physical environment observations) and also to concurrent phenomena such as higher tides, more frequent storm surges. Fishers understand that floods are exacerbated by changing weather patterns that produce more frequent heavy rainfall events, increased siltation in river (Logavatu, 2011; Mataki e*t al.,* 2006; Vlassova, 2006). All of these physical changes can make fishing more challenging and lead to loss of land/property, loss of coastal vegetation and reduced access to freshwater (Barnett and Adger, 2003). Indeed, a reduction in fresh water availability often combined with saltwater intrusion into local groundwater sources.

Climate change mainly hampered on environmental condition of fisher communities in the study area. Fishers lived in unfavorable environment (9% of records of impacts of climate change on well-being) and continued their life with various problems e.g., lack of drinking water (12.4% of records of impacts of climate change on well-being), malnutrition (10.5% of records of impacts of climate change on well-being), sanitary problem (8.6% of records of impacts of climate change on well-being), electricity (3.1% of records of impacts of climate change on well-being), lack of food and cloths (2.1% of records of impacts of climate change on well-being) and lack of proper treatment (13.3% of records of impacts of climate change on well-being). Drinking water was not available in the fisher communities. Rain's or pond's water was drunk by most of the fisher families. Few fishers have tubewall facilities in their communities achieved by Govt. But ground freshwater level was gradually reduced due to increased salinity intrusion. Sanitary was another big issue in the study area. Few fishers have their own well facilitated sanitary system. But most of the fishers used unhealthy sanitary and some used river bank also. Children and women of the communities were suffered by malnutrition problem due to lack of nutrient foods. As a result, several diseases (11.7% of records of impacts of climate change on well-being) such as skin related diseases, waterborne diseases, malnutrition disorders etc. were frequently happened in the communities. Some fishers' communities were also observed health effects, such as skin rashes, burns and waterborne diseases, especially after extreme events such as floods and hurricanes found by Furgal and Seguin (2006). These observations, even if not numerous, support the research of Patz *et al.* (2005), which suggests an increase in some diseases due to climate change. Because of reduction of fish production, fishers didn't earn enough money to maintain properly their family. As a result, most of the fishers took huge amounts of loan with 5-7% interest per month from local money lender to maintain their family during banned seasons and to release fishers from pirates of the Sundarbans. They didn't get enough economic help from govt. and non-govt. organization. In fact, they didn't have scope to move others activities due to their illiteracy. In that case, women became burden in the fishers' community and the community took early marriage as their solution which is the alarming problem of society.

Compering of the observations of fishers with previous study, it is clear that the production of fish (17.9% of records of changes in fisheries) was greatly reduced and the biodiversity (16.3% of records of changes in fisheries) was also damaged. Fishes were affected by elevated water salinity, pH, temperature and DO (Moyle and Cech, 2004). Freshwater fish diversity and production mainly hampered than others due to increase the rate of salinity intrusion. Most of the freshwater aquatic habitats in Sundarbans regions were altered into saline environment which was the reason for reduced freshwater fish species (11.7% of records of changes in fisheries). Marsh and intertidal habitat of estuarine and coastal systems are lost due to change in water circulation and ocean water volum and greater marine intrusion which cause to increased eutrophication, hypoxia, and anoxia (Officer *et al.,* 1984; Kennedy, 1990) Most of the areas in northern side of Sundarbans were converted into Shrimp and aquaculture (13.5% of records of changes in fisheries) farms for some selective species through making folder to retained saline water. Different types of fish fry were destroyed by small mesh sized nets during collecting fry of Shrimp for culture from wild sources. Besides, fish fry was also destroyed due to blocking fish migration route (7.9% of records of changes in fisheries) by small mesh sized nets in the rivers in different place. Fish migration route was also blocked due to siltation in the rivers. The Sundarbans is considered as nursery (13.9% of records of changes in fisheries) and spawning ground (3.3% of records of changes in fisheries) for many fish and crustacean. But these important grounds were hampered due to change of water qualities especially salinity. As a result fish reproduction (3% of records of changes in fisheries) rate and survival rate was gradually reduced. Climate change related influences have significant impacts on fishes and their populations (Roessig *et al.*, 2004).

11.14.5 Religion and age structure of fishers in Chandpur and Patuakhali

About 75% and 25% of the fishers were Muslims and Hindus respectively. Different categories of age groups: young (20-30 years), middle aged (31-40 years) and old (41-60 years) were considered to examine the age structure. It appeared (Figure 16) that age group of 41-60 years was the highest (45%) and 20-30 years was the lowest (23%) considering all fishers (Figure 20).

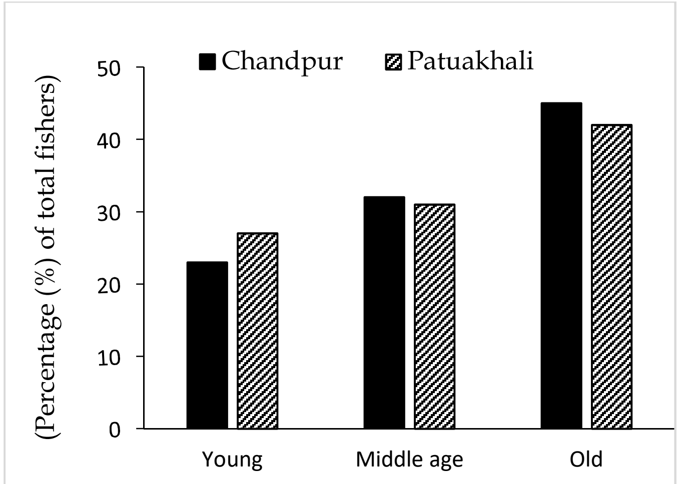

Figure 20: Age structure of fishers in the study areas

11.14.6 Family size and type of fishers in Chandpur and Patuakhali

In the present study, families were classified into two types as nuclear family and joint family. About 61% of fishers lived in joint families and 39% in nuclear families at Chandpur Sadar Upazila and Dashpara near Meghna River. On the contrary, about 84% of fishermen lived in joint families and 16% in nuclear families at Patuakhali Sadar and Dashmina Upazila near Laukhati and Galachipa River (Figure 21).

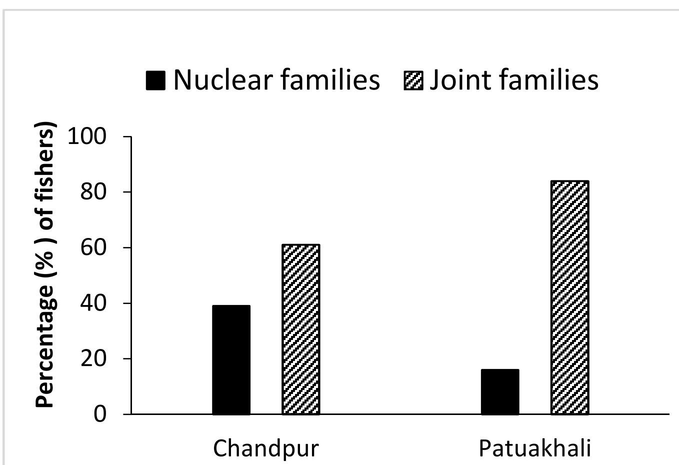

Figure 21: Family size and type of fishers in the study areas

11.14.7 Educational level of fishers in Chandpur and Patuakhali

Fishers were categorized into five categories on the basis of the level of education. Out of 100 fishermen, 12% had no education, 24% had primary level, 40% had secondary level, 17% had higher secondary level and 7% had bachelor level of education at Chandpur. On the contrary, 17% had no education, 45% had primary level, 30% secondary level, 5% higher secondary and 3% bachelor at Patuakhali (Figure 22).

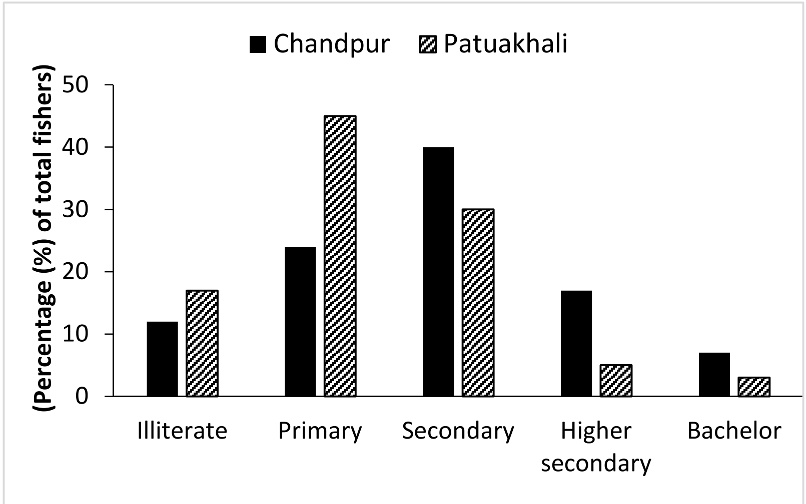

Figure 22: Educational level of fishers in the study areas

11.14.8 Natural and financial capital of fishers in Chandpur and Patuakhali

Natural capital of fishers involved in fishing represent the natural resources such as land, open water, fish availability, soil type, and wider environmental goods that are critical for fishers and associated groups to support production. Large areas of land, water and natural resources had been used for high fish production. Rapid population growth had to some extent led to accelerate natural capital depletion that had affected their income. The existence of floodplains, lack of food (both phytoplankton and zooplankton) in the vicinity of the study area offer tremendous scope for harnessing natural resources for sustainable livelihood management of the fishing community.It was found that 41% received loan from different NGOs, 32% of the fishers used their own money for fishing, 17% borrow from relatives and 10% of the fishers borrow from neighbors at Chandpur and 38% received loan from different NGOs, 29% self-dependent, 21% from relatives, 12% from neighbors at Patuakhali region (Figure 23).

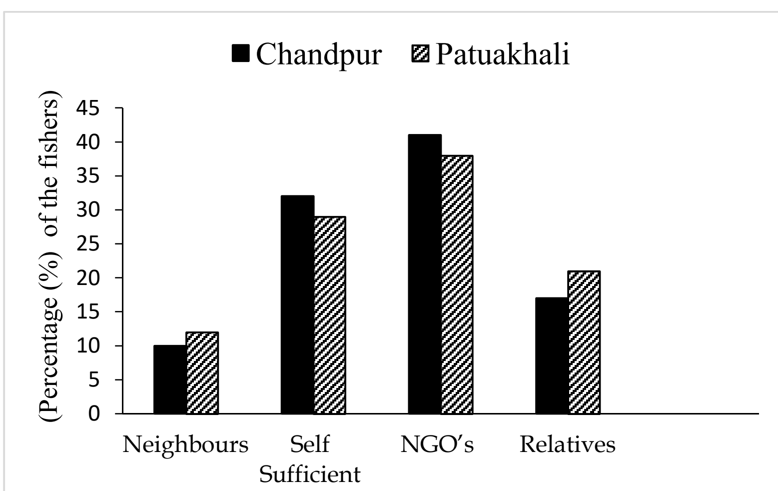

Figure 23: Credit access of the fishers in the study areas of Chandpur and Patuakhali

11.14.9 Annual income of fishers in Chandpur and Patuakhali

TheAnnual income of fishers was varied from 20,000 to 100000 BDT. The selected fishers were grouped into four categories based on the level of their annual income (Table 28). The highest percentage (44%) fishers earned BDT 20,080 to 24,000 per year at Chandpur and 46% at Patuakhali (Table 28).

Table 28. Annual incomes of fishers in the study area of Chandpur and Patuakhali

Annual Incomes (USD)	Chandpur	Patuakhali
Up to 250	25	23
251-300	44	46
301-375	21	16
> 625	10	15
(1 USD @ 80 BDT)		

11.14.10 Housing of fishers in the study area of Chandpur and Patuakhali

The nature of house indicates the social status of the people. During the survey, endeavors were made to find out the condition of living house of the people. Thodar matha and Dashpara was not developed as like as the main town of Chandpur district, so most of the house of fishers (74%) was made of tin-shed. 19% half cemented building and 7% cemented building. On the contrary, 76% was made of tin-shed, 20% half cemented building and 4% was cemented building at Patuakhali (Figure 24).

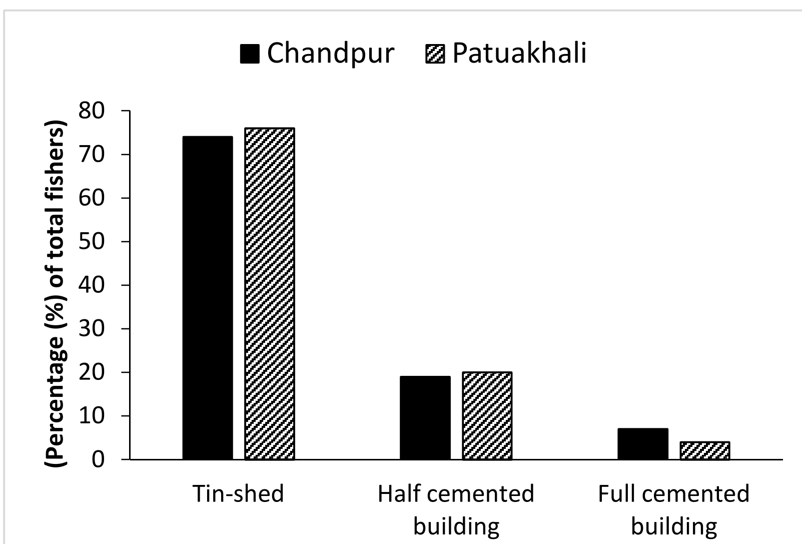

Figure 24: Housing condition of fishers in the study areas of Chandpur and Patuakhali

11.14.11 Health facilities of fishers in the study area of Chandpur and Patuakhali

Health facilities of the fishers were poor and it was found that 57% of the fishers were dependent on Upazila health complex, 27% on village doctors and 16% on MBBS (Bachelor of Medicine, Bachelor of Surgery) doctors respectively at Dashpara and Thodar matha at Chandpur while 46% on upazila health complex, 45% on village doctor and 9% on MBBS doctor at Dashmina and Galachipa region at Patuakhali (Figure 25).

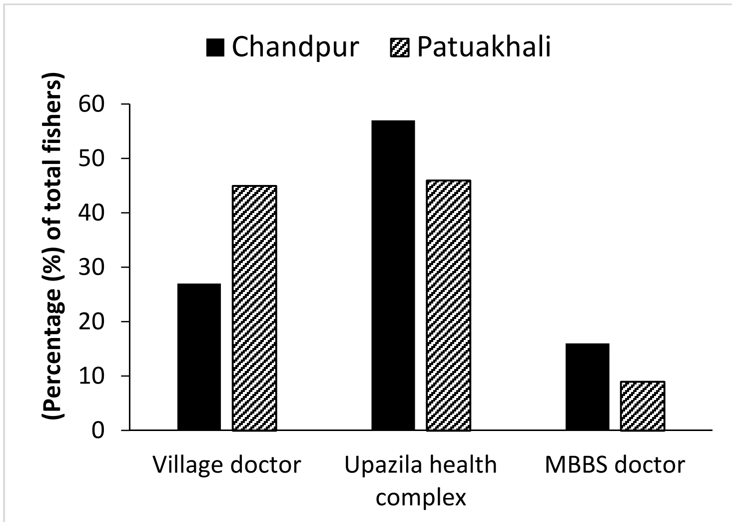

Figure 25: Health facilities of fishers in the study areasof Chandpur and Patuakhali

11.14.12 Drinking water sources in the study areas of Chandpur and Patuakhali

The provision of clean and safe drinking water is considered to be the most valued element in the society. The study showed that 87% of the fishers used tube-well water for drinking purposes, about 13% depend on river water at Chandpur Sadar Upazila while 91% depends on tube-well and 9% on river at Dashmina upazila of Patuakhali (Table 29).

