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Jagannathpur Upazila



Report on Climate Risk and Vulnerability Assessment and Climate Resilience Action Plan for Aquatic Ecosystem

2024

Project: Community Based Climate Resilient Fisheries
and Aquaculture Development in Bangladesh



Report on Climate Risk and Vulnerability Assessment and Climate
Resilience Action Plan for Aquatic Ecosystem

Jagannathpur Upazila

2024

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Abbreviations

AIGA	Alternate Income Generating Activity
AR5	IPCC Fifth Assessment Report
AT	Air Temperature
BBS	Bangladesh Bureau of Statistics
BDT	Bangladeshi Taka
BFRI	Bangladesh Forest Research Institute
BMD	Bangladesh Meteorological Department
BMDA	Barind Multipurpose Development Authority
BOD	Bio-chemical Oxygen Demand
BPP	Biodiversity Protection Program
BWDB	Bangladesh Water Development Board
CBO	Community based Organization
CC	Climate Change
CC&DRR	Climate Change and Disaster Risk Reduction
CEGIS	Center for Environment and Geographic Information Services
CIS	Climate Information Services
CMIP5	Coupled Model Intercomparison Project Phase 5
CMIP6	Coupled Model Intercomparison Project Phase 6
COD	Chemical Oxygen Demand
CORDEX	Coordinated Regional Climate Downscaling Experiment
CPUE	Catch Per Unit Effort
CRA	Climate Resilience Action
CRV	Climate Risk and Vulnerability
CRVA	Climate change Risk and Vulnerability Assessment
DAE	Department of Agricultural Extension
DBHWD	Bangladesh Haor and Wetland Development Board
DGHS	Directorate General of Health Services
DJF	December January February
DO	Dissolved Oxygen
DoE	Department of Environmet
DoF	Department of Fisheries
DRR	Disaster Risk Reduction
DSS	Department of Social Services
DYD	Department of Youth Development
EAA	Ecosystem Approaches for Aquaculture
EAF	Ecosystem Approach to Fisheries
EbA	Ecosystem Based Adaptation
EC	Electrical conductivity
ECA	Ecologically Critical Area
EQS	Environmental Quality Standard
ES	Ecosystem Services

ETP	Effluent Treatment Plant
EUS	Epizootic Ulcerative Syndrome
EWS	Early Warning System
F&A	Fisheries and Aquaculture
FAO	Food Agriculture Organization
FFWC	Flood Forecasting and Warning Center
FGD	Focus Group Discussion
FRSS	Fisheries Resources Survey System
FW	Fresh Water
GCM	General Circulation Model
GED	General Economic Division
GIS	Geographic Information System
HYV	High Yielding Variety
ICT	Information and Communication Technology
IFF	Integrated Fish Farming
IGA	Income Generating Authority
IPCC	Intergovernmental Panel on Climate Change
IUU	Illegal, Unreported and Unregulated
JJAS	June July August September
JRC	Joint River Commission
KII	Key Informant Interview
LGD	Local Government Division
LGED	Local Government Engineering Department
LGI	Local Government Institutes
MAM	March April May
MoDMR	Ministry of Disaster Management and Relief
MoEFCC	Ministry of Environment, Forest and Climate Change
MoF	Ministry of Finance
MoLJPA	Ministry of Law, Justice and Parliamentary Affairs
MoS	Ministry of Shipping
MoWCA	Ministry of Women and Children Affairs
MoWR	Ministry of Water Resources
MP	Muriate of Potash
MSL	Mean Sea Level
MT	Metric Tons
NCVA	Nationwide Climate Vulnerability Assessment
NGOs	Non-Government Organization
NRCC	National River Conservation Commission
NWRD	National Water Resources Database
ON	October November
PAs	Protected Areas
PES	Payment for Ecosystem Services
RAS	Recirculation Aquaculture Systems
RAWES	Rapid Assessment of Wetland Ecosystem Services
RHD	Roads and Highways Department
RSEMF	Rainfall Sensitive Environment for Migratory Fishes

RSERF	Rainfall Sensitive Environment for Resident Fishes
SGR	Specific Growth Rate
SLR	Sea Level Rise
SSP	Shared Socioeconomic Pathway
SPARRSO	Space Research and Remote Sensing Organization
SUFO	Senior Upazila Fisheries Officer
SWOT	Strength, Weakness, Opportunities and Threats
TDS	Total Dissolved Solids
TSE	Temperature Sensitive Environment
TSP	Triple Super Phosphate
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations Office for Disaster Risk Reduction
WARPO	Water Resources Planning Organization
WSS	White Spot Syndrome
WT	Water Temperature

Executive Summary

Bangladesh's economic, nutritional, and social reliance on the fisheries sector makes it extremely vulnerable to the effects of climate change on fisheries. Climate change adaptation plans are essential to reduce these vulnerabilities. At the moment, Bangladesh's early warning system (EWS) does not include particular messages on fishers' and fish farmers' readiness, thereby affecting community's capacity to respond to climate change hazards, particularly women and children. Therefore, climate-related risks and vulnerabilities affecting the fisheries and aquaculture sector, putting a particular emphasis on gender, need to be identified and analyzed at the national and local levels.

The current study evaluated climate change vulnerability of Jagannathpur Upazila of Sunamganj District of the Sylhet Division of Bangladesh, as it is one of the most severely affected regions by recent catastrophic climatic events, such as flash floods of 2010, 2017, and 2022. The land elevation of Jagannathpur Upazila mostly varies between 2 to 8 m. Flash floods in this region inundates crops, damages pond fishery and creates negative impacts on the local economy, damages infrastructure by erosion and often causes loss of lives and properties. The fish production as well as the agriculture sector, were severely damaged by the 2017 flash flood.

Besides flash floods; droughts, lightning, heat stress, etc. have severely affected the people living in this region. Tremendous rise in apparent temperature in the North-East zone causes fish farmers in Jagannathpur to face numerous challenges, most importantly oxygen level drop in water and various viral, bacterial and fungal diseases. Droughts cause drying up of waterbodies and have adverse impacts on aquaculture and inland open-water fisheries in some areas in Jagannathpur. The lightning susceptibility of the North-East zone is comparatively higher than other zones of Bangladesh and locals reported the spawning and breeding of fisheries to have been affected by this. Land erosion due to wave action is another major problem in this area.

Future climate projections by CEGIS (2022) show that, maximum temperature will rise by 1.7°C and 1.2°C during winter and summer respectively in 2050s for SSP5-8.5 when compared to 1981-2010. Likewise, minimum temperature will rise by 1.5°C and 1.2°C during winter and summer respectively in 2050s for SSP5-8.5 when compared to 1981-2010. Future rainfall projections show that rainfall will decrease during DJF, JJAS and ON season by 74%, 4% and 48% respectively, and increase in MAM by 37% while the total annual rainfall will be increased by around 3% in the 2050s when compared to the base period 1981-2010 under SSP5-8.5.