Table 29. Drinking water sources in the study area of Chandpur and Patuakhali

Drinking watersources	Chandpur	Patuakhali
Tube well	87%	91%
River	13%	9%

11.14.13 Sanitary facilities in the study areaof Chandpur and Patuakhali

Two types of toilets were used semi-puccatoilet: made of tin or wood with inadequate drainage disposal and puccatoilet: made of brick with good drainage disposal. It was found that 59%, 13%, 21% and 7% of fishers used semi-pucca, Kacha, pucca and opentoilet respectively at Chandpur where as 52%, 26%, 16% and 6% at Patuakhali region (Figure 26).

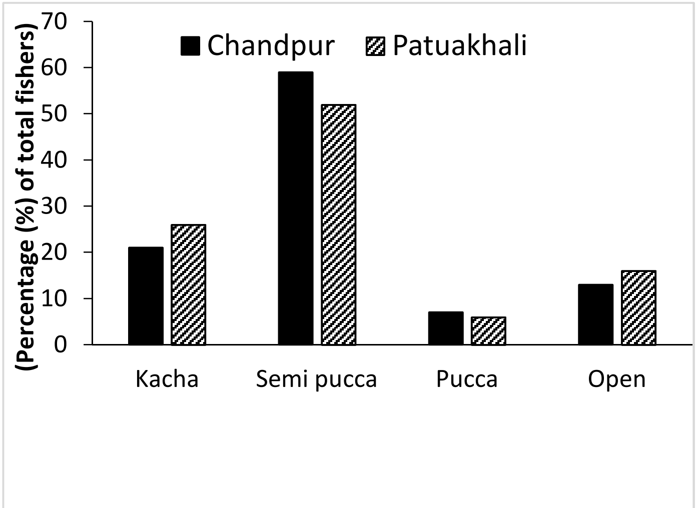

Figure 26: Sanitary facilities of fishers in the study areas of Chandpur and Patuakhali

11.14.14 Fishers´ comments about the present condition of the Meghna, Laukhati and Galachipa rivers

Most of the fishers go for fishing in the river 10-12 km away from their residences. For this reason, they go as a team of partnership mostly. Generally, they go twice a day for fishing. But, at the time of day of the new moon and night of the full moon they go 3-4 times for fishing because in this time the amount of fishes intensified. They have been doing this work since 20-30 years. Therefore, they have mammoth experience about the wave pattern, flow of water, high tide, low tide, the abundance of fishes in the river and the extinction of the fish species in the river. By the following table it is seen that the condition of river is at now vulnerable condition in a great extent. Fishers said that the price of fish is not good enough to do well their socio-economic condition. Fishing zones are altering and 93% fishermen were saying that fishing zones are altering and only 7% were responding negatively (Table 30). They also said about the decreases of water in river and amount of fish in river.

Table 30. Comments of fishers about the Meghna, Laukhati and Galachipa rivers

Results	Choice of fish price (%)	Irregular change (%)	Fishing zone alter (%)	Are fish less amount in river? (%)	Decreases of water (%)
Yes	9	87	93	81	100
No	91	13	7	19	0

11.14.15 Fishers´ opinion on climatic effect of fish and their habitats in Chandpur and Patuakhali

Now-a-days climate is affecting severely on fisheries resources in the world. Especially in the present study area, fishers were estimated about the climate change and the amount of deleterious by different climatic factors. World temperature, inadequate rainfall, intrusion of salinity and other natural calamity are influencing extremely on the crucial fisheries resources. According to the fisher's opinion, Increased temperature (96.25%),increased cost of fishing materials (91.25%), reduced fish production (76.25%), intensify soil erosion (68.3%), block fish migration road (66.25%), damaged biodiversity (53.75%), change water flow level (51.25%), extinct fish species (48.75%), reduced rainfall (47.5%), and storm frequency (40%), on the contrary, disagreed fishermen were 1%, 3.1%, 12%, 12.9%, 17.3%, 43.75%, 23.8%, 13.7 %, 15.7% and 35.7%, respectively and no comments ranking were 2.75%, 5.65%, 11.25%, 18.8%, 16.45%, 2.5%, 24.75%, 37.55, 10.5% and 37%, respectively (Figure 27).

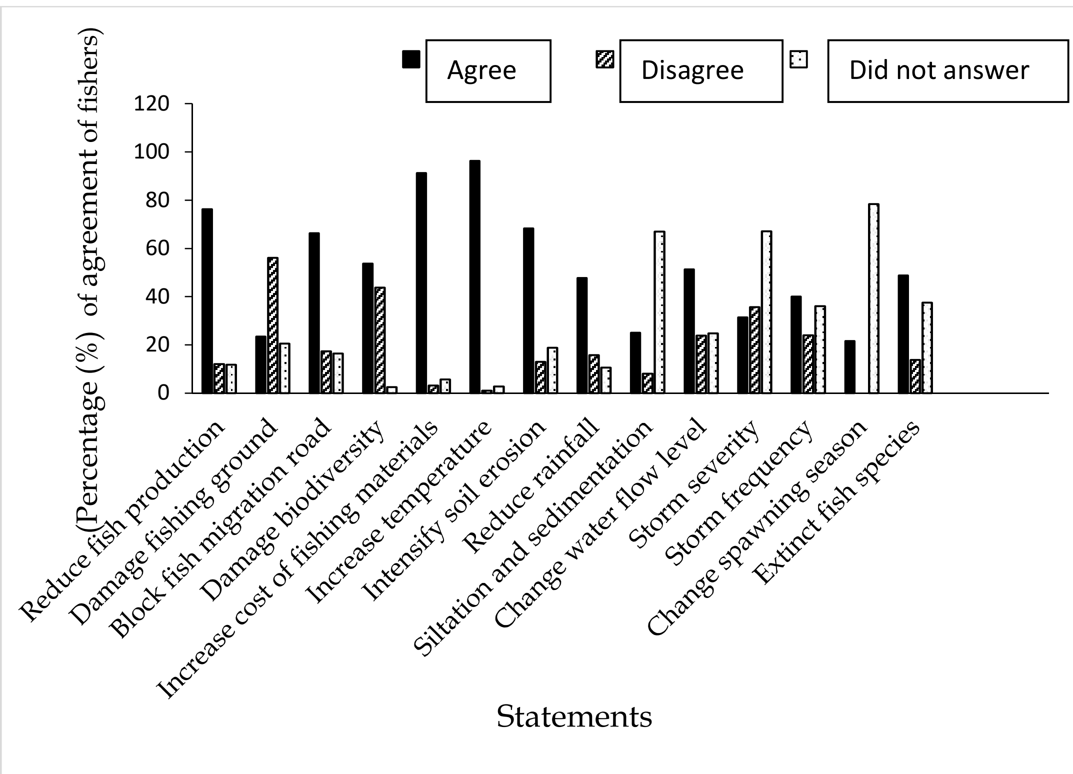

Figure 27: Agreement index regarding the impacts of climate change in Chandpur andPatuakahli

11.14.16 Impact of climate change on livelihood pattern by hazardous events in Chandpur andPatuakhali

Climate change creates numerous hazards event and these badly effect on livelihood patterns.The augmentation in frequency and intensity of natural disasters, i.e. floods and cyclones, has made it arduous for the fishermento secure their livelihood.According to fishermen’s perception, rainfall is increasing both in terms of amount and timing. Rainfall is ill-timed but increasing. The majority of the respondent replied that temperature has risen since few years.They felt that summer is being hotter as before.The key expert’s interviews and consultation workshops revealed that flood and cyclone affect fisheries severely while effects on other shocks such as drought, salinity intrusion, erratic rainfall, heat wave, cold wave, fogginess is low to moderate. This leads to loss of livelihoods of the poor fishermen and decrease nutrition status of the rural poor. Moreover, frequent warnings of cyclone lead the fishermen to stay at home for longer periods and thus their income decreased which increased their poverty level. Here, Leopold matrix is used to identify the impact of hazard events on livelihood patterns. Impact factors have been evaluated separately for each hazard event and relevant livelihood pattern, and scored on a scale from 0 to 4 for impact magnitude, according to the following scale: 0 – no observable effect; 1 – low effect; 2 – tolerable effect; 3 –high effect; 4-very high effect (devastation). From the Leopold matrix it can be said that, the impact of hazardous events on livelihood is tolerable (Table 31 and 32).

Table 31. Ranking of hazardous events at Dashmina and Patuakhali Sadar upazila

Hazard	Frequency and intensity priority (%)					Total frequency	Ranking
	Very high(4)	High(3)	Medium(2)	Low(1)	No(0)		
Flood	50	21	22	7	0	100	1
Cyclone	49	25	21	5	0	100	2
Storm surge	46	23	27	4	0	100	3
River Erosion	26	31	26	6	11	100	4
Temperature	21	45	21	9	4	100	5
Densely fog	11	24	41	19	5	100	6
Drought	2	6	5	40	47	100	7
High Tide	1	11	23	22	43	100	8

Table 32. Ranking of hazardous events at Sadar Upazila, Chandpur

Hazard	Frequency and intensity priority (%)					Total frequency	Ranking
	Very high(4)	High(3)	Medium(2)	Low(1)	No(0)		
Flood	57	21	15	7	0	100	1
Cyclone	54	22	19	5	0	100	2
Storm surge	51	27	18	4	0	100	3
Heavy Rainfall	26	34	23	6	11	100	4
Temperature	21	45	21	9	4	100	5
Extreme cold	5	15	45	17	18	100	6
Densely fog	4	31	41	19	5	100	7
Drought	2	8	5	38	47	100	8
High tide	1	14	20	22	43	100	9

11.14.17 Demographic information of the fishers in Louhajang, Munshiganj

The basic information of the fishers is represented in Table 33. It is seen that average household size of the fishers was 5.0 and average dependency ratio was 2.13 in fishers' community. In the study area, the average sex ratio of male and female were 56.67% and 43.33%, respectively. The age group of below 15 to 60 years which is considered as active and working group in the fishers' community and their religion ration were Islam 45% and Hindu 55%. Most of the fishers have nuclear family (60%) and few have joint family (40%). In the study area, most of fishers were illiterate (80.83%) and (12.5%) could put sign only. During study period, fishers are considered as permanent (65%) and temporary (35%) fishers. In fishers' community, the average children number was 3. Most of house was tin-shed house (86.4%) and drinking water source was tube well (100%). Most of the fishers were used semi hygienic sanitation type (92.40%), only 7.60% fishers were used unhygienic sanitation. The average fishing activity time was 12 hr/day and only 73.33% fishers' community get benefits of electricity (Table 33).

Table 33. Basic information about the fishers in Louhaganj, Munshiganj

Particulars		Percentages of fishers
Average household size (no.)		5.00
Average dependency ratio (no.)		2.13
Average sex distribution	Male	56.67
	Female	43.33
Average age	Below15.00 years	9.17
	15.01 to 30.00years	32.50
	30.01 to 45.00years	39.17
	45.01 to 60.00 years	19.17
Religion	Islam	45.00
	Hindu	55.00
Marital status	Unmarried	19.17
	Married	80.83
Family type	Nuclear family	60.00
	Joint family	40.00
Average children (no.)	Male	1.70
	Female	1.30
Literacy rate	Illiterate	70.83
	Sign only	12.50
	Primary and above	6.67
Occupational status	Fishing only (with licence)	34.17
	Fishing only (without licence)	36.67
	Fishing and others	39.17
Fishers type	Permanent	65.00
	Temporary	35.00
Housing condition	Muddy house	13.60
	Tin-shed	86.40
Source of drinking water	Pond	0.00
	Own tube well	46.00
	Others tube well	54.50
Sanitation type	Unhygienic	7.60
	Semi- hygienic	92.40
Average fishing time (hr/day)		12.00
Electricity facilities		73.33

11.14.18 Fishers' perceptions about the impact of climate change in Munshiganj

Fishers' perceptions about the impact of climate change on their day-to-day life were evaluated using agreement index (AI). Fishers observations were recorded on impact of climate change on 15 statements, and their depth of agreements on the selected statements were calculated consequently. Table 34 showed that 70% fishers of the study areas were agreed with the statements about reduce fish production, damage fishing ground, blockage of fish migration road, damage biodiversity, increasing temperature, enhance soil erosion, reduce rainfall, siltation, water flow, storm frequency, changing spawning season, decrease fish production, extinction fish species. However, 37.3% fishers were disagreed with the statements.

Table 34. Agreement index regarding the impacts of climate change

Statements	Fishers agreement		Weights
	Agreed	Disagreed	
Reduce fish production	84/120	36/120	1/15
Damage fishing ground	77/120	53/120	1/15
Blockage fish migration route	75/120	45/120	1/15
Damage biodiversity	81/120	39/120	1/15
Increase cost of fishing materials	86/120	34/120	1/15
Increase temperature	78/120	52/120	1/15
Enhance soil erosion	67/120	53/120	1/15
Reduce rainfall	77/120	43/120	1/15
Siltation and sedimentation	69/120	51/120	1/15
Change water flow level	76/120	49/120	1/15
Storm Severity	96/120	24/120	1/15
Storm frequency	86/120	34/120	1/15
Change spawning season	68/120	52/120	1/15
Decrease fish reproduction	87/120	33/120	1/15
Extinct fish species	80/120	40/120	1/15
Index score	0.627	0.373	-
Depth of agreement (%)	62.7	37.3	-

Source: Authors' estimation based on field survey, 2017-2018. (Modified from Uddin *et al.,* 2017).

Note: Calculation of index score for agreed opinions = (77/120 × 1/15) + (67/120 × 1/15) + (73/120 × 1/15) + (81/120 × 1/15) + (86/120 × 1/15) + (68/120 × 1/15) + (62/120 × 1/15) + (77/120 × 1/15) + (69/120 × 1/15) + (71/120 × 1/15) + (96/120 × 1/15) + (86/120 × 1/15) + (63/120 × 1/15) + (87/120 × 1/15) +80/120 × 1/15) = 0.627

Calculation of index score for disagreed opinions = (43/120 × 1/15) + (53/120 × 1/15) + (47/120 × 1/15) + (39/120 × 1/15) + (34/120 × 1/15) + (52/120 × 1/15)+ (58/120 × 1/15) + (43/120 × 1/15) + (51/120 × 1/15) + (49/120 × 1/15) + (24/120 × 1/15) + (34/120 × 1/15) + (57/120 × 1/15) + (33/120 × 1/15) + (40/120 × 1/15) = 0.373

Calculation of depth of agreement for agreed opinions = 0.627 × 100 = 62.7%

Calculation of depth of agreement for disagreed opinions = 0.373 × 100 = 37.3%

The climatic factors include rainfall and water, light, temperature, relative humidity, air, and wind. They are abiotic components, including topography and soil, of the environmental factors that influence plant growth and development. The two most important factors in the climate of an area are temperature and rainfall. The yearly maximum and minimum temperature of the area is obviously important. Some areas have a much larger range between highest and lowest temperature than other areas. Likewise, average rainfall is important, but the yearly variation in rainfall is also important. Some areas have about the same rainfall throughout the year. Other areas have very little rainfall for part of the year and a lot of rainfall for the other part of the year.

Rainfall is the most common form of precipitation. It is the falling of water in droplets on the surface of the Earth from clouds. Other forms of precipitation are freezing rain, sleet or ice pellets, snowfall, and hail (Eagleman, 1985; Miller, 2001). The amount and regularity of rainfall vary with location and climate types and affect the dominance of certain types of vegetation as well as crop growth and yield.

Light is a climatic factor that is essential in the production of chlorophyll and in photosynthesis, the process by which plants manufacture food in the form of sugar (carbohydrate).

The degree of hotness or coldness of a substance is called air temperature (Eagleman, 1985). It is commonly expressed in degree Celsius or centigrade (C) and degree Fahrenheit (F). This climatic factor influences all plant growth processes such as photosynthesis, respiration, transpiration, breaking of seed dormancy, seed germination, protein synthesis, and translocation. At high temperatures the translocation of photosynthetic is faster so that plants tend to mature earlier. Enzymatic activity and the rate of most chemical reactions generally increase with rise in temperature. Up to a certain point, there is doubling of enzymatic reaction with every 10 °C temperature increase (Mader, 1993). But at excessively high temperatures, denaturation of enzymes and other proteins occur temperature. Up to a certain point, there is doubling of enzymatic reaction with every 10 °C temperature increases. (Mader, 1993). But at excessively high temperatures, denaturation of enzymes and other proteins occur

Relative humidity, the amount of water vapor that the air can hold depends on its temperature; warm air has the capacity to hold more water vapor than cold air. According to Eagleman (1985), there is almost one-half reduction in the amount of water vapor that the air can hold for every 10 °C drop in temperature. Air movement or wind is due to the existence of pressure gradient on a global or local scale caused by differences in heating. On a global scale it consists of the jet stream flow and movement of large air masses. On the local scale only a smaller quantity of air moves. Surface winds are lower and less turbulent at night due to the absence of solar heating (Eagleman 1985).When air that is close to the ground cools, it contracts and the pressure rises; when it warms, it expands and loses pressure. Where both cold and warm air occur in proximity, as over a lake and its adjacent shore, the cold flows to the direction of the warm air or from high to low pressure area to correct the pressure imbalance. This also happens in tropical Asia but in a larger and more complex way, as the monsoon wind.

Fishers are actually most vulnerable to climate change because they live in areas more prone to flooding, cyclones, droughts etc., and have low capacity to adapt to such shocks. They are also more rely on ecosystem services and products for their livelihoods. Any impact that climate change has on natural systems therefore threatens the livelihoods, food intake and health of poor people. Loss of employment and impacts on assets are likely to diminish opportunities for education in several ways. In this aspect, many researchers have found many documents on fishermen who are living near coastal areas.

Ali *et al*. (2009) found that most of the fishermen (50%) belonged to livelihood status of the fishermen in some selected areas of Shahrasti Upazila of Chandpur district. The family size has considerable influence on the income and expenditure of the family. The reported literacy rate was found higher than the national adult literacy level of 65% Zaman *et al*.(2006) found that 23.3% fishermen were illiterate whereas 14.4%, 8.9% and 6.7% were educated up to primary, secondary and higher secondary or above level respectively. Quddus *et al*.(2000) found that, only 34% fishermen got bank loan for fishing while Majority (53%) of fishermen expend from their own sources. Small fishermen were found in disadvantageous situation due to poor financial resources for fishing and they did not have financial support from institutional credit.

According to Ali *et al*. (2014), most of the fishermen (60%) belong to age group of 31 to 40 years in Lohalia River, Patuakhali. Kabir *et al*. (2012) also found that 100% fishermen's household used tube-well water for drinking purposes, among them 40% had their own tube-well, 50% used shared tube-well and remaining 10% used neighbors tube-well in this area. The present findings of annual income of fishermen correspond well with the findings of Rahman *et al.* (2012) and in the health status, about 27% of the fishermen received health service from village doctors, 57% from upazila health complex and 16% from MBBS doctors at Sadar and Dashpara upazila at Chandpur where as 45%, 46% and 9% at Dashmina and Galachipa upazila of Patuakhali that is almost similar of Ali *et al*.(2008).In the present studythe highest percentage (44%) fishermen earned BDT 20,080 to 24,000 per year at Chandpur and 46% at Patuakhali. The reason of getting less income is the fish production in the rivers due to continuously impediment of various natural calamity, the change of water flow and low price of fish in the market in accordance with fishermen's opinion.

11.14.19 Demographic information of the fishers in Kishoreganj haor

The basic information of the fishers is represented in Table 11.14.19.35. It is seen that average household size of the fishers was 6.0 and average dependency ratio was 2.23 in fishers' community. In the study area, the average sex ratio of male and female were 76.67% and 23.33%, respectively. The age group of below 15 to 60 years which is considered as active and working group in the fishers' community and their religion ration were Islam 65% and Hindu 35%. Most of the fishers have nuclear family (60%) and few have joint family (40%). In the study area, most of fishers were illiterate (80.83%) and (12.5%) could put sign only. During study period, fishers are considered as permanent (65%) and temporary (35%) fishers. In fishers' community, the average children number was 3. Most of house was muddy house (73.6%) and drinking water source was tube well (96.5). Most of the fishers were used semi hygienic sanitation type (92.40%), only 7.60% fishers were used hygienic sanitation. The average fishing activity time was 9 hr/day and only 43.33% fishers' community get benefits of electricity (Table35).

Table 35. Basic information about the fishers of Kishoreganj haor

Particulars		**Percentages of fishers**
Average household size (no.)		6.00
Average dependency ratio (no.)		2.23
Average sex distribution	Male	76.67
	Female	23.33
Average age	Below15.00 years	9.17
	15.01 to 30.00years	32.50
	30.01 to 45.00years	39.17
	45.01 to 60.00 years	19.17
Religion	Islam	65.00
	Hindu	35.00
Marital status	Unmarried	9.17
	Married	90.83

Family type	Nuclear family	60.00
	Joint family	40.00
Average children (no.)	Male	1.70
	Female	1.30
	Illiterate	80.83
Literacy rate	Sign only	12.50
	Primary and above	6.67
	Fishing only (with licence)	24.17
Occupational status	Fishing only (without licence)	36.67
	Fishing and others	39.17
Fishers type	Permanent	65.00
	Temporary	35.00
Housing condition	Muddy house	73.60
	Tin-shed	26.40
Source of drinking water	Pond	3.50
	Own tube well	42.00
	Others tube well	54.50
Sanitation type	Unhygienic	7.60
	Semi- hygienic	92.40
Average fishing time (hr/day)		9.00
Electricity facilities		43.33

Source: **Field survey, 2017-2018**

11.14.20 Fishers' activity during ban period in the study area of Kishoreganj haor

Activity during ban period is presented in Table 36. Most of the fishers were doing illegal fishing (34.17%) during ban period and there were 14.17% day laborer. Other fishers were also involved no activity, net making, agriculture, agriculture and illegal fishing, handicraft making etc. during ban period in the study area.

Table 36. Fishers' activity during ban period in Kishoreganj haor

Activity	Number	Percentage
No activity	07	5.83
Net making	12	10.00
Illegal fishing (poaching)	41	34.17
Agriculture	18	15.00
Agriculture and illegal fishing	11	9.17
Handicraft making	03	2.50
Day laborer	17	14.17
Other	11	9.17
Total	**120**	**100**

Source: Field survey, 2017-2018

11.14.21 Women participation in fishers' community on livelihood in Kishoreganj haor

Women participation is presented in Table 37. In the study area, majority percentage of women was housewife (39.29%). Small percentage was involved in rearing domestic animals (21.28%) for contribution in their family. Few women were also involved in handicraft making, helping in fishing activity, helping in agriculture etc. In the study area, women participation is increasing day by day.

Table 37. Women participation on livelihood in Kishoreganj haor region

Activity	Number	Percentage (%)
Housewife	11	39.29
Handicraft making	03	10.71
Helping in fishing activity	02	7.14
Helping in agriculture	02	7.14
Rearing domestic animals	06	21.43
Others	04	14.28
Total	**28**	**100**

Source: Field survey, 2017-2018

11.14.22 Children's activity in Kishoreganj haor region

Children activities were also investigated during study period. Most of the children were avoiding school (46.17%) for helping their family members. School going children was 21.31% in the study area present in Table 33. Small percentage of the children was also involved in helping in fishing (7.38%), helping in household activity (9.01%) etc. (Table 38).

Table 38. Children's activity in Kishoreganj haor region

Activity	Number	Percentage (%)
School going children	78	21.31
School avoiding children	169	46.17
Helping in fishing	27	7.38
Helping in household activity	59	16.12
Others	33	9.01
Total	**366**	**100**

Source: Field survey, 2017-2018

11.14.23 Annual average income of fishers in the study area of Kishoreganj haor

The annual average income of the fishers in the study area is presented in Table 39. Most of the fishers' income was very low according to the fishers' opinion. Based on field survey, 39.17% fishers' income range was 20,000-30,000 BDT and 32.5% fishers' income was 30,000-50,000 BDT in the study area. Many fishers take loan from some NGO's and arotdar for a long period of time. Only small percentage of the fishers (7.5%) income was 70,000 BDT or above in the study area.

Table 39. Annual average income of the fishers in Kishoreganj Haor

Income Range(BDT)	Number	Percentage (%)
20,000-30,000	47	39.17
30,000-50,000	39	32.50
50,000-70,000	25	20.83
70,000-above	09	7.50
Total	**120**	**100**

Source: Field survey, 2017-2018

12.14.24 Major problems and constraints associated with fishing and livelihood in Kishoreganjhaor region

Table 11.14.24.40 represents major problems and constraints faced by the fishers in the study areas. It is seen that lack of knowledge was the most frequently faced problem (ranked 1st) by the farmers. 63.3% fishers stated about this problem. Low price of fishes was the 2nd major problem and constraints in the study area that was 59.9% fishers faced frequently and Access to information and training (ranked 3rd) which were frequently faced by 57.5 percent fishers, respectively. Other problems and constraints included disease, unfavorable environment, access to bank loans, safety, lack of foods and cloths, access to water and lack of fish storage which were ranked as 4th, 5th, 6th, 7th 8th 9th and 10th, respectively according to the fishers opinion (Table 40).

Table 40. Problems and constraints faced by the fishers in Kishoreganj haor

Problems identified	Extent of problem (% of fishers)			Rank
	Frequent	Occasional	Rare	
Lack of knowledge	63.3	21.4	15.3	1
Access to information and training	57.5	29.2	13.3	3
Low price of fishes	59.9	26.3	13.8	2
Access to bank loans	39.3	31.7	30.0	6
Unfavorable environment	40.8	34.2	25.0	5
Safety	37.3	31.5	31.2	7
Disease	41.7	40.1	18.2	4
Lack of foods and cloths	35.1	33.7	31.2	8
Access to water	34.0	33.5	32.5	9
Lack of fish storage	33.4	33.1	33.6	10

Source: Field survey, 2017-2018

11.14.25 Fishers' perceptions about the impact of climate change in Kishoreganj haor region

Fishers' perceptions about the impact of climate change on their day-to-day life were evaluated using agreement index (AI). Fishers observations were recorded on impact of climate change on 15 statements, and their depth of agreements on the selected statements were calculated consequently.

Table 41 showed that 62.7% fishers of the study areas were agreed with the statements about reduce fish production, damage fishing ground, blockage of fish migration road, damage biodiversity, increasing temperature, enhance soil erosion, reduce rainfall, siltation, water flow, storm frequency, changing spawning season, decrease fish production, extinction fish species. However, 37.3% fishers were disagreed with the statements.

Table 41. Agreement index regarding the impacts of climate change in Kishoreganj haor region

Statements	**Fishers agreement**		**Weights**
	Agreed	**Disagreed**	
Reduce fish production	77/120	43/120	1/15
Damage fishing ground	67/120	53/120	1/15
Blockage fish migration route	73/120	47/120	1/15
Damage biodiversity	81/120	39/120	1/15
Increase cost of fishing materials	86/120	34/120	1/15
Increase temperature	68/120	52/120	1/15
Enhance soil erosion	62/120	58/120	1/15
Reduce rainfall	77/120	43/120	1/15
Siltation and sedimentation	69/120	51/120	1/15
Change water flow level	71/120	49/120	1/15
Storm Severity	96/120	24/120	1/15
Storm frequency	86/120	34/120	1/15
Change spawning season	63/120	57/120	1/15
Decrease fish reproduction	87/120	33/120	1/15
Extinct fish species	80/120	40/120	1/15
Index score	0.627	0.373	-
Depth of agreement (%)	62.7	37.3	-

Source: Authors' estimation based on field survey, 2017-2018. (Modified from Uddin *et al.,* 2017).

Note: Calculation of index score for agreed opinions = (77/120 × 1/15) + (67/120 × 1/15) + (73/120 × 1/15) + (81/120 × 1/15) + (86/120 × 1/15) + (68/120 × 1/15) + (62/120 × 1/15) + (77/120 × 1/15) + (69/120 × 1/15) + (71/120 × 1/15) + (96/120 × 1/15) + (86/120 × 1/15) + (63/120 × 1/15) + (87/120 × 1/15) +80/120 × 1/15) = 0.627

Calculation of index score for disagreed opinions = (43/120 × 1/15) + (53/120 × 1/15) + (47/120 × 1/15) + (39/120 × 1/15) + (34/120 × 1/15) + (52/120 × 1/15)+ (58/120 × 1/15) + (43/120 × 1/15) + (51/120 × 1/15) + (49/120 × 1/15) + (24/120 × 1/15) + (34/120 × 1/15) + (57/120 × 1/15) + (33/120 × 1/15) + (40/120 × 1/15) = 0.373

Calculation of depth of agreement for agreed opinions = 0.627 × 100 = 62.7%

Calculation of depth of agreement for disagreed opinions = 0.373 × 100 = 37.3%

11.14.26 People's perception level about various climatic problems in Kishoreganj haor

People's perception level of the respondents on different climatic problems in the study area was measured. There were various climatic problems that affect the overall livelihood pattern of the fishers' communities. This is very much crucial for the fishers' communities to recognize the adverse climatic problems. The perception levels on different climatic events are shown in Table 42.

Table 42. Perception level of the respondents on different climatic problems in Kishoreganjhaor region

Climatic problems	Respondent (%) (N=120)	Frequency of occurrence/year	Perception level (%)	Ranking problems based on vulnerabilities (%)		
				High	**Medium**	**Low**
Flash flood	100	1~2 times	87.5 (n=105)	88	10	2
Heavy rainfall	100	4~5 times	63.33 (n=76)	85	12	3
Storm surge	100	6~8 times	73.33 (n=88)	77	23	0
Soil erosion	100	Throughout the year	64.16 (n=77)	25	30	45
Drought	100	1~2 times	45.83 (n=43)	47	23	30
Potable water crisis	100	Throughout the year	14.16 (n=17)	15	25	60
Water borne Disease	100	Throughout the year	37.5 (n=45)	30	30	40

Source: Field survey, 2017-2018

Notes: (%) Indicate percentage of respondent perception level, N= Total no. of people surveyed (120), n = No. of respondent perceive about different climatic problems.

11.14.27 Perception about the flash floods of Kishoreganj haor

The climate impacts result not only from gradual changes in temperature and sea level rise, but also, increasing flash floods, droughts, storms etc. Flash floods are happening more and more frequently in recent years. The perception level of flash flood as a phenomenon of climate change of the selected communities is 87.5%. Floods cause 4.17% respondents to migrate and 35% population switching occupation (Table 41 and 42).

11.14.28 Perception about the heavy rainfall of Kishoreganj haor

The frequency of heavy rainfall was 4~5 times over the study area and the perception level about heavy rainfall was 63.33% in the study area. Heavy rainfall forces 69.16% of the respondents to change their fishing calendar, 54.17% of the respondents face problem of house damage (Table 41 and 42).

11.14.29 Perception about storm surge of Kishoreganj haor

The people of the Kishoreganj haor region are facing storm surge frequent problem of climate change and thus the perception level of this climatic event is 73.33% which is higher than climatic events such as soil erosion, potable water crises, etc. Frequency of occurrence of storm surge per year is 6~8 times in the study area. Storm surge has devastating effect on the communities which also make their lives vulnerable in the study area (Table 41 and 42).

11.14.30 Perception about the soil erosion of Kishoreganj haor

Soil erosion is a very common and a serious problem in the Kishoreganj haor region. The consequences of soil erosion are migration, loosing cultivated land, job switching. The perception level of soil erosion was 64.16% in the haor region. Soil erosion related to the results of climate change (Table 42).

11.14.31 Perception about the drought of Kishoreganj haor

Drought is not a very common problem in the study area. But as they face this problem in November-February and the water dried out sometimes in the haor and drought happens in there. The perception level of drought was 45.83% in the study area (Table 42).

11.14.32 Perception about the potable water crisis of Kishoreganj haor

Very few people face potable water crisis in the study area. The perception level about the crisis of potable water in this village community was about 14.16%. The people of the fishers' communities use haor water as their daily needs and they used other tube-well water for drinking purposes. It was found that 55.83% of the respondents use or drink rain water to meet their demand. About 5% of the respondents use potash alum to purify their water for drinking purpose (Table 41 and Table 42).