An assessment was also undertaken regarding changes in water bodies. The permanent and seasonal water bodies were found to have decreased from 1990 to 2020 by 19.58% and 42.5% on average respectively. The reasons behind these changes are many, including the aftermath of erratic and insufficient rainfall. Due to rising bed levels caused by sediment deposition, the internal khals and canals have created drainage problems for the haor area and the sedimentation in beels have hampered the fisheries and agricultural activities. As a result, the ecosystem in and around the haors have become vulnerable, in regards to increased exposure and sensitivity, and reduced adaptive capacity.

The water quality tests undertaken found that water quality parameters were within allowable range and suitable for aquaculture. In a study by Rodgers (2008) was found out that fish mortalities occur in relation to harmful algal blooms during summer. This occurrence was also reported by communities who observed high fish mortalities during summer. The vulnerability assessment found that Haldipur, Mirpur and Raniganj unions were highly vulnerable to climate change induced hazards and also had low adaptive capacity. Climate change risk on ecosystem was assessed for the base period (2011) and 2050s. In this case, Mirpur, Haldipur, Jagannathpur Pourashava, Pailgaon and Asharkandi unions were found under high risk in both time slices.

The study further estimated that the magnitude of temperature induced stress on river seasonal migratory fishes will increase in the 2036-2065 and 2070-2100 under SSP1-2.6 scenario by 0.41% and 0.22% respectively with increasing 1°C mean water temperature. However, this magnitude decreased by 0.19%

with increasing 1°C mean water temperature under SSP5-8.5 scenario. It was also noted that, the magnitude of the temperature induced stress on resident fishes increased in SSP1-2.6 scenario and decreased in SSP5-8.5 scenario with increasing minimum temperature. Sensitivity of capture fisheries was assessed through indicator-based analysis where it was found that Kalkalia, Mirpur, Patali, Syed Pur and Jagannath Paurashava unions were found highly sensitive to climate change induced hazards. Sensitivity assessment of culture fisheries show Kalkalia to be highly sensitive to climate change induced hazards. Adaptive capacity assessment reveals that Kalkalia, Mirpur, Patali and Syed Pur unions have high adaptive capacity for capture fisheries whereas all the unions have low adaptive capacity for capture fisheries. Climate change induced hazard risk for capture fisheries impact chain analysis showed Kalkalia union in high risk and Haldipur and Asharkandi unions under moderate risk for the base period. In 2050s Haldipur and Asharkandi unions will be in high risk zone along with the high-risk union at the base period. For culture fisheries, Kalkalia union was in high risk and Haldipur, Asharkandi, Jagannathpur Pourashava and Pailgaon unions were in moderate risk for base period. In 2050s, Haldipur and Asharkandi will be in high risk zone and Raniganj will be in moderate risk zone as well.

Most of the women in Jagannathpur are involved in household related activities with only a few of them involved in fry collection, net making, pond preparation and culture fishing. However, these women involved in fish related activities were found to earn little from these compared to male counterparts. Exposure for gender-based livelihood analysis showed Haldipur union was highly exposed, whereas sensitivity analysis showed Asharkandi, Kalkalia, Mirpur, Pailgaon and Raniganj unions were highly sensitive for gender-based livelihood. Adaptive capacity assessment revealed that all the unions had low adaptive capacity for gender specific fisheries livelihood. Risk assessment shows Kalkalia, Haldipur and Asharkandi unions are in high risk for gender-based livelihood in both time periods. On the other hand, Pailgaon, Raniganj unions and Jagannathpur Pourashava are in moderate risk zone for both time slices. Initially, Mirpur union was in low risk at the base period but in 2050s due to increased impact of climate change induced hazard it showed moderate risk.

Gender inclusive climate resilience action plan for aquatic ecosystem, capture fisheries and culture fisheries livelihoods are proposed. These adaptation action plans include structural and non-structural options, considering all the existing climate hazards in the study area such as cyclone, storm surge, salinity intrusion, drought, lightning, etc. For capture fisheries, adaptation actions include the development of climate-smart open water fisheries management, restoration of connectivity between the habitats, strengthening gender inclusive EWS for fisheries and aquaculture sector etc. Adaptation actions centering the culture fisheries include promotion of IoT based technology, climate resilient technology for combating climate related stresses in aquaculture, such as development of stress tolerant species of commercially important fish and species diversification.

1 Introduction

1.1 Background

Every sector, including fisheries and aquaculture (F&A) in Bangladesh is experiencing the adverse impact of climate change. Communities that depend on the F&A sector for their livelihood are already experiencing losses and damages due to climate change impacts. The uncertain future climate appears to be making things worse in addition to the inadequate capacity for climate-resilient planning at the governmental and community levels being a key barrier to effective adaptation strategies. Governments and local communities must therefore improve their capacity to assess, plan, implement, and track adaptation to climate change impacts on the fisheries and aquaculture sectors.

Climate change adaptation planning is complex as it requires short- and long-term planning to address short-term adaptation measures and long-term climate scenarios. Such planning can only be possible if long-term climate information for trend and impact analysis is generated and maintained in a reliable database. Consistent and proper synchronization between discrete data sets (e.g., the Bangladesh Meteorological Department's site-specific and time-series climate data, and the Department of Fisheries' (DoF) site-specific fisheries datasets) is required for assessing the impacts of climate change on the F&A.

The study is one of the first initiatives to assess climate change risk and vulnerability, particularly for the Fisheries and Aquaculture (F&A) sector. CRVA is performed for capture fisheries, culture fisheries, aquatic ecosystems, and gender engagement in the fishing sector, illustrating the variations of risk and vulnerability levels up to the union level. Further, this assessment is unique as it follows the latest IPCC AR5 approach, i.e., impact chain and indicators-based approach for CRVA, and utilizes all available latest data, including the downscaled datasets of ensembles of GCMs from CMIP6. Performing SWOT for services provided by the aquatic system is also done as a first initiative to facilitate the CRVA, identify climate-sensitive ecosystems, and develop a climate resilience action plan.

The findings from this study contributes to knowledge enhancement and awareness about the impacts of climate change at the national and local levels with a particular emphasis on gender issues. The CRVA will strengthen knowledge on climate-resilient F&A through natural resources and disaster management planning. Additionally, the study provides insights and/or recommendations as regards to mainstreaming disaster risk reduction/management in local development plans and programs for enhanced climate change resilience.