11.14.33 Perception about water borne disease

Water borne disease is very common problem to the haor peoples. The perception level about water borne disease was 37.5% and people face this problem throughout the year in the study area. About 26.69% of the respondent used rain water for their daily needs (Table 41 and 42).

11.15 Histological observation

11.15.1 Kidney of the fishes of Sundarbans region

There were some histological differences found between the normal freshwater fish i.e., *Clarias batrachus,Mystus cavasius* and *Tilapia zillii* (Figure 28 A and C; Figure 29 A) and saline water river fish species i.e., *Plotosus canius, Mystus gulio, Glossogobius giuris*, *Lates calcarifer*, *Polynemous paradiseus*, *Liza parsia* and *Silaginopsis panijus* (Figure 28 B and D; Figure 29 B, C, D, E and F) collected from Sundarbans regions. The glomerular structure had shrunk in *Plotosus canius, Mystus gulio, Glossogobius giuris*, *Lates calcarifer*, *Polynemous paradiseus*, *Liza parsia* and *Silaginopsis panijus* that had acclimated to saline zone of the rivers of Sundarbans (Figure 28 B and D; Figure 29 B, C, D, E and F), while *Clarias batrachus,Mystus cavasius* and *Tilapia zillii*acclimated to the freshwater, collecting canals had a thin and narrow lumen and the glomerular structures were larger (Figure 28 A and C; Figure 29 A).

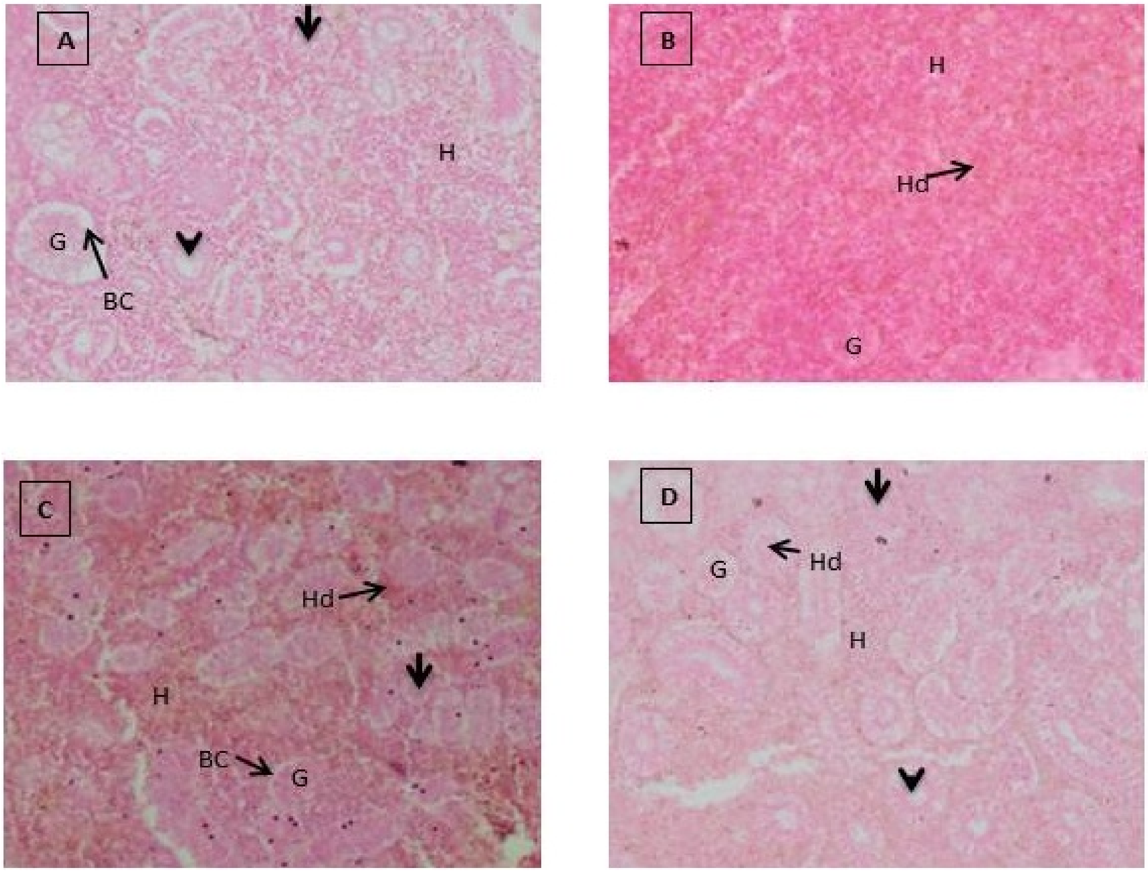

Figure 28: Periodic hematoxylin staining of paraffin section of kidneys (Siluriformes); A) *Clarias batrachus* (normal); B)*Plotosus canius;* C) *Mystus cavasius* (normal); D) *Mystus gulio.* H hematopoietic tissue, Hd hyaline droplets, G glomerulus, BC Bowman's capsule, proximal tubule (arrows), distal tubule (arrow heads). (H and E, 100).

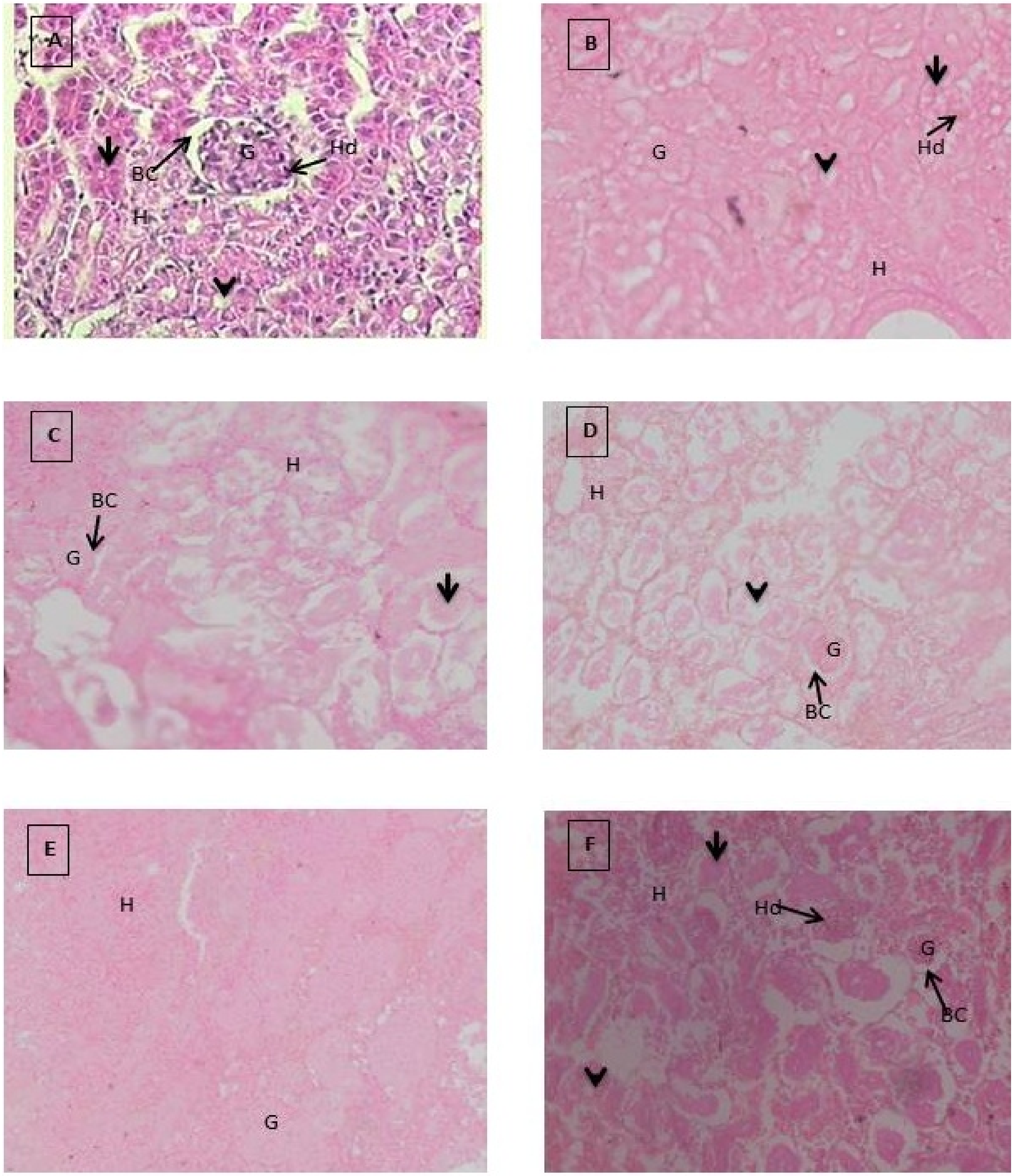

Figure 29: Periodic hematoxylin staining of paraffin section of kidneys (Perciformes); A) *Tilapia zillii* (normal) (Hadi and Alwan, 2012); B)*Glossogobius giuris*; C) *Lates calcarifer* D) *Polynemous paradiseus* E) *Liza parsia* F) *Silaginopsis panijus*. H hematopoietic tissue, Hd hyaline droplets, G glomerulus, BC Bowman's capsule, proximal tubule (arrows), distal tubule (arrow heads). (H and E, 100).

The diameter of the glomerulus and the diameter and thickness of the collecting tubules were significantly larger in freshwater samples than in the samples of Sundarbans regions. In kidney of

Plotosus canius, Mystus gulio, Glossogobius giuris, *Lates calcarifer* and *Liza parsia* had an occasional glomerulus completely filling Bowman's capsule(Figure 28 B and D; Figure 29 B, C and E) and *Polynemous paradiseus* and *Silaginopsis panijus* had three-fourthsof their glomeruli completely filling Bowman's capsule (Figure 29 D and F). The presence ofoccasional hyaline droplets in glomeruli and hematopoietic tissues was observed in *Plotosus canius* and *Mystus gulio* (Figure 28 B and D). *Mystus cavasius, Glossogobius giuris* and *Silaginopsis panijus* were showed extreme amounts of hyaline deposition (Figure 28 C; Figure 29 B and F).

11.15.2 Gillof the fishes of Sundarbans region

The gill histology of the collected fish was different from other freshwater teleost species. Each gill composed of a primary filament and secondary lamellae. The secondary lamellae were thinner in the gill of *Pseudapocryptes elongates*, *Tenualosa ilisha* and *Liza parsia* (Figure 30 B, C and D) than the freshwater fish *Oreochromis mossambicus* (Figure 30A). The mucous cells and mitochondria-rich cells were observed. Few numbers of mitochondria-rich cells were found in *Liza parsia* sampled from study area (Figure 30 D). The presence of a small number of mucous secreting cells was also identified in the secondary lamellae of the *Pseudapocryptes elongates*, *Tenualosa ilisha* and *Liza parsia* (Figure 30 B, C and D) where the gill of normal freshwater fish *Oreochromis mossambicus* showed large number of mucus secreting cells (Figure 30 A). Histological examination showed some lamellar fusion in gill of *Pseudapocryptes elongatus* (Figure 30 B) which was not found in others but it was common in normal freshwater fish. However, necrosis and epithelial lifting were not found in the gills sampled from Sundarbans region. Cell proliferation increased with increasing freshwater flow in rivers and caused the secondary lamellae to fuse.

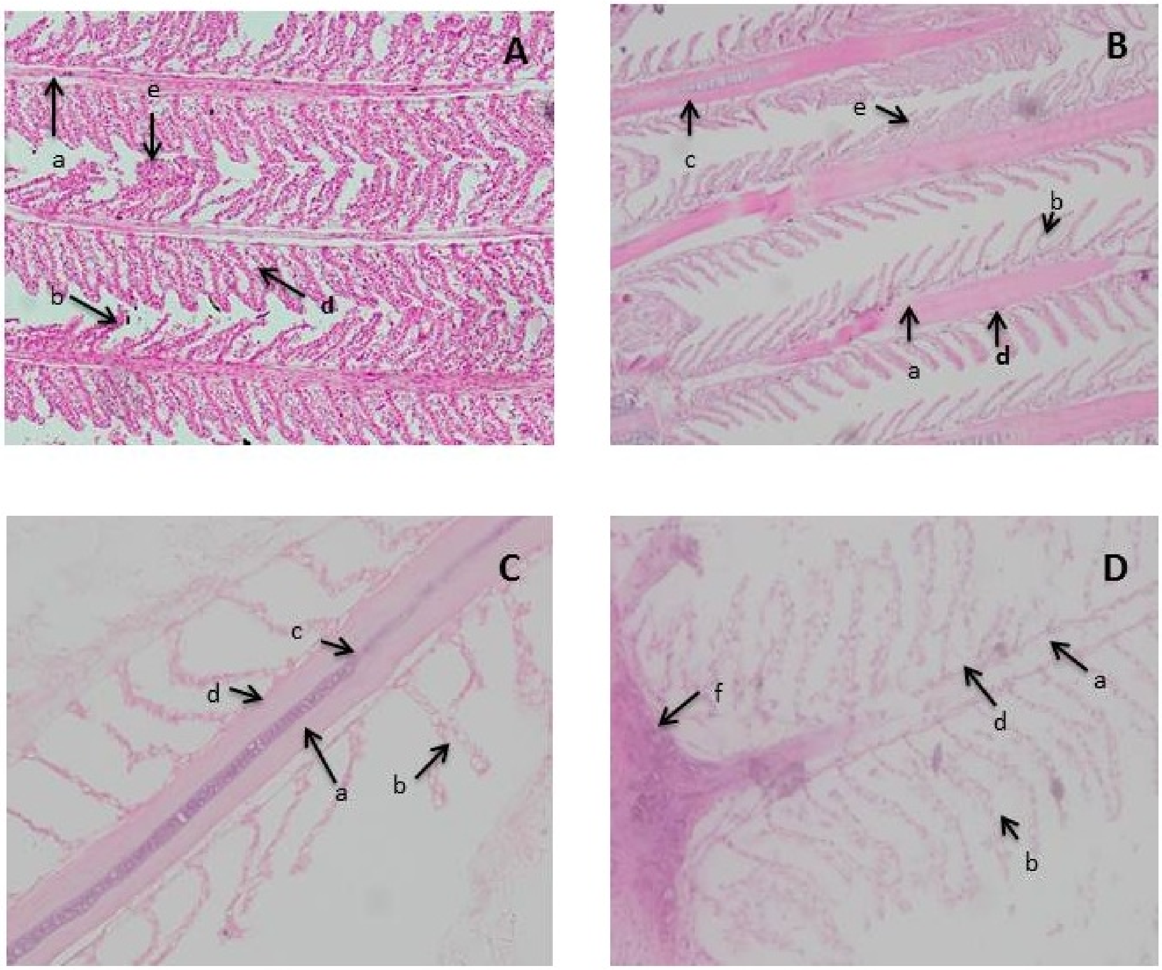

Figure 30: Periodic hematoxylin staining of paraffin section of gills; A) *Oreochromis mossambicus* (normal); B)*Pseudapocryptes elongatus*; C) *Tenualosa ilisha* D) *Liza parsia.* a) primary lamellae, b) secondary lamellae, c) cartilage, d) mucus secreting cells, e) lamellae fusion, f) mitochondria rich cell. (H and E, 100).

11.15.3 Muscle of the fishes of Sundarbans region

The muscle histology of the collected fish was similar to other freshwater teleost species. There was no significant effect found in muscle of *Lates calcarifer*, *Silaginopsis panijus*, *Glossogobius giuris* and *Liza parsia* (Figure 31B, C, D and E). In this histological analysis, all muscles were seems to be normal as like freshwater fish *Oreochromis mossambicus* (Figure 31A).

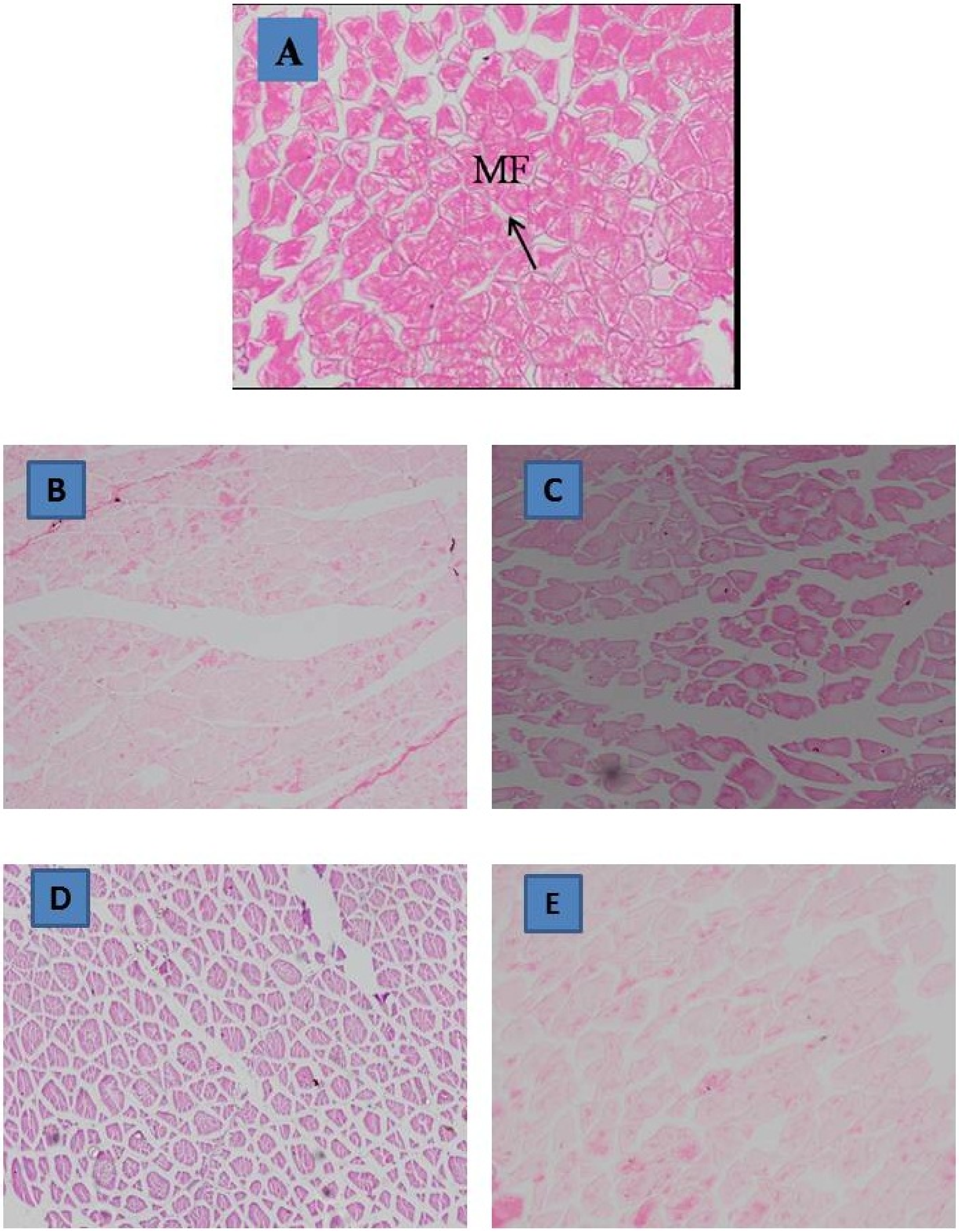

Figure 31: Histological sections of muscle: A) Normal muscle (freshwater fish *Oreochromis mossambicus*) B) *Lates calcarifer*; C) *Silaginopsis panijus*. D) *Glossogobius giuris* E) *Liza parsia*. (H and E, 40). MF muscle fibre.

11.15.4 Liver of the fishes of Sundarbans region

Histological analysis of liver of fish collected from Sundarbans revealed that the hepatocytes were containing less cytoplasm and nuclei weren't place at center. In addition, the nucleus did not show a uniform coloration in liver of *Plotosus canius*, *Liza parsia* and *Polynemous paradiseus* (Figure 32 C; Figure 33 B and E). The number of MMC was higher in liver of *Mystus gulio,Plotosus canius*, *Lates calcarifer* and

Silaginopsis panijus (Figure 32 B and C; Figure 33 C and D) which means liver depicted. Mild necrosis (Ne) was observed in liver of *Mystus gulio* and*Liza parsia* (Figure 32 B; Figure 33 B) which ultimate result was vacuolation found in most of the fish sampled i.e., *Mystus gulio,Plotosus canius*, *Liza parsia,Lates calcarifer, Silaginopsis panijus* and *Polynemous paradiseus* (Figure 32 B and C; Figure 33 B, C, D and E). Disintegration of normal cellular architecture (DCA) of liver tissue was observed in most of the fish sampled from Sundarbans regions i.e., *Mystus gulio,Plotosus canius*, *Lates calcarifer, Silaginopsis panijus* and *Polynemous paradiseus* (Figure 32 B and C; Figure 33 C, D and E). Picnotic nuclei were evident and in some cases looked fragmented, which can lead to cell death due to apoptosis.

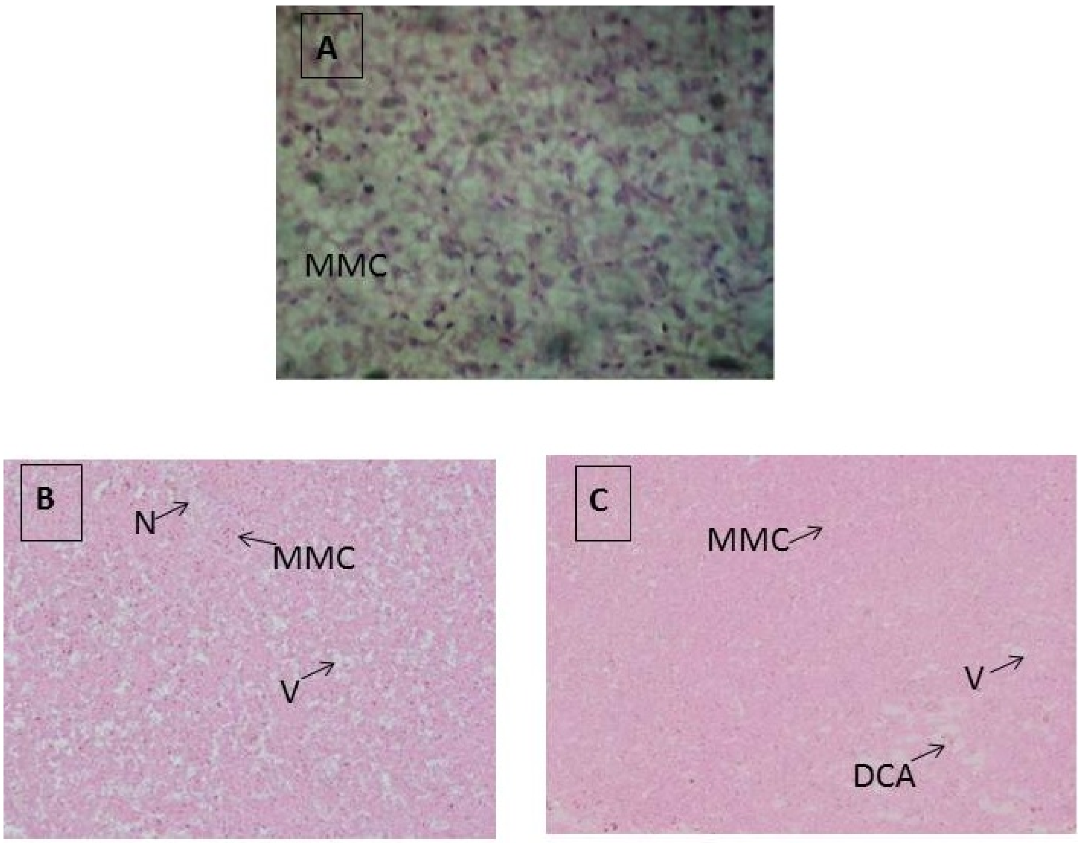

Figure 32: Periodic hematoxylin staining of paraffin section of livers (Siluriformes); A) *Heterobranchus bidorsalis*(normal) (Adebola and Folorunsho, 2014); B)*Mystus gulio* C) *Plotosus canius.* (H and E, 100). H hepatocytes, Ne necrosis, V vacuolation, MMC melanomacrophage centres, DCA degenerative cellular architecture.

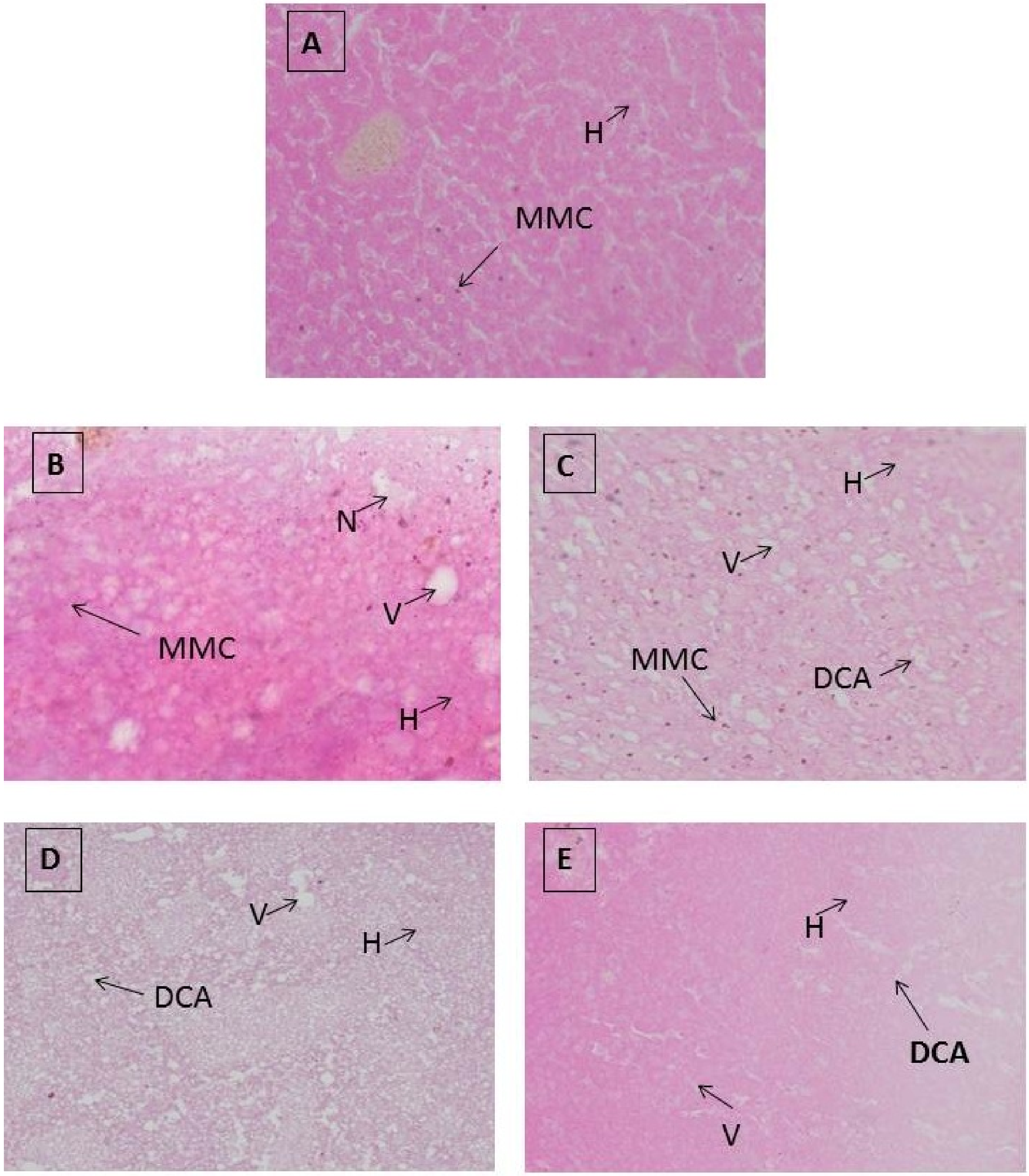

Figure 33: Periodic hematoxylin staining of paraffin section of livers (Perciformes); A) *Nandus nandus* (normal) (freshwater fish); B)*Liza parsia*; C) *Lates calcarifer* D) *Silaginopsis panijus*. E) *Polynemous paradiseus.* (H and E, 100). H hepatocytes, Ne necrosis, V vacuolation, MMC melanomacrophage centres, DCA degenerative cellular architecture.

The diameter of glomeruli and collecting tubules in each fish collected from Sundarbans region was smaller than freshwater fish species. Shrunken glomerular structure and lumen in the collecting tubules of the fish acclimated to the rivers of Sundarbans indicate that this fish has low glomerular filtration rates. In contrast, fish acclimated to the freshwater had expanded glomerular structure and lumen width in collecting canals, indicating that filtration in the nephrons is higher. Kumar and Srivastava (1980) found that glomerular shrinkage in *Channa punctatus* after 10 days in an 8 pptsodium chloride solution. Therefore, these changes are related to osmoregulation of the fish which is occurred due to the intense environmental changes in the two different aquatic environments. Similar morphologic changes have been found invan fish sturgeon, silver sea bream, and spotted scate (Oğuz 2015; Krayushkina *et al.,* 1996; Wong and Woo 2006; Ghazilou *et al.,* 2011). Hyaline droplets were observed in most of the fish kidneys sampled in Sundarbans region. A previous study conducted by Galat *et al.* (1985) found that increasing ionic concentrations were significantly associated with hyaline droplets in Lahontan cutthroat trout kidneys and SO_4^{2-} accounted for 50% of the variability in hyaline severity in kidney. A high range (9.02-968.3 mg/L) of sulfate concentration was observed in the Sundarbans mangrove forest (Rahman *et al.,* 2013). In contrast, Silva and Martinez (2007) showed that different pollution factors caused to formation hyaline droplet in kidney. The occurrence of hyaline droplets in fish kidneys may be due to increasing salinity levels and contamination in rivers of Sundarbans.

Histological analysis of the fish gills in the present study revealed that the primary lamellae were thinner in the fish collected from Sundarbans. The reason can be ascribed to the salinity of the rivers which is higher compared to freshwater. In a previous study, Oğuz (2013) mentioned that primary lamellae were become thinner due to the high ion level of water. This hyperosmotic environment of rivers of the Sundarbans enhances fish resistance power to negative environmental impacts by increasing in the quantity of ions that they secrete. Due to saline environment of rivers on Sundarbans, less mitochondria-rich cells were present in the fish gills. Mucus secreting cell were also reported less in the fish gills. Previous studies identified the presence of different types of mucous cells on fish gills depending on their chemical composition. The glucoconjugates produced by mucous secreting cells isolate the gills from the external environment. The basic function of mucous secreting cells is protection. These cells also contribute to various functions, such as ion and gas exchange, antimicrobial activity, and pH balance (Diaz *et al*., 2001). Thus, the increase in the number of mucous secreting cells in the gills of Sundarbans river fish might be caused by the differentiation of the cells to carry out different functions under freshwater conditions. When the fish enter the freshwater environment, the protective conditions caused by the salinity of rivers, which restricts bacteria, disappears; consequently, the gills become exposed to bacteria. Perry and Laurent (1993) stated that morphological changes in the gills represent adaptations that occur as a response to environmental changes.

In this study, muscles of the fish samples from the rivers of Sundarbans were represented similar to the muscle of normal fish. No effect was reported from the histological analysis of muscles. Muscle composition may not be change with environmental change of water. Similar result was also found by Oğuz (2015). According to Freire *et al.* (2008) the information about their osmoregulatory capacity, adaptation to different halophilic areas, and euryhalinity levels were provided by the muscle water control in crustaceans and fish. Muscle water content remained unchanged with acclimation to different halophilic areas in many euryhaline species (Oğuz 2015; Jensen *et al.,* 1998; Tang *et al.,* 2009).