1.2 Study objectives

The overall goal of the study was to conduct a comprehensive Climate Change Risk and Vulnerability Assessment (CRVA) of the F&A sector by highlighting the risk and vulnerability of local fishers, and fish farmers from the observed and predicted effects of climate change on F&A livelihood with particular focus on women for Jagannathpur Upazila. Specifically, the study aimed to:

- Assess detailed climate risks and vulnerabilities on F&A in the project site (Upazilas) in the integrative approach of participatory and scientific tools.
- Assess climate risks and formulate climate-resilient action plans for fishery ecosystems
- Identify and map out climate change-sensitive areas for F&A in Jagannathpur Upazila

1.3 Approach of the study

This study was conducted following the developed CRVA framework¹ for the F&A, through collecting and analyzing datasets from both scientific and participatory approaches. Three types of participatory tools

¹ FAO (2022). Draft National Level Climate Risk and Vulnerability Assessment for Fisheries and Aquaculture (F&A) Sector in Bangladesh.

were used: Focused Group Discussions (FGDs), Community Surveys, and Key Informant Interviews (KIIs). The study conducted 3 FGDs with Community based Organizations led by Women, capture fisheries group and culture fisheries group/fish farm owner. Senior Upazila Fisheries Officer (SUFO), fish trader and beel owner were interviewed for KIIs. Three community surveys at Badaura, Jagannathpur municipality were conducted to collect primary data of different indicators as developed under impact chains for capture fisheries, culture fisheries, aquatic ecosystem and gender-based F&A livelihoods. A catch assessment survey was conducted in nearby fish landing stations to assess the species diversity, uniformity or evenness, availability of species and fish production. Focus Group Discussions (FGDs) were conducted in Jagannathpur Upazila with mostly groups of people from the fishing community to collect qualitative information regarding hazards, exposure, vulnerabilities, existing coping mechanism or adaptation practices, and challenges of gender for risk reduction, livelihood mapping, ecosystem vulnerability assessment etc. The primary focus of the FGDs was to customize of the impact chain, particularly for their project site and extract weights of identified elements by them. For FGDs, about 12 people, both male and female. Aged between 25-65 years were chosen.

In this study, the water temperature was calculated from the air temperature by applying the global conversion coefficient value for flowing water bodies:

$$WT_{Wet\ Season} = 1.2195 * AT - 6.0976; WT_{Dry\ Season} = 1.1842 * AT - 2.0395;$$

where, WT = Water Temperature and AT = Air Temperature

This study also calculated the instantaneous rate of natural mortality (M; 1/year), which refers to the mortality of a generation (from late juvenile to adult phases) of a population and was calculated here from Pauly's empirical equation based on the parameters of the von Bertalanffy growth function and on the mean water temperature (T) (Pauly et al., 1980).

$$M = 10^{(0.566 - 0.718 * \log(L_{inf}) + 0.02 * T)}$$

where, M = Natural Mortality, T = Mean Water Temperature and L_{inf} = the length that the fish of a population would reach if they were to grow indefinitely also known as asymptotic length

In situ water quality parameters were collected from major river, ponds and haors for laboratory tests to assess the habitat condition. SWOT (Strength, Weakness, Opportunities and Threats) analysis was performed for numerous ecosystem services to facilitate the development of climate resilience action plan. The process involved Focus group discussion (FGD), Community surveys, and Key Informant Interviews (KIIs), where participants were simply asked to share their perceptions about the Strengths, Weaknesses, Opportunities, and Threats (SWOT) of the four categories of ecosystem services (i.e. provisioning, regulating, supporting and cultural). Field observation findings were also used to validate the results. Respondent's answers were ranked by selecting the three most important themes within each of the four SWOT categories analysis (i.e. scores per respondent: 1=Less/Poor condition, 2=Medium/Good condition, 3=High/Better condition. A high score for Strength/Opportunities reflects Better/High Condition, but Less/Poor condition for Weakness/Threats. Scoring of different ecosystem services had been recorded and analyzed according to the concept from RAWES method (2017) and Land-cover scores for ecosystem service assessment (A Smith, & R Dunford; 2018). The scores of SWOT for each of the major ecosystem categories were estimated using arithmetic aggregation method.

In addition to primary data of different risk and vulnerability related indicators for open water fisheries, aquaculture, gender and aquatic ecosystem, data from various secondary sources such as FRSS, BBS, NWRD and CEGIS model-based outcome have been used to scrutinize and utilize datasets for relevant geo-spatial analysis of hazards, exposure, sensitivity, adaptive capacity, vulnerability and risk following the IPCC AR5 approach. Risk and vulnerability assessment were done based on blended approach of participatory appraisal techniques and scientific analysis for base and 2050s under extreme climate change scenarios. The arithmetic weighted aggregation method has been used to assess normalized score of climate risk and vulnerability for capture fisheries, culture fisheries, aquatic ecosystem and gender as per approved methodology of the CRVA framework. All relevant questionnaires and checklists for the primary surveys were developed and validated in consultation with the Department of Fisheries and FAO and later piloted

in the Dumuria Upazila. **Figure 2.1** in **Chapter 2** shows the survey locations for primary data collection. Photo album of surveys are illustrated in Annex III.

1.4 Limitations of the study

The developed CRVA framework will be useful as a benchmark to replicate the CRVA in other locations as well. Yet, there were limitations, some of the major limitations of the study include the following:

- Limited availability of adequate data and information to desired spatial and temporal level for different indicators
- Lack of gender or sex-disaggregated datasets
- Limited resources resulted in few representative samplings. For instance, union-level primary data collection was collected in 3-4 unions only, FGDs, KIIs, water samples were limited and collected data was attributed to all other unions through appropriate correlation and expert judgment.
- For future CRVA, only future projected climate and hazard data were used without socio-economic-related data due to a lack of data and resources.

2 Description of Project Area

This chapter provides the general description of the study area in the Jagannathpur Upazila, highlighting the geographical setting, hydrology, climate, land cover, demography of fisheries communities, etc. Further, the prevailing aquatic ecosystem and its services are outlined.

2.1 Geographical features

Jagannathpur is an Upazila in the Sunamganj District of the Sylhet Division of Bangladesh. It covers an area of 368.3 sq. km. It is surrounded by Balaganj and Biswanath upazilas of Sylhet district, Chhatak and South Sunamganj Upazilas on the north, Dirai on the west and Nabiganj Upazila of Habiganj district on the south and Jagannathpur Upazila on the east. The most dominant land use type here is rural settlement which covers about 37% of total land cover. Fresh water aquaculture is observed to be the second most dominant land type among the other classes. The croplands cover around 3870 ha area and 12% of total land cover. A total 8% of total land use is detected as brackish water aquaculture. Besides, the other remaining land types are less dominant compared to these land classes, which are namely brickfield, built up non-linear, multiple crops, ponds, rivers and khals, orchards, sand etc. The land elevation of Jagannathpur Upazila mostly varies between 2 to 8 m. It has been found that, almost no area is lying below Mean Sea Level (MSL) and about 70% of the areas lie between 4-8 m from Mean Sea Level, respectively. Jagannathpur is surrounded by small high land mass from north-east. The slope direction is from north-east to south-west. Places having lower elevation than 3.5 to 4m are filled with water in most of the months. These depressions are the sources of fresh water.

2.2 Hydrological system

The main rivers of Jagannathpur Upazila are Kushiara, Naljur. The region's primary source of fertile wealth is Kushiara River. The Naljur River is renowned for being a significant transportation route. Nollahr Haor is another major water body of Jagannathpur Upazila. It is a large source of fish. There are also some khals and beels containing fresh water. **Figure 2.1** illustrates the hydrologic system of Jagannathpur Upazila.