The salinity effect wasn't found in fish liver but temperature had great effects on liver of fish. *Mystus gulio, Plotosus canius, Lates calcarifer* and *Silaginopsis panijus* fish liver exhibited the increase in MMCs which have been reported to be the chief indicators of stress induced by different kind of stressors mainly fluctuating temperature (Fournie *et al.,* 2001). MMC was accumulates of macrophages and considered as the key cells in the liver tissue which dealing with foreign agents and cellular debris (Vinodhini and Narayan, 2009). During summer season, the pathogenic prevalence is more due to increasing temperature (Bowden, 2008) and in order to protect the liver, MMCs increase in number through proliferate and help fishes species to get rid of such pathogenic attacks during summer at high temperature exposure. Similar result was found by Raina *et al.* (2015). Liver tissue also revealed necrosis, which simply implies that as the exposure of high temperature, prolonged, liver becomes unable to withstand severity of high temperature resulting thereby in disintegration of normal cellular architecture of liver tissue. Dash *et al*. (2011) stated that higher temperatures are stressful to fishes.

11.15.5 Histological observations of the organs of collected fish from the Meghna and Galachipa

Histologically, it was observed the organs (muscle, gill, liver, kidney and intestine) of Cluepiformes, Cypriniformes, Siluriformes and Perciformes Orders involving *Tenualosa ilisha, Labeo rohita, Wallago attu* and *Nandas nandas* fishes.

11.15.5.1 Muscle

The histology of muscle of the collected fish was similar to other freshwater teleost species. There was no significant effect found in the muscle (Figure 34B). The histological observations of muscle exposed to be normal as like as freshwater fish (Figure 36L and 39D1).

11.15.5.2 Gill

The gill histology revealed that it was different from other freshwater species. Generally, gill consists of a primary filament, secondary lamellae, gill racker, pillar cell and chloride cell. There were much mucous secreting cell presented in the secondary lamellae of fish and epithelial tissue was lifting. Histological analysis was also showed some fusion in the fish gills (Figure 35 J and Figure 36 P). Be that as it may, hemorrhage, necrosis and other epidemic were not found in the gills.

11.15.5.3 Kidney

There were some differences in the histology of kidney which was collected from the sampling rivers. In the analysis of kidney, it was revealed that the diameter of renal tubule was increased and glomerulous was expanded (Figure 34 F), hyaline droplet and enlarged glomerulous were observed (Figure 38 N,38X) whereas it was normal in other normal fish.

11.15.5.4 Liver

Histological analysis of liver of fish which was collected from the sampling rivers revealed that the Melanomacrophage Centres was increased, hepatocyte vacuolation and irregular shape was also found in some species (Figure 11.15.5.4.34 D and Figure 11.15.5.4.39 Z).

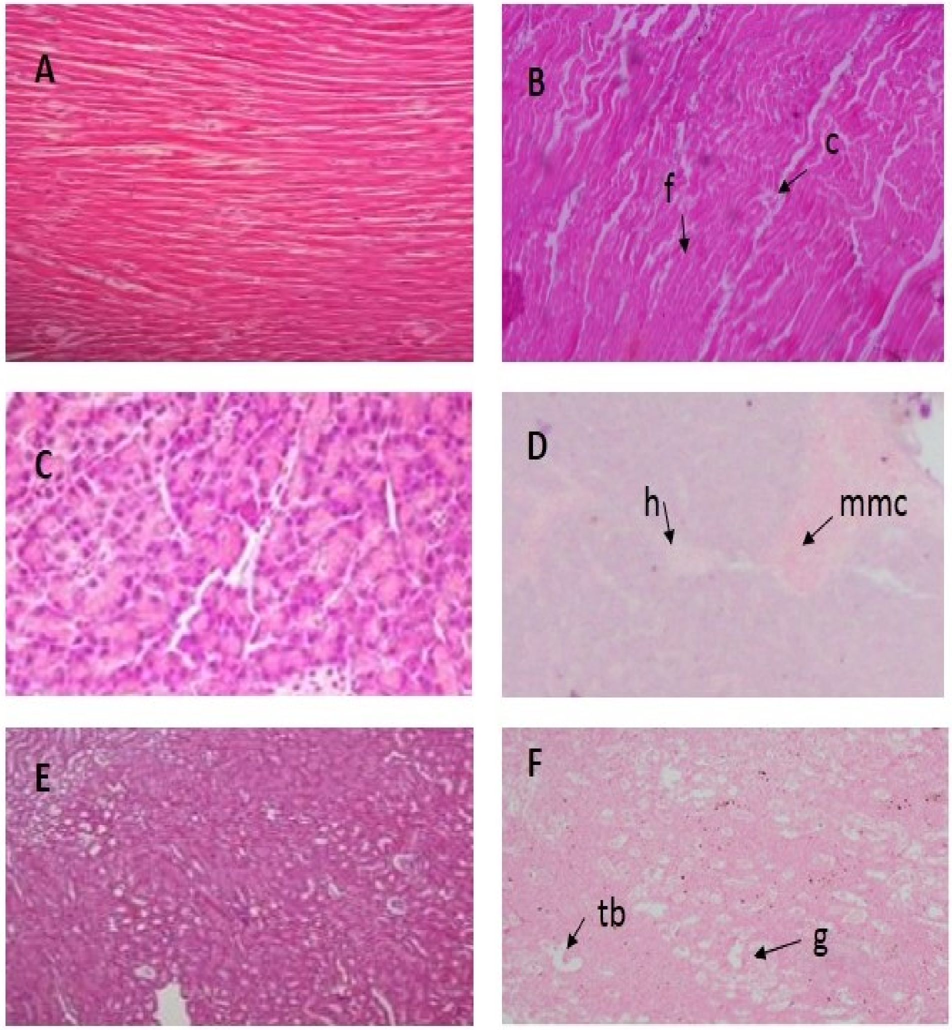

Figure 34: Histological section of muscle (A & B), liver (C & D), and kidney (E & F) of *Tenualosa ilisha* at 40X magnification, where nm, normal muscle; f, muscle fibres; c, capillaries; mmc, melanomacrophage centres; h, hepatocyte; tb, tubule; g, glomerulous are observed.

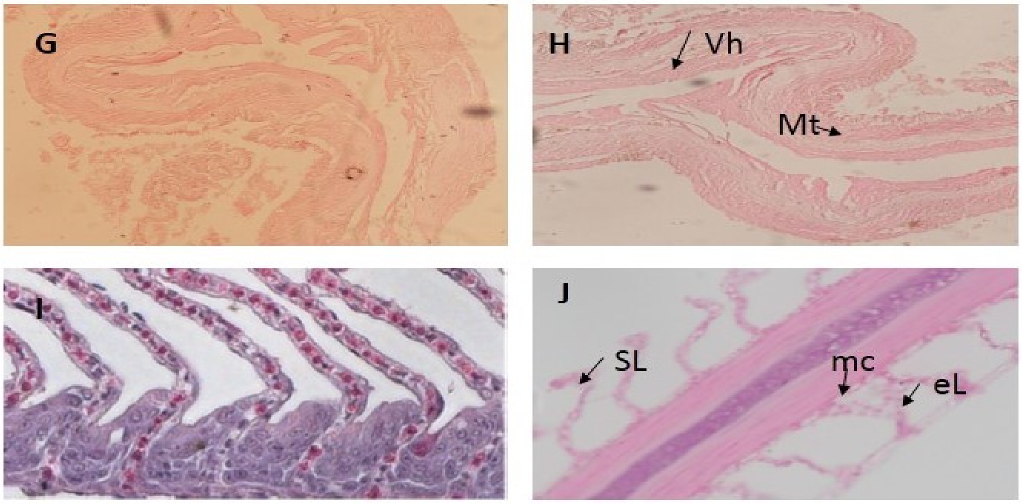

Figure 35: Histological section of intestine (G & H) and Gill (I & J) of *Tenualosa ilisha* at 40X magnification; where ni (left), normal intestine; vh, villus height; mt, muscle thickness; sl, secondary lamellae; mc, mucous cell and el, epithelial lifting were observed.

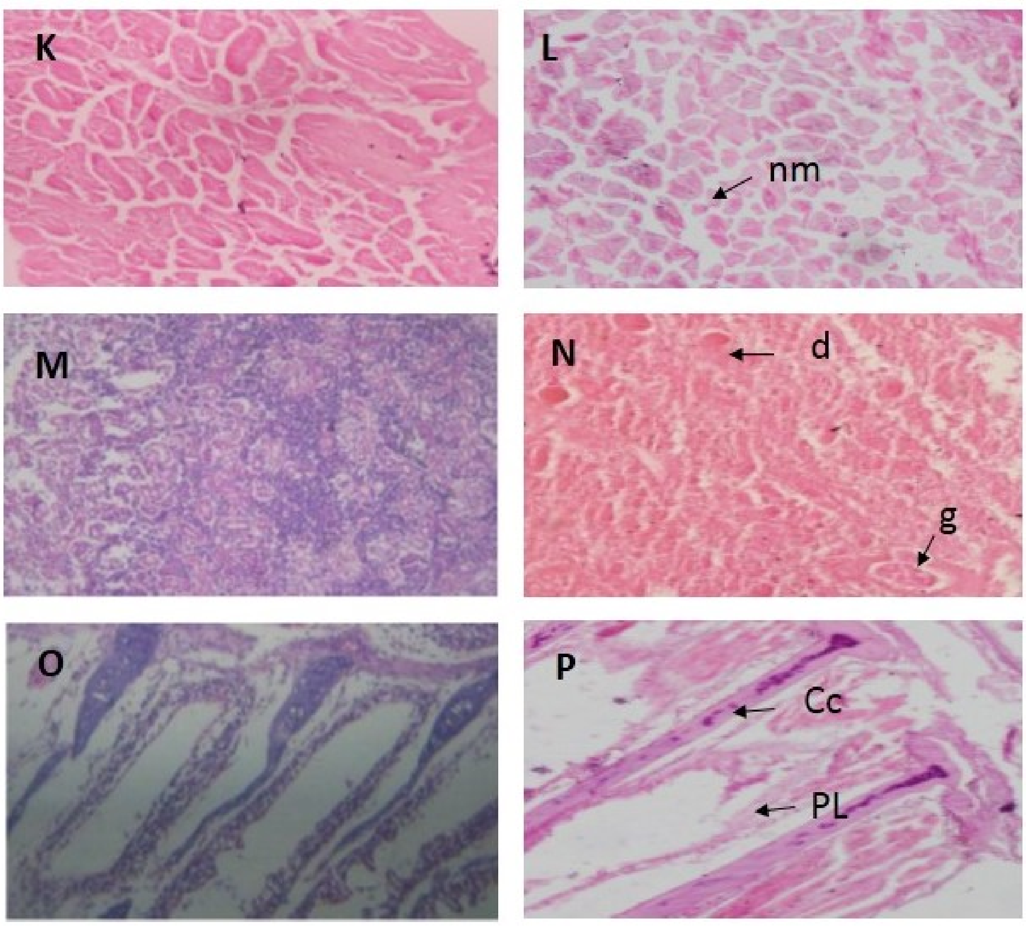

Figure 36: Histological section of muscle (K & L), Kidney (M & N) and Gill (O & P) of *Wallago attu* at 40X magnification; where, nm (left), normal muscle; d, droplet; g, glomerulous; cc, chloride cell and pl, primary lamellae are observed.

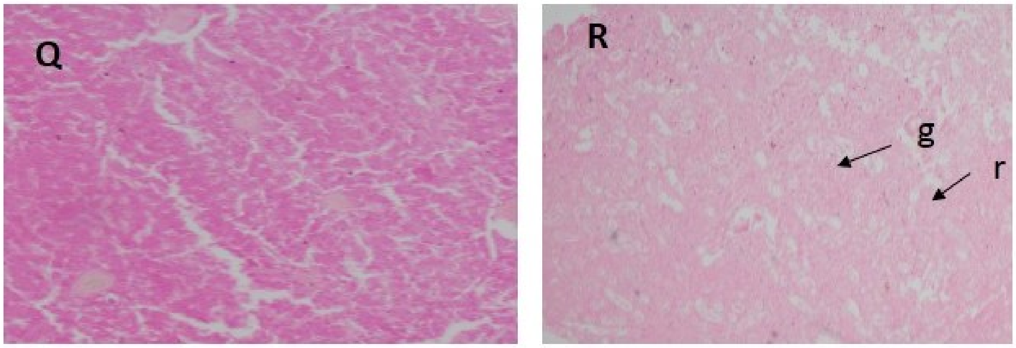

Figure 37: Histological section of liver (Q & R) of *Wallago attu* at 40X magnification; where nk (left), normal kidney; g, glomerulous; r, renal tubule are observed.

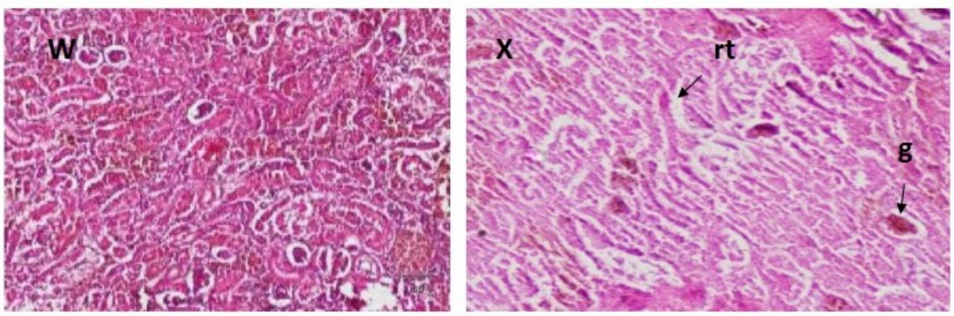

Figure 38: Histological section of kidney (W & X) of *Labeo rohita* at 40X magnification; where nk, normal kidney; rt, renal tuble and g, glomerulous are observed.

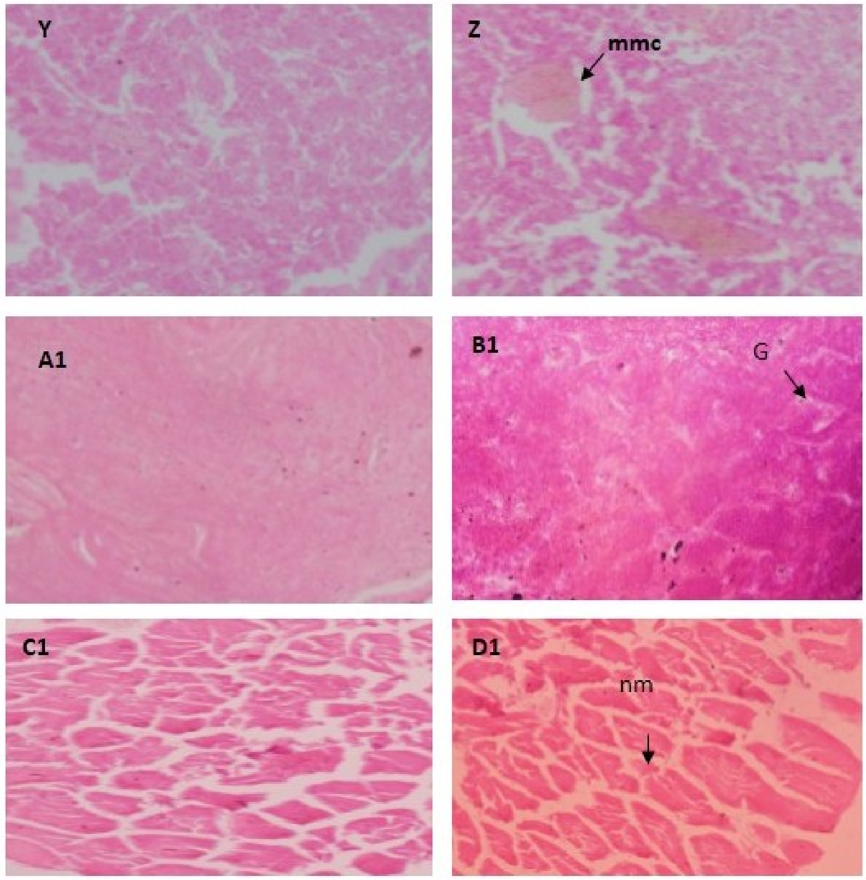

Figure 39: Histological section of Liver (Y & Z), Kidney (A1 & B1) and Muscle (C1 % D1) of *Nandus nandus* at 40X magnification where nl (left), normal liver; mmc, melanomacrophage centre; g, glomerulous are observed.

According toAntal *et al*. (2013), fish are sensitive to environmental impacts, such as pollution, acid-base, ionic change and climatic changes. Therefore, histological process has been taken as a useful tool to assess the changes in the status of vital organs of different collected fishes.

It has been observed that muscle water content remained unchanged with acclimation to different areas in many euryhaline and freshwater species, it was almost similar to the Tang *et al*., (2009). Muscle water control in crustaceans and fish may provide information about their osmoregulatory capacity, adaptation to different halophilic areas, and euryhalinity levels (Freire *et al.,*2008). In this study, it was determined that muscle water content did not change in either environment.

In the kidney, the diameter of glomeruli and collecting tubules in *A. tarichi* was larger in freshwater samples than lake or salt water. Expanded glomerular structure and collecting tubules of the fish acclimated to freshwater indicate that this fish has high glomerular filtration rates. In contrast, fish acclimated to the alkaline lake had collapsed glomerular structure and shrunken lumen in collecting canals, indicating that filtration in the nephrons is lower. Due to the drastic environmental changes in the two different aquatic environments, the fish excretes dilute urine in hypo-osmotic environments and reabsorbs needed ions. These changes led us to surmise that they are related to osmoregulation of the fish. Similar morphologic changes have been found in sturgeon, silver sea bream, and spotted scat (Krayushkina *et al*., 1996; Wong & Woo, 2006; Ghazilou *et al*., 2011). Hyaline droplets were observed in Van Lake fish kidneys sampled in both areas. Hyaline droplets in Lahontan cutthroat trout kidneys were significantly associated with increasing ionic concentrations in lakes differing in salinity and alkalinity (Galat *et al*., 1985). Further, different pollution factors have been shown to cause hyaline droplet formation. The appearance of hyaline droplets in Van fish kidneys may be due to high ion levels and contamination and haphazardly rising level of temperature in the lake. In the present study disclosed the above similar result. We suggest that trout from the less saline lakes and fresh waters must process more blood through the larger quantities of urine. The glomerular arterioles probably dilate to allow for increased flow of blood, which may account for the observed glomerular swelling and congestion. Conversely, glomeruli appeared shrunken in kidneys of trout from the most saline lakes when compared with those in fresh water. Kumar &Srivastava, (1980) also observed glomerular shrinkage in *Channa punctatus* after 10 days in an 8%sodium chloride solution.

The histological lesions, increased mucous cell and epithelial lifting in the fish gills found in the present study might arise also because of the stress and irregular change of water environment that the fish were subjected to within a short period of time. Pereira *et al*. (2013) stated that anomalies observed in the gills did not reflect the impacts of a certain pollutant, as these anomalies may be caused by irregularity in the ecosystem. Moreover, Perry and Laurent, (1993) stated that morphological changes in the gills represent adaptations that occur as a response to environmental changes. Haaparanta *et al.* (1997) stated that there is no correlation between anomalies and pollution, and that these anomalies are caused by seasonal temperature changes and fluctuating water quality. It is also known that pH has the strongest influence on gill histopathology (Rašković *et al*., 2013). In the present study, we hypothesized that changes to the fish gill histology were primarily caused by physicochemical changes in the water and the stress to which the fish were subjected, with a minor contribution by pollutants, such as heavy metals (Oğuz and Yeltekin, 2014)**.**

In the present study, hepatocytes with irregular shaped and vacuolation and melanomacrophase has centre (mmc) found in the liver and its reason was irregular change of temperature, pH and heavy metals in the water body along with water pollution. In accordance with Raina *et al*. (2015) liver depicted increase in MMCs (melanomacrophages centres) by the 12th day of experiment and its proliferation by 30th day of experiment. Mild necrosis (N) was evident after 48th day of experiment and by the end of 60 days of high temperature exposure, there has been observed disintegration of normal cellular architecture (DCA) of liver tissue. However, at higher temperature of 32 °C, liver exhibited the increase in MMCs which have been reported to be the chief indicators of stress induced by different kind of stressors (presently fluctuating temperature). The results were the clear indication of the fact that lower temperature (20 °C) (in winter season) proved to be more deleterious to physiological functioning of the liver compared to higher temperature (32 °C). Dash *et al.* (2011) reported in agreement with present findings also stated that higher temperatures are stressful to fishes. While studying the effect of higher temperature of 36 °C on fish *Labeo rohita*, they also noted disarrangement of the hepatic cells and degeneration of the normal cellular architecture of fish liver.

The present study demonstrated that the fishes of sampling rivers can endure slightly saline-alkaline environments in spite of histological changes. Deposition of hyaline droplets in proximal kidney tubules was the most significant histological alteration observed. Fishery managers should be cognizant of the potential for this histological condition to occur when they evaluate saline-alkaline water body for the fishes in the rivers. Otherwise this little change can prevalence in future.

11.15.6 Histological observations of the organs in Kishoreganj haor region

Histologically, it was observed in present study that all organs (Kidney, Gill, Muscle, Intestine and Liver) of *Wallago attu, Rita rita, Clarias batrachus* and *Puntius sarana* fishes. Most of the fish organs were normal in condition except few changes.

11.15.6.1 Kidney

Kidneys were almost normal except hyaline droplets in collected samples (Figure40 A; Figure 41 A and Figure 43 A). Glomerulus and Bowman's space were also in normal condition. The diameter of the glomerulus and the diameter and thickness of tubules were also normal in all collected fish samples (Figure 40 A; Figure 41 A; Figure 42 A; Figure 43 A).

11.15.6.2 Gill

The gill was almost normal except some secondary gill lamellae were missing in all collected fish (*Wallago attu, Rita rita, Clarias batrachus* and *Puntius sarana)* species. Primary gill lamellae were separated in all fishes. The mucous cells and mitochondria-rich cells were observed. A large number of mucus secretion cells were found in all samples which are normal for freshwater fishes. However, necrosis and epithelial lifting were not found in the gills sampled from Kishoreganj haor region (Figure 40 B; Figure 41 B; Figure 42 B; Figure 43 B).

11.15.6.3 Muscle

The muscle histology of the collected fish (*Wallago attu, Rita rita, Clarias batrachus* and *Puntius sarana)* was similar to other freshwater teleost species. There is no significant abnormalities found in muscle of all fish species and all parts were also normal in condition. In this histological analysis, all muscles were seems to be normal as like other freshwater fish (Figure 40 C; Figure.41 C; Figure 42 C; Figure 43 C).

11.15.6.4 Intestine

Histologically, there is no significant climatic effect found in intestine. In intestine, Mucosa and Lamina propia were found and all were normal in condition (Figure 40 D; Figure 41 D; Figure 42 D; Figure 43 D).

11.15.6.5 Liver

Liver was almost normal except vacuums, (V), (Figure 40 E; Figure 41 E; Figure 42 E and Figure 43 E). Histological analysis of liver of fish (*Wallago attu, Rita rita, Clarias batrachus* and *Puntius sarana)* collected from Kishoreganj haor region revealed that the hepatocytes were containing high cytoplasm and nuclei were place at center. In addition, the nucleus showed uniform coloration in all fishes (Figure 40 E; Figure 41 E; Figure 42 E; Figure 43 E).

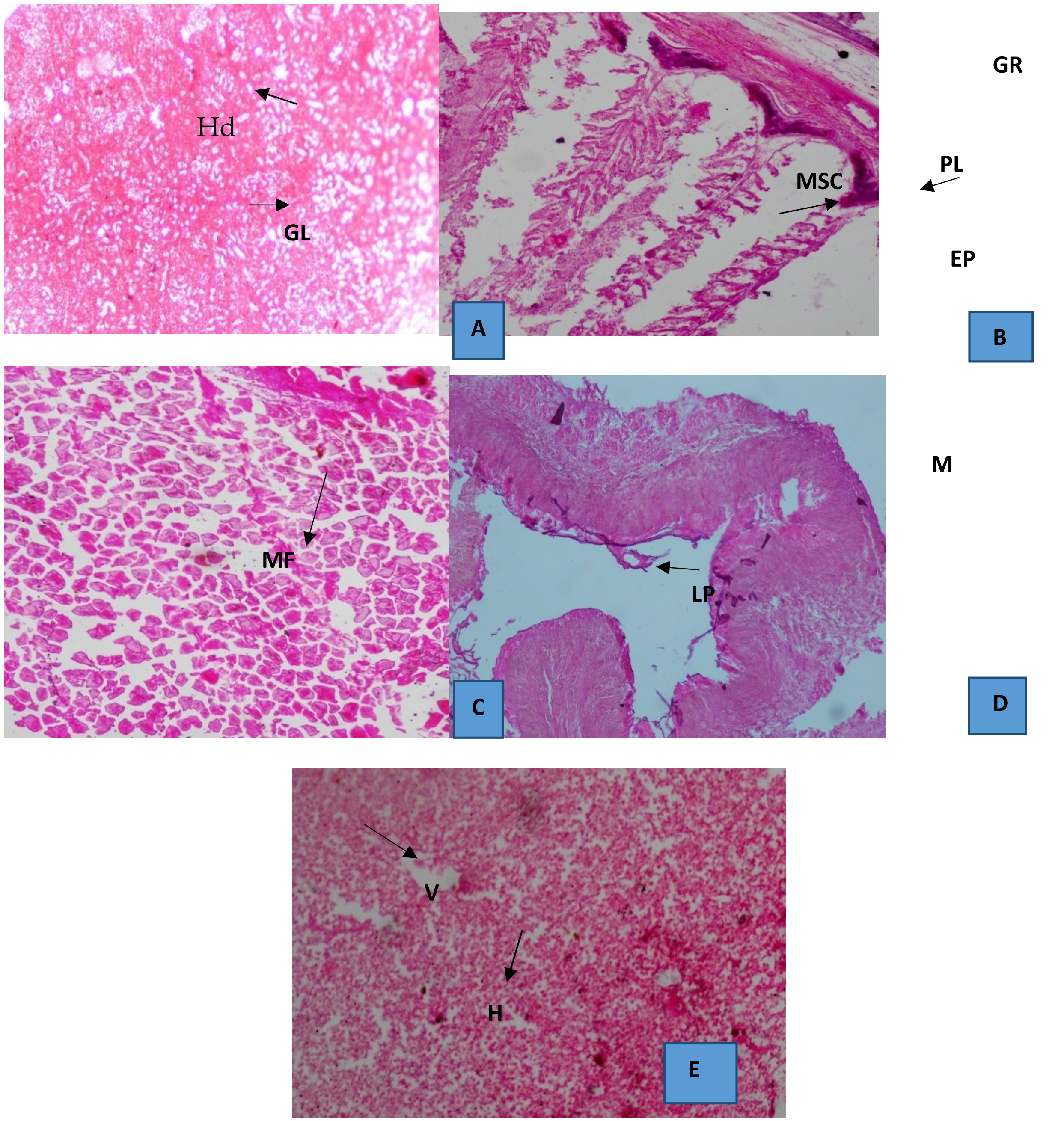

Figure 40: Photomicrograph of *Wallago attu*: (A) kidney- hyaline droplets (Hd), glomerulus (GL); (B) gill- primary lamellae (PL), gill arch (GR), epithelial cell (EP), mucus secreting cell (MSC); (C) muscle- muscle fiber (MF); (D) intestine- mucosa (M), lamina propia (LP) and (E) liver - vacuums (v), hepatocytes (H). ** (H&E×100).

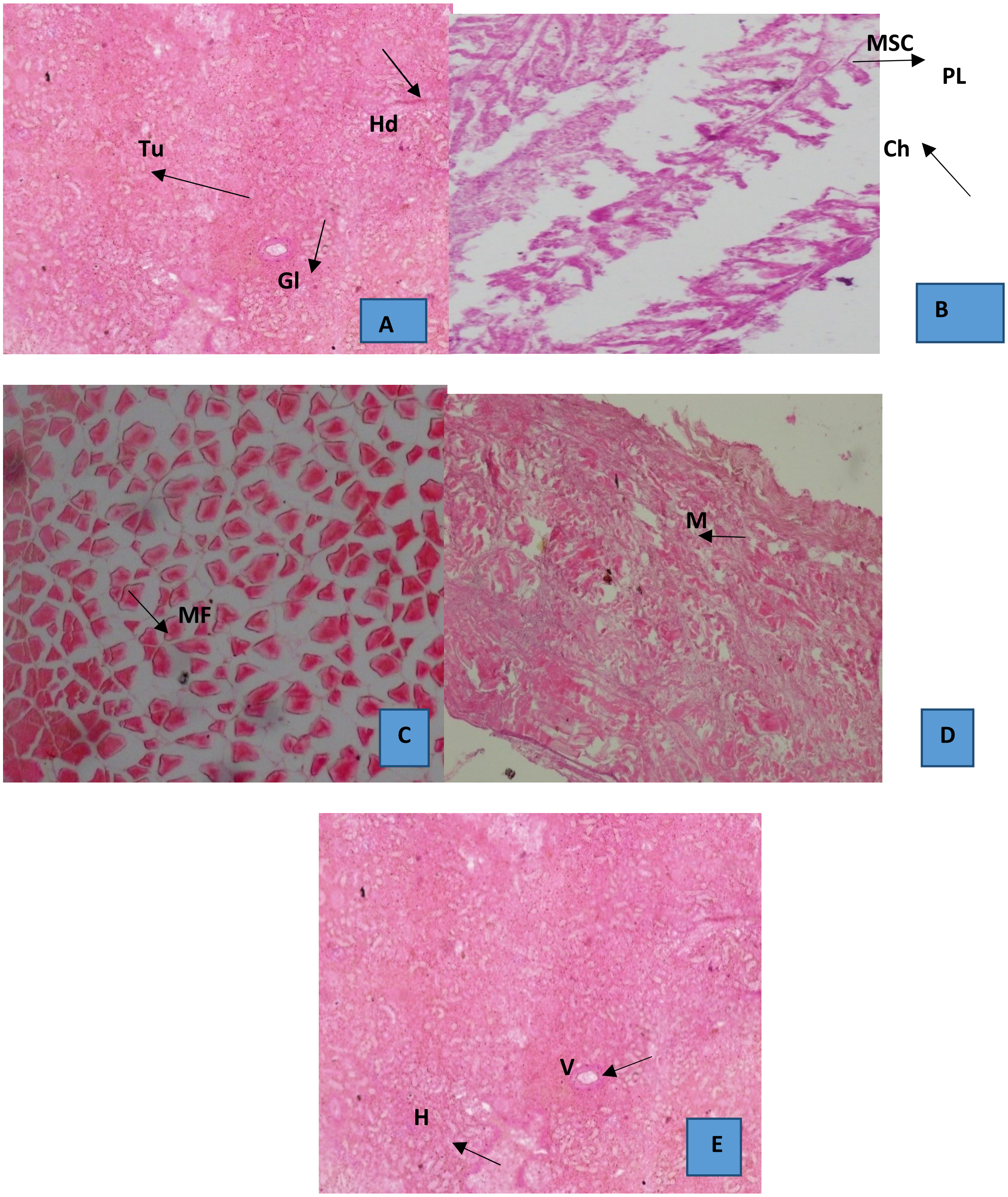

Figure 41: Photomicrograph of *Rita rita*: (A) kidney- glomerulus (GL), hyaline droplets (Hd), tubules (Tu); (B) gill- mucus secreting cell (MSC), primary lamellae (PL); (C) muscle- muscle fiber (MF); (D) intestine- mucosa (M); and (E) liver vacuums (v), hepatocytes (H). ** (H&E×100).