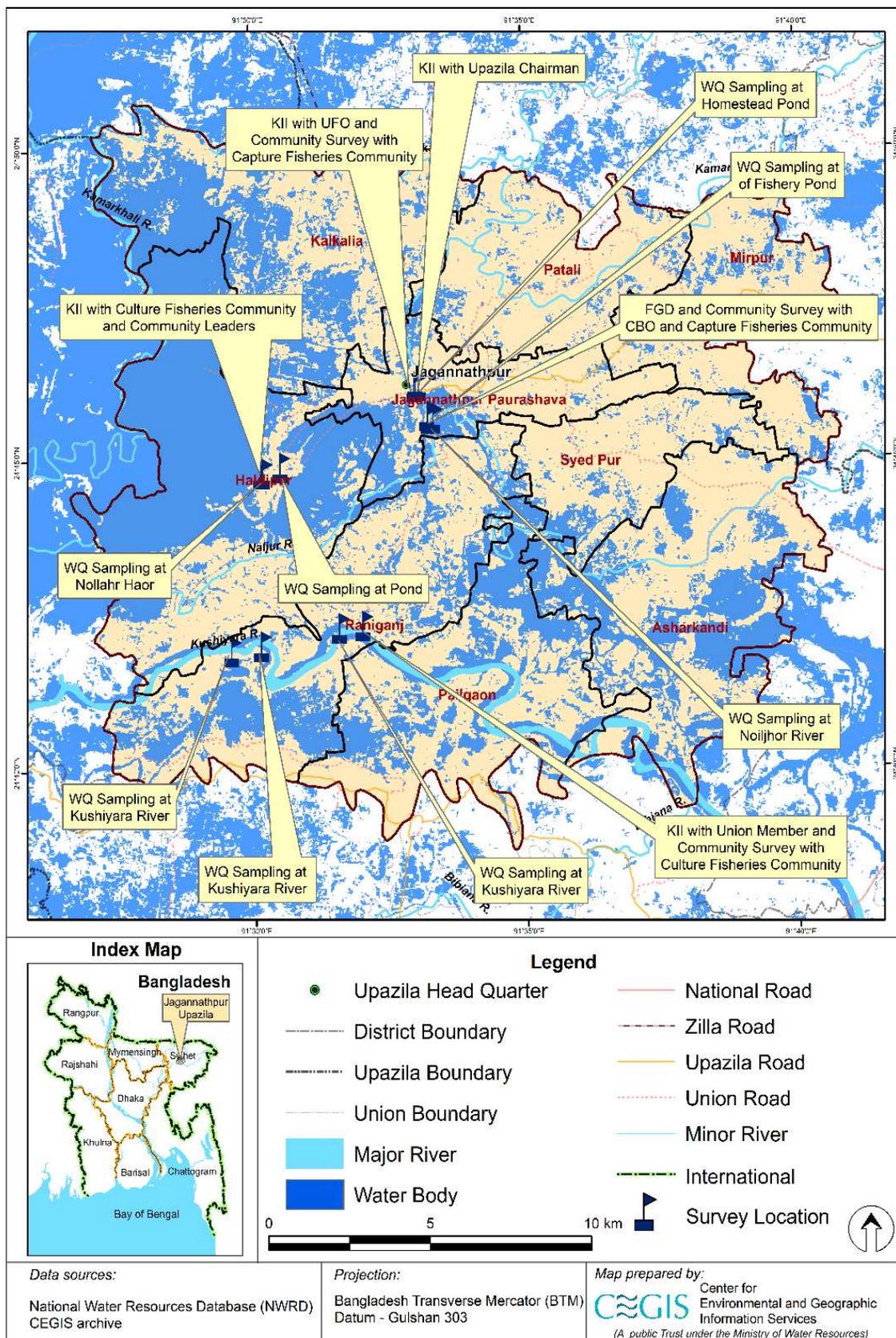


Figure 2.1: Hydrological system and locations of primary survey

2.3 Aquatic ecosystem and its services

The major aquatic ecosystem within the study area consists of river, haor and fish pond. Apart from major rivers described in Section 2.4, there are 260 Jalmahals, and 5010 ponds (835 ha) in Jagannathpur Upazila. The aquatic ecosystem provides numerous services in the project area including provisioning, regulating, supporting, and cultural services. Wetland ecosystem usually provides fresh water, fish, fuel wood, sand and gravel, and medicinal plants as provisioning services; it regulates seasonal floods, carries sediment, nutrients for aquatic plants and fauna, sequesters carbon, absorb heat, purify water naturally, transportation of freshwater, irrigation water for agriculture and flows for navigation purposes; supports diversified flora and fauna; additionally, promotes tourism.

2.4 Fisheries resources

Jagannathpur Upazila is very rich in fisheries resources due to having multiple rivers, connecting Khals, haors and beels. The Upazila comprises a huge water area covering of river 385 ha, Khal 21 ha, Beel 1,310 ha, floodplain 3,650 ha and pond 835 ha which contribute about 6,163 MT of fish annually. The Upazila has 8,420 registered fishers who engage in fishing activities in the nearer river, khal, beel or floodplain. Moreover, good numbers of fishers including male and female engage in fishing activities as subsistence fishers. In addition to this, a considerable number of people involve in trading related activities.

2.5 Demographic characteristics

Jagannathpur Upazila has 8 unions, 1 Paurashava, 262 mouzas and 334 villages. The Upazila has a population of 2,59,490; 50.1% male and 49.9% female. The density of population is 705 per km². Total no of household in this Upazila is 42,866 and the average household size is 6.05. According to BBS 2012, the overall literacy rate, based on the definition “ability to write a letter in any language” in the study area is 39.7%, in which male accounts to 41.1% and female accounts to 38.3%. The overall literacy rate is relatively lower compared to the national rate (51.8%). Main occupation of the people is agriculture, agricultural labour, fishing, foreign job, commerce, wage laborer, service, transport and forestry. People in this area are dependent on both capture and culture fishing. According to Jagannathpur Upazila Fisheries office, there are about 12,100 fishermen living in this area based on the capture fishing, among which 8,420 fishermen are registered. There are 52 co-operative societies for capture fishing and 19 for culture fishing.

3 Climate Change Induced Hazards

The study area faces natural disasters and slow onset events regularly and with various intensities. Many of them are driven by climate change as recognized by the community people. This chapter portrays the evidence of climate induced hazards in study area based on both community perceptions and scientific information. Both historical trends and future projections are assessed and described to highlight the potential impacts of climate change.

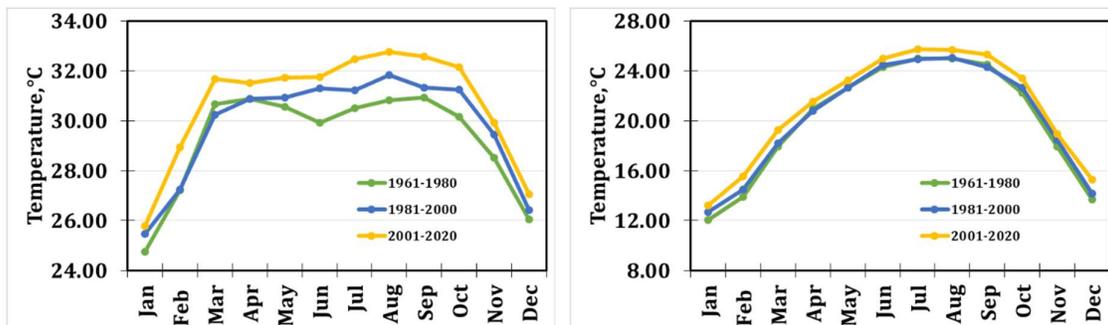
3.1 Climate change scenarios

3.1.1 Temperature

Temperature data analysis from 1961 to 2020 for Sylhet Station of Bangladesh Meteorological Department (BMD) station is presented in **Figure 3.1**. It depicts a significant increase in minimum and maximum temperature especially during August, September, and October in last two decades (20 years) than 1961-1980. During summer (March-May) average increase in maximum temperature was about 2.5°C and minimum temperature was 2.8°C while in winter season (December-February), minimum temperature increase was about 1.7°C in the last 20 years compared from 1961-1980. This variation in temperature, where both annual maximum and minimum temperature are found increasing during this last 20 years, might have substantial adverse impacts on fisheries biology and production.

Trend analysis of annual average maximum and minimum temperature reveals, the minimum temperature is increasing at a rate of (0.2°/decade) in 1961-1980, (0.7°C/decade) in 1981-2000, and then again at (0.12°C/decade) in more recent time slices. Whereas, annual maximum temperature has a decreasing trend in 1961-1980 but in next decade it had a significant increasing trend (0.4°/decade). Both annual maximum and minimum temperature are found increasing during this last 20 years' period, historically which might affect the readiness, maturity and gonad development of fishes in breeding season.

Future climate projections by CEGIS (2022) based on 1981-2010 data illustrate that, maximum temperature will rise 2.2°C and 0.9°C during winter and summer respectively in 2050s for SSP5-8.5. Likewise, minimum temperature will rise 1.7°C and 1.2°C during winter and summer, respectively, in 2050s for SSP5-8.5. Likewise, the minimum temperature will rise to 1.5°C and 1.2°C during winter and summer, respectively, in the 2050s for SSP5-8.5. The mean average maximum temperature of DJF, MAM, JJAS, and ON season will be 28.4°C, 32.2°C, 33.2°C and 31.6 °C for the 2050s, and the mean average minimum temperature of DJF, MAM, JJAS and ON season will be 15.6°C, 22.0°C, 26.2°C and 22.2°C for 2050s under extreme climate change scenario SSP5-8.5. Higher water temperature may bring changes in physiology and sex ratios of fished species, altered timing of spawning, migrations, and/or peak abundance, changes in timing and levels of productivity across marine and freshwater systems, increased invasive species, diseases and algal blooms.



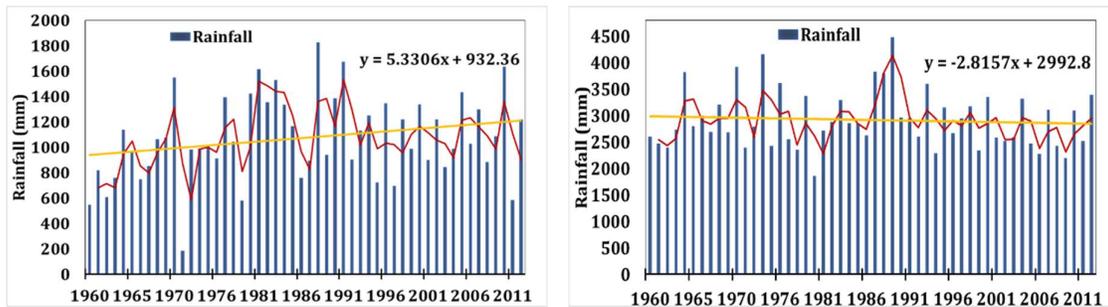
NWRD, BMD

Figure 3.1: Monthly average maximum (left) and minimum (right) temperature of Sylhet station

3.1.2 Rainfall variability

Rainfall analysis (1961-2020) for the dry season (October to March) and wet season (April to September) represents that the annual average dry and wet period rainfall is about 1076 mm and 2910 mm, respectively. Dry season rainfall is increasing at 5.3 mm/year, and that of the wet season is found to be decreasing at 2.82 mm/year (**Figure 3.2**). The area experiences distinct seasonal variations: the winter season (DJF) is dried and only contributes 1.36 percent of the total annual rainfall; the pre-monsoon hot season (MAM), receives 27.13 percent of the total rain; the rainy or the monsoon season (JJAS), receives 65.97 percent of the total annual rainfall and the post-monsoon (ON) receives 5.54 percent of the total annual rainfall. Rainfall can range from 227 mm to 1394 mm, during the rainy or monsoon season with June-July often having the highest rainfall.

The future projections show that rainfall will decrease during DJF, JJAS, and ON seasons by 74%, 4%, and 48%, respectively, and increase in MAM by 37% in the 2050s for the base period 1981-2010 under extreme climate change scenario. Total annual rainfall will increase by around 3%.

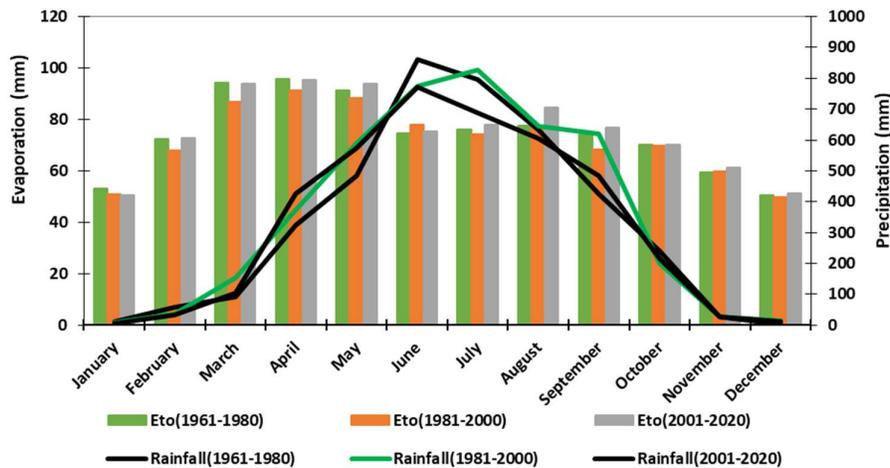


NWRD, BMD

Figure 3.2: Dry season (left) and wet season (right) rainfall at Sylhet station

3.1.3 Evaporation

Monthly variation analysis of evapotranspiration shows increasing trend during pre-monsoon and monsoon but decreasing trend during post-monsoon and dry season in 2001-2020 compared to 1981-2000. According to a study by Wang et al (2012), reduction in evapotranspiration is generally caused by both significant decreases in wind speed and sunshine hours. Furthermore, decreasing trend in evapotranspiration signifies the water stress at the root zone as soil water content is proportional to the evapotranspiration. **Figure 3.3** shows monthly variation of evapotranspiration and rate of evapotranspiration is increasing in recent years meaning higher water availability in this region.



NWRD, BMD

Figure 3.3: Monthly variation of rainfall and evaporation in Sylhet station

3.2 Climate hazards and its impacts

The Jagannathpur Upazila is particularly vulnerable to flash flood, wave action, drought, extreme hot days, river bank erosion, siltation, lightning, severe cold days etc. A total of 8 types of hazards (shown in the **Table 3.1** below) are identified by communities under this study. According to the respondents, the frequency and intensity of almost all reported hazards are increasing with high magnitude. For instance, flash flood and drought were ranked more impactful than lightning, wave action, extreme hot days, siltation etc.

Table 3.1: Hazard ranking by local community (2022)

Hazard	Ranking	Trends/Frequency	Intensity
		Increasing (↑)	High=3
		Decreasing (↓)	Moderate=2
		Static (↔)	Low=1
Flash Flood	1	↑	3
Wave Action	7	↑	2
Drought	2	↑	3
Extreme Hot Days	4	↑	3
River Bank Erosion	5	↔	3
Siltation	3	↑	3
Lightning	6	↑	3
Severe cold days	8	↔	2

CEGIS Field Survey, 2022

The present study identified five major climatic hazards for fisheries and aquaculture as found in Jagannathpur Upazila (**Figure 3.4**). Among the hazards, heavy rainfall is identified as the most prominent hazard for aquaculture. Moreover, fishing activities are highly exposed to extreme hot days. Furthermore, most of the fishers face the problem of fish handling and transportation to the existing fish landing sites and even fish markets during heavy rainfall.

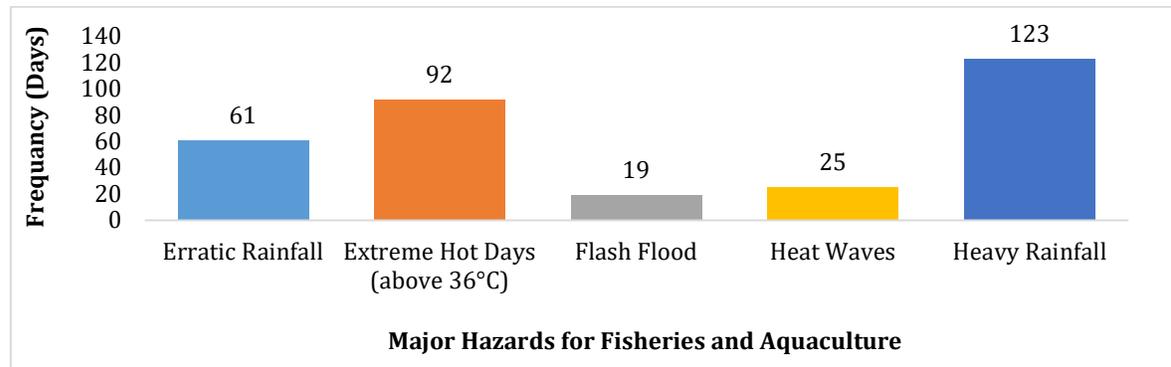


Figure 3.4: Frequency of climatic hazards on fisheries and aquaculture

CEGIS Field Survey, 2022

According to the hazard calendar developed by the fishing community, flash floods are the most devastating hazards of this region that has increased at present. Flash floods used to occur from mid-May to mid-July in the past, but now it occurs from mid-April to mid-September. The occurrence of droughts, the second-most devastating hazard in this region, used to occur from mid-February to mid-April, but now it starts from mid-January and lasts up to mid-April. The fishing community observed heat stress did not appear in the past, but it occurs from mid-March to mid-June and from mid-August to mid-September. Siltation used to happen from mid-May to August, and now it occurs from May to mid-September. Wave actions used to emerge from mid-April to mid-June and from September to mid-October. Now wave actions occur from mid-April to mid-October at a stretch. In this region, Lightning strikes during mid-April-May and September - mid-October, but now occurs from mid-April to mid-October at a stretch.

Heat wave

Heat wave frequency and severity are expected to increase in the future (Kirtman et al. 2013). About 39 heat waves in last 23 years (1989-2011) have been observed in Bangladesh (Hannah et al. 2017). With increased environmental temperature increase in bacterial decomposition, pH drops, imbalance between DO and CO₂, change in size and growth, high mortality, reduced digestion capacity and less food intake happen in fisheries, which decreases fisheries production and affects fishers' livelihoods. Due to this temperature rise, fish farmers in Jagannathpur Upazila are facing numerous challenges, most importantly various viral, bacterial and fungal diseases (Islam et al. 2018).

Flash floods

Flash flood is a common phenomenon in the northeast Haor region of Bangladesh due to the rivers' extreme flashiness and the abrupt, substantial rainfall in the area. In addition to carrying water, this floodwater also transports a substantial amount of sediment that comes primarily from hills. As a result, when flash flood due to sudden heavy rainfall creates pressure on the water resources system, water is easily overtopped creating breaching at several locations on the submersible embankment, eventually causing the water to quickly enter into the haor. According to the local people, Jagannathpur Upazila is highly vulnerable to flash flood because of its bowl-shaped large tectonic depression. The Upazila frequently gets affected by the flash floods as all the flood water from upstream hilly regions passes through the Upazila and falls into Meghna. It is one of the most impacted areas by recent devastating climate-induced events, i.e., flash floods of 2017, 2022, etc. Because of the maximum duration, flash flood damages in Haor areas were also greater in 2000, 2002, 2004, and 2010. (Salauddin, 2010). In most cases, flood water comes into the haor very early in the monsoon, and farmers do not get sufficient time to harvest their standing Boro crops. The 2017 flash flood damaged 149,224 hectares of Boro rice farming and 393,855 MT of rice in the Haors of Sunamganj. A total of 315,084 farms were impacted.

Almost every year, many fish farms in Jagannathpur also get flooded. Water gets contaminated in Ghers and ponds; fishes are washed away by flood currents, unwanted substances, and harmful creatures, different types of harmful species of insects and animals enter the fish farm with flood water. According to the Department of Fisheries, a total of 18,749 fisheries, including enclosures and fish farms in 11 Upazilas of Haor region have been inundated by the flash floods, forcing 2.13 crore fish fry and 2,305 tonnes of fish to get washed away by the flood waters in 2022. An estimated 7.2 million people have been severely affected following devastating flash floods which began in May 2022 with a second wave starting around 15 June 2022 in 9 northeastern districts of Bangladesh: Sylhet, Sunamganj, Moulvibazar, Habiganj, Kishorganj, Netrakona, Brahmanbaria, Mymensing, and Sherpur. Among the 9 districts, the 5 most heavily impacted districts are Sylhet, Sunamganj, Moulivazar, Habiganj, and Netrakona. (Source: UN). 131 people have died in these floods, according to DGHS. Flash floods damage river infrastructures and vegetation coverage yearly as they uproot trees and erode the soil, damaging existing river vegetation and ecosystems and ultimately hampering fish habitat. So, assessing the flash flood susceptibility, occurrence and extent can minimize the vulnerabilities induced due to flash food.

The flash flood extent map (**Figure 3.5**) shows that the flash floods in Jagannathpur will increase in the 2050s compared to the base period. It can be observed that in the base period, most parts of Haldipur, Kalkalia, Jagannathpur pourashava and some regions of Asharkandi get inundated by flash flood. Under SSP 5-8.5 in 2050s time period inundation increases and affects parts of Mirpur, Patali and Raniganj as well. The reason behind the increasing flash floods is the increasing trend of both dry and wet season rainfalls in this region. Amongst the anthropogenic causes, the increasing human settlements and encroachments are major reasons behind flash floods and drainage congestion in this area.

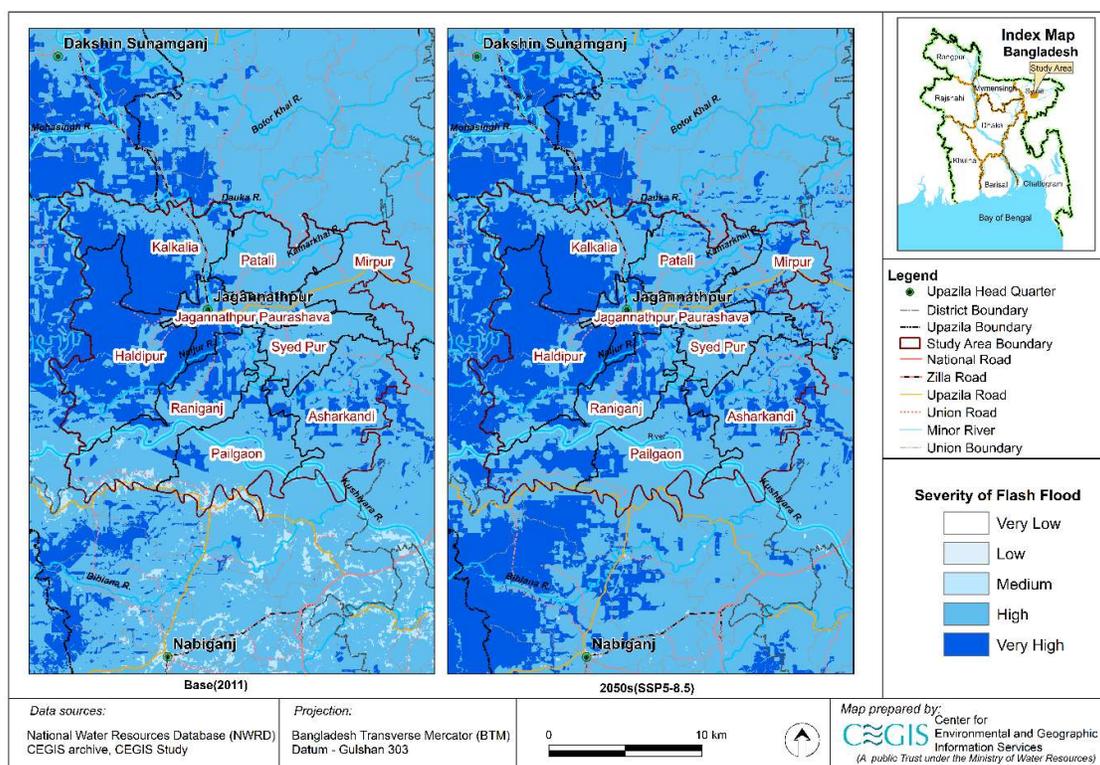


Figure 3.5: Flash flood severity in Jagannathpur Upazila

Drought

Droughts associated with high temperatures and low rainfall have adverse impacts on aquaculture and inland open-water fisheries in some areas in Jagannathpur. Ponds, rivers, canals, and beels dry or retain insufficient water during the dry/drought period, affecting fish production in aquaculture and open water systems in some localities of Jagannathpur. This also affects fish and other aquatic animals' migration, breeding, and growth.

Lightning

CEGIS (2022) analyzed lightning susceptibility of Bangladesh based on historical human death toll due to lightning based on BMD data. It depicted that the lightening susceptibility of North-East zone is comparatively higher than other zones of Bangladesh. Reportedly, untimely lightning and thunderstorms are increasing all over the country, which are anticipated to affect the spawning and breeding of fisheries. Besides this, lightning damages infrastructure in fish-cultivated areas. There is some evidence that fishermen and fish farm owners get injured and die from lightning strikes while fishing in open waterbodies.

Wave action

Haor areas are submerged under deep water from July to November due to overflowing of rivers and heavy rainfall, causing them to appear like seas with erosive waves. Recently, the wave attack has drastically increased because of deforestation and changing cropping patterns to allow for more agricultural production (Alam.M.K. et al.2010). This wave attack is called 'afal' in the local language. It hampers fish capturing and fish culture in beels. It damages the total aquaculture setup, boats and nets get damaged and the situation gets worse when heavy wind and heavy lightning start together and make afal more dangerous. Afal is also a major cause of haor bank erosion. The settlements and the communication system of this area are on raised platforms. These man-made platforms keep them above the water level during the flood season, which lasts for about five months of a year. Bamboo and tarja fencing for platform protection often proves ineffective. However, patches of Hijal and Koroach tree in front of the villages act as fence against wave action to protect the villages. The platforms of settlements are under the threat of erosion because of wave action. These settlements remain exposed to wave attack for around five months

in a year. The Haor Master Plan identified about 202 locations of the settlement area, which are more vulnerable in deeply flooded zones due to wave action during the wet season. It should be noted that in recent years, wave attacks have increased tremendously due to large scale deforestation.

Siltation

Soil erosion, mainly due to heavy rainfall and surface runoff in Meghalaya’s hilly region, are causing river siltation in Nollah Haor and Noljur River in Jagannathpur Upazila. This reduced the water holding capacity of rivers, degrades fish habitats, and reduces fresh water availability in winter for fish production and the conservation of biodiversity. Water sources are contracting as siltation is rising bed level of the rivers and canals. It is also a reason for flooding. Siltation sometimes decrease soil quality and hampers fish-breeding ground. It increases turbidity and deteriorates the water quality, which hampers aquaculture.

3.3 Hazard wise impact matrix based on community perception

Bio physical, fisheries, ecosystem and livelihood impact of each hazard have been identified and ranked from low to high in **Table 3.2** where, red indicates high vulnerability, yellow indicates medium vulnerability and green indicates low vulnerability. During FGDs, hazards-wise effects on different aspects of the fisheries and aquaculture sector have also been identified based on the opinion of respondents. The following table shows the hazard-wise vulnerability matrix based on respondents' feedback in the FGD. The frequency and impacts of such extreme events are increased under climate change scenarios.

Table 3.2: Impact of hazards based on community perception

Sector	Impact	Flash Flood	Drought	Wave Action	Extreme hot temperature	Severe Cold Days	Siltation	River Bank Erosion	Lightning
Bio physical	Area Inundated	Red						Yellow	
	Low water availability		Yellow		Yellow				
Ecosystem	Extensive Algae Bloom (FW)	Red			Yellow				
	Decreased flora & Fauna		Yellow		Green		Red		
	Stress on aquatic species abundance and distribution		Yellow		Green		Yellow		
	Infrastructure damage	Red		Red				Yellow	

CEGIS Field Survey, 2022

3.4 Multi-hazard mapping for Jagannathpur Upazila

A multi-hazard scenario (**Figure 3.6**) for Jagannathpur Upazila was also assessed using field finding, community perceptions and available secondary data layer. Flash flood, drought, siltation, extreme hot days, river bank erosion, lightning, wave action, severe cold days etc. were considered while assessing multi-hazard conditions. Multi-hazard conditions were assessed for two-time periods, as such base period and 2050s. For future projection, due to limitation of resources only flash floods, landslides and temperature data are projected for 2050s and other hazards are considered constant as base period during the multi-hazard mapping using geo-spatial techniques. Kalkalia and Asharkandi unions of Jagannathpur Upazila are found exposed to multiple climate hazards, with highest severity in the base period. In 2050s Haldipur, Pailgaon, unions and Jagannathpur Pourshava will be in high-risk zone along with the high risk unions at the base period. The rest of the unions, i.e., Patali, Syed Pur, Mirpur and Raniganj, are found to be in moderate risk of multi hazards for both time slices.

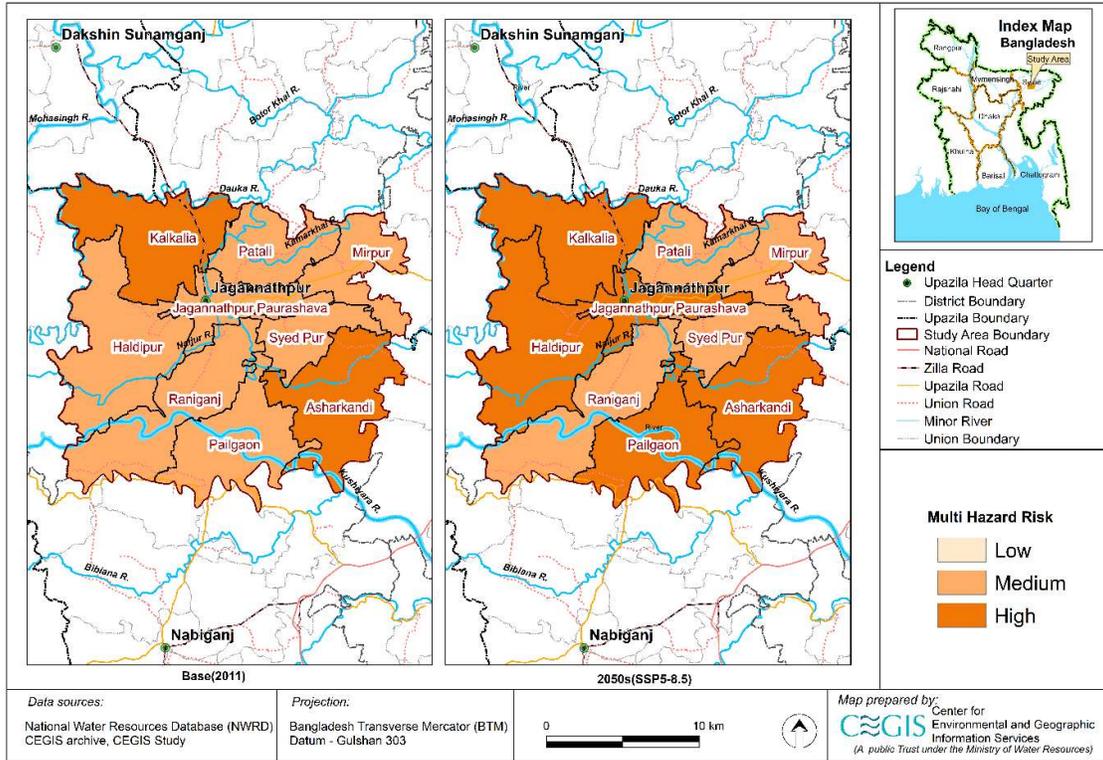


Figure 3.6: Multi hazard maps in Jagannathpur Upazila

4 Climate Risk and Vulnerability

This chapter presents the key outcome of the study, which is climate risk and vulnerability for the Jagannathpur Upazila covering all of its unions. Risk and vulnerability were assessed following indicator-based approach and based on the developed CRVA framework and impact chains. Separate impact chains were developed for the CRVA framework focusing on capture fisheries, culture fisheries, fisheries ecosystem and gender-based F&A livelihoods. Following sections describe the key elements of risk and vulnerability separately for these four priority focus areas, which are exposure, sensitivity, adaptive capacity, vulnerability, and risk. Risk and vulnerability assessment is done based on blended approach of participatory appraisal techniques and scientific analysis for base and 2050s under extreme climate change scenarios.

4.1 Aquatic ecosystem

4.1.1 Exposure

Almost every year the seasonal floods and associated storm surges, and other climate change induced hazards cause severe devastation to the ecosystem in this region. Indicator based assessment for the developed impact chains was also used to access the ecosystem exposure to climate change induced hazards in Jagannathpur (Annex I). The exposure of hazards to aquatic ecosystem in Asharkandi, Haldipur, Mirpur, Pailgaon, Patali, Syed Pur and Jagannathpur Paurashava were identified as high (**Table 4.2**).

4.1.2 Climate sensitivity of aquatic ecosystem

The rich and diversified aquatic ecosystem of the study area is found sensitive to climate change in various ways. Climate change and its extreme variability make the habitat condition unfavourable and severely disrupt the ecosystem services. The study analysed the climate sensitivity (change in habitat area, disruption of ecosystem services and aquatic ecosystem conditions) of River, Haor and Pond ecosystem

Change in habitat area

The change of perennial and seasonal waterbodies assessed provides information of the intra-annual behavior of such waterbodies. **Figure 4.1** shows the change in waterbody extent from 1990-2020. Jagannathpur Upazila shows considerably higher extent of surface water loss. The