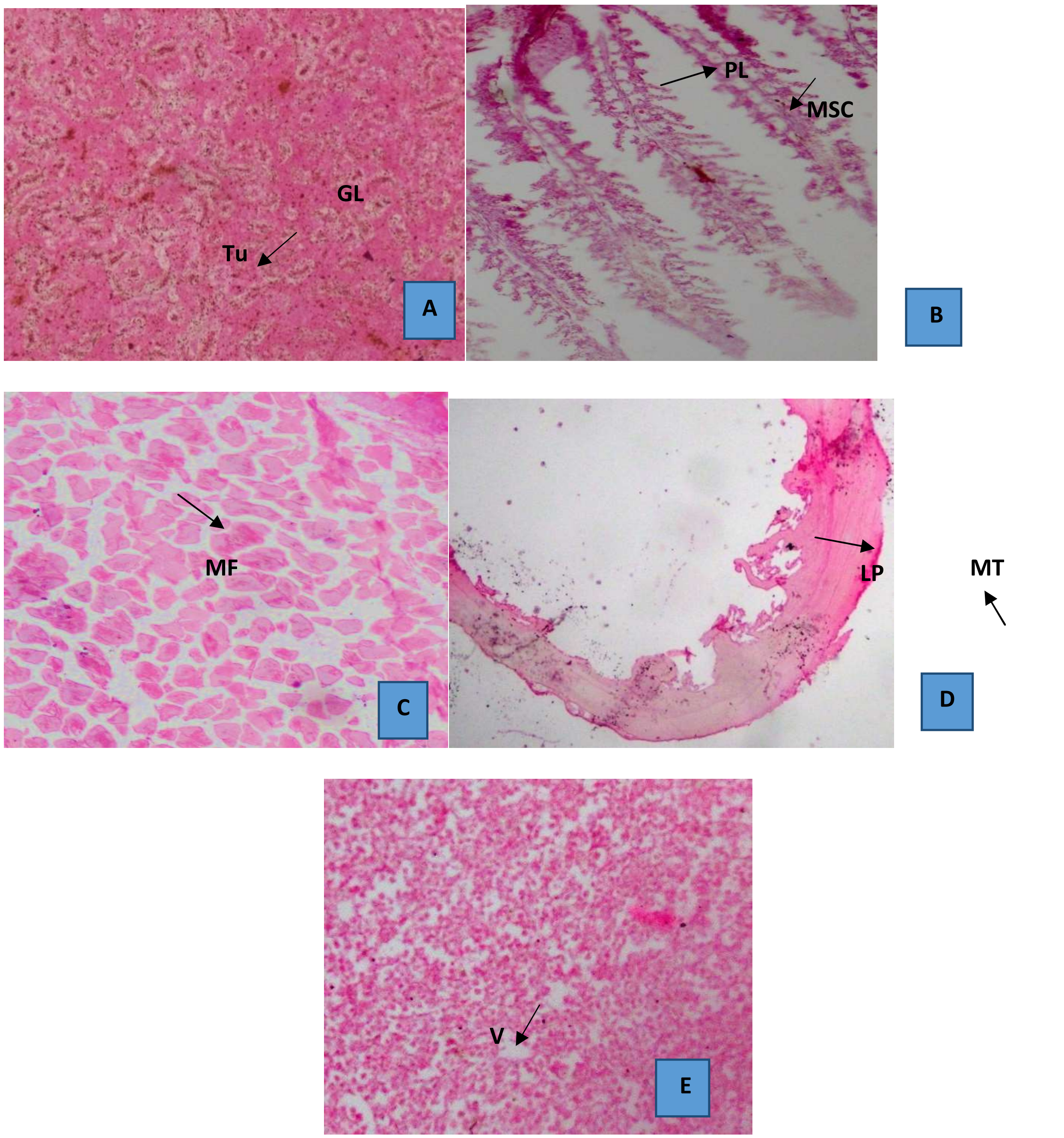

Figure 42: Photomicrograph of *Clarias batrachus*: (A)kidney- glomerulus (GL), tubules (Tu); (B)- gill- mucus secreting cells (MSC), primary lamellae (PL); (C) muscle- muscle fiber (MF); (D) intestine- muscular thickness (MT), lamina propia (LP); and (E) liver- vacuums (v).** (H&E×100).

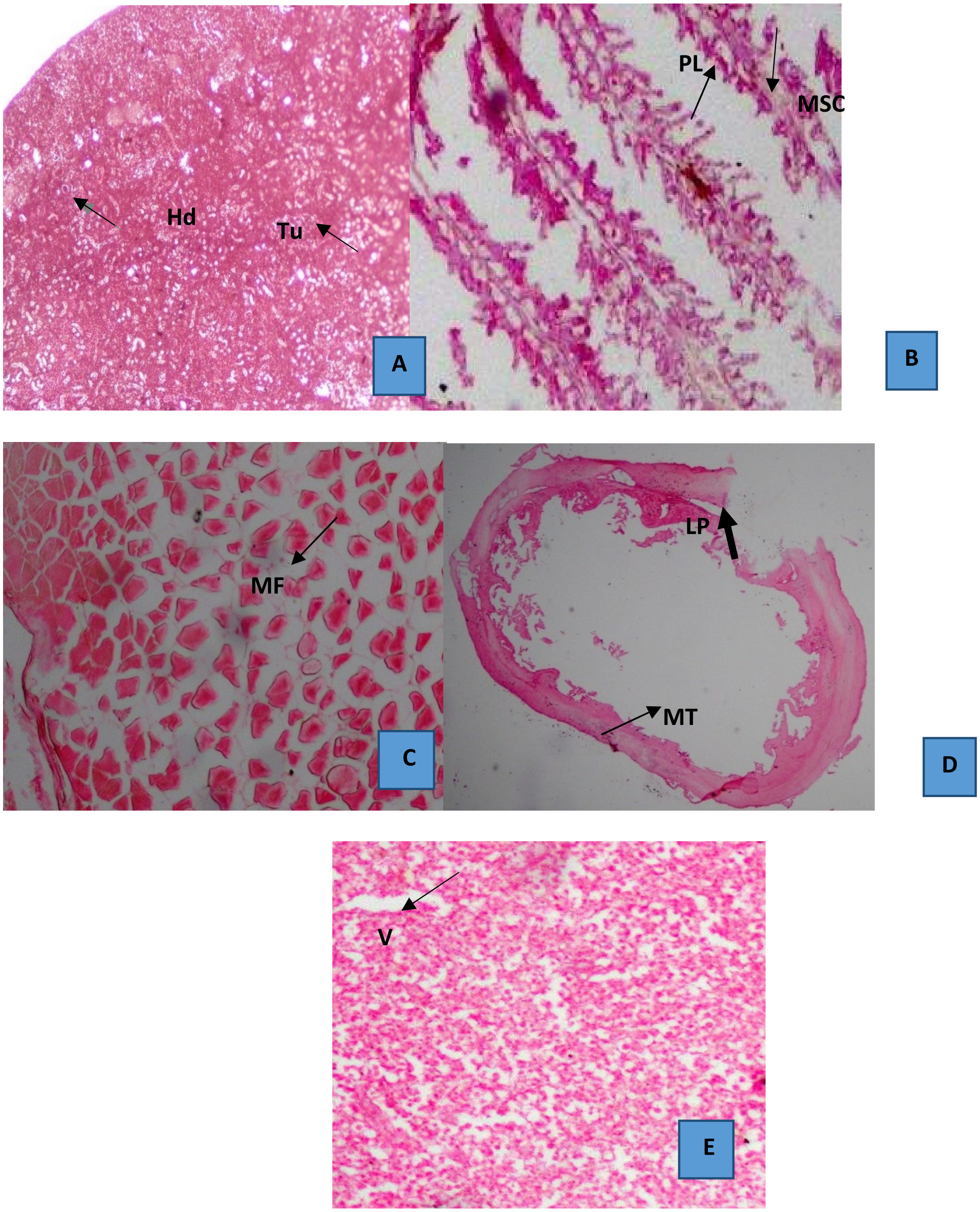

Figure 43: Photomicrograph of *Puntius sarana*: (A) kidney- hyaline droplets (Hd), tubules (Tu); (B) gill- mucus secreting cells (MSC); (C) muscle- muscle fiber (MF); (D) intestine- muscular thickness (MT), lamina propia (LP); and (E) liver- vacuums (v).
** (H&E×100).

Histologically, it was observed in present study that the organs of *Wallago attu, Rita rita, Clarias batrachus, Puntius sarana,* likes i.e. kidney, gill, muscle, intestine and liver was almost normal. In the kidney, the diameter of glomerulus and tubules were normal in all fishes. The structure of glomerulus and lumen in the collecting tubules was also normal in collected fish samples. Hyaline droplets were found in most of the fish kidneys sampled in Kishoreganj haor region. Silva and Martinez (2007) showed that different pollution factors caused to formation hyaline droplets in fish kidney. The occurrences of hyaline droplets in the fish kidney may be due to changing of water quality parameters in Kishoreganj haor region.

Histological analysis of the fish gills in the present study revealed that the secondary gill lamellae were missing and large number of mucus secretion cells was found in all samples. The glucoconjugates produced by mucous secreting cells isolate the gill from the external environment. The basic function of mucous secretion cells is protection. Mucous cells also contribute in various functions, such as ion exchange and gas exchange, antimicrobial activity and pH balance (Diaz *et al.,* 2001). Perry and Laurent (1993) stated that morphological changes in the gills represent adaptations that occur as a response to environmental changes. The occurrences of large mucus secreting cells in fish gill may be due to climate change to adapt in adverse environmental condition.

In the present study, no effect was found from the histological analysis of fish muscle and intestine. Muscle and intestine composition may not be changed with environmental change of water quality parameters. Similar result was also found by Oğuz (2015). According to Freire *et al.* (2008) osmoregulation capacity, adaptation to different halophilic areas, and euryhalinity levels were provided by the muscle water. Muscle water content remained unchanged with acclimation to different halophilic area in many euryhalie species (Jensen *et al.* 1998; Tang *et al.* 2009).

Liver was almost normal except vacuums in fishes. Change in water quality parameters had a serious effect on fish liver. The liver is the main organ for detoxification (Dutta *et al.,* 1993) that suffers serious morphological alterations in fish (Rodrigues and Fanta, 1998). Alterations in the liver may be useful as markers that indicate prior exposure to environmental stressors. Similar result was also found by (Fanta *et al.,* 2003) in the *Corydoras paleatus* exposed to methyl parathion. The occurrences of vacuums in the fish liver may be due to changing of water quality parameters in Kishoreganj haor region.

12. Research highlight/findings (Bullet point – max 10 nos.):

- Decreased Ganges riverflow and sealevel rise due to global warming accelerate the high rate of salinity intrusion in the rivers of Sundarbans and othe major rivers day by day. As a result, water quality parameters are fluctuated and directly or indirectly impact on primary productivity and fisheries resources. In fact, breeding and nursery ground of many fish species may hamper.
- Primary and secondary productivity of the Sundarbans, Meghna, Padma, Bay of Bengal and Kishoreganj haor are decreasing day by day.
- Fish species are decreasing in the Sundarbans, Meghna, Padma, Bay of Bengal and Kishoreganj haor.
- Climate change impacts on fishers' community, caused serious problems such as outbreaks diseases, lack of freshwater, lack of foods, lack of lands, lack of economic support and lack of other facilities. Flood, cyclone, siltation, erosion and windstorm were common in Sundarbans and coastal regions at present. Now thunder storm is also added with these natural calamities. All of these natural calamities were happened because of climate change.
- Shelters construction for protecting fishers from disaster (thunder) particularly in the haor.
- Alternative livelihood opportunity must be developed in these areas for diminishing fishers' sorrow and increase development.

- In all regions women and children were found to be affected severely such as malnutrition, lack of education, lack of treatment opportunity, early marriage etc.

B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP Target		Achievement		Remarks
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
(a) Office equipment	Furniture (Table and chairs) Desktop computer and accessories Laptop computer Printer	50000 60000 60000 20000	Furniture (Table and chairs) Desktop computer and accessories Laptop computer Printer	50000 60000 60000 20000	1oo% Achievement
(b) Lab &field equipment	Salinometer Oxygen meter pH meter Plankton collection net (4) Portable electronic balance Digital camera	40000 30000 30000 20000 20000 25000	Salinometer Oxygen meter pH meter Plankton collection net (4) Portable electronic balance Digital camera	40000 30000 30000 20000 20000 25000	1oo% Achievement
(c) Other capital items					

2. Establishment/renovation facilities: N/A

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. Training/study tour/ seminar/workshop/conference organized: N/A

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop					

C. Financial and physical progress

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance / unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	741,120	741,120	708,575	32,545	100%	Salary for one month laps
B. Field research/lab expenses and supplies	2147,880	2070,715	2004,195	66520	95%	-
C. Operating expenses	780,000	780,000	777,987	2013	100%	-
D. Vehicle hire and fuel, oil & maintenance	200,000	200,000	196120	3880	100%	-
E. Training/workshop/seminar etc.	-	-	-	-		
F. Publications and printing	220,000	18,000	17250	750	30%	Research articles submitted to the journals and preparing to submit to the journal; PCR will publish by the PIU
G. Miscellaneous	40,000	40,000	39900	100	100%	100% Achieved
H. Capital expenses	371,000	371000	370900	100	100%	100% Achieved
	4500,000	**4220,835**	4114927	105908	95%	

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	**Major technical activities performed in respect of the set objectives**	**Output(i.e. product obtained, visible, measurable)**	**Outcome(short term effect of the research)**
To determine the changes in livelihood (education, health, nutrition, water sanitation, children and women protection and migration) of fishers´ particularly women	i. Development of questionnaire; ii. Survey to the climate hotspot zone;	i. Prepared questionnaire; ii. Collected data iii. Perodical reports iv.PCR v. Masters thesis vi.Journal articles	Policy maker gets the guideline to take the adaptive measures for the fishers of Bangladesh

and children in selected climate hotspot zone;			
To determine the change in availability of fish species through survey, as well as the primary productivity and water quality parameters of climate hotspot zone and non-affected areas;	i. To determine the available fish species in selected climate hotspot zones; ii. To measure the temperature, dissolved oxygen, CO_2, pH, salinity; iii. To identify the Phyto/ zooplankton in in selected climate hotspot zones	i. Collected data ii. Perodical reports iii. PCR iv.Masters thesis v. Journal articles	Researchers will be benefitted to conduct their present and future research
Histopathological analysis of gonad, liver, gills, muscles and kidney of the fishes of climate hotspot zone with those of non-affected ones and evaluation of eggs and sperm quality.	i. To collect the fish sample from the selected sampling points once in a month ii. Histology of organs (gills, liver, kidney, gonads etc.)	i. Prepared histology slides ii. Photos of histology	Researchers will be benefitted to conduct their present and future research

E. Materials Development/Publication made under the Sub-project:

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.			
Journal publication	Expecting 10-12 journal articles; Six articles submitted.		
Information development			
Other publications, if any		Three MS thesis completed	Annexure-1

F. Technology/Knowledge generation/Policy Support (as applied):

i. **Generation of technology (Commodity & Non-commodity)**

N/A

ii. **Generation of new knowledge that help in developing more technology in future**

These data will be a valuable baseline to conduct research on climate change.

iii. **Technology transferred that help increased agricultural productivity and farmers' income**

N/A

iv. **Policy Support**

Policy makers need to develop appropriate adaptive measures for protecting the fishers from thunder stroms happening due to climatic changes. National climate policy and guidelines need to be updated using the data generated by this project.

G. Information regarding Desk and Field Monitoring

i) **Desk Monitoring:**

- CRG Sub- Project Implementation Progress Workshop/Seminar held in BARC, Farmgate Dhaka on 21 December 2017. Advised for further improvement.
- CRG Sub-Project Final output Workshop held in BARC, Farmgate Dhaka on 19-20 September 2018. Satisfied with the outcome.

ii) **Field Monitoring : N/A**

H. Lesson Learned/Challenges (if any)

i) Survey work is harder particularly in the remote and security concern areas of Sundarbans.
ii) Motivation was necessary to get the information from the fishers.

I. Challenges (if any)

Volume of work was huge but time was short. It was our challenge to complete this big volume of work within short time.

Signature of the Principal Investigator
Date ………………………….
Seal

Counter signature of the Head of the organization/authorized representative
Date …………………………..
Seal

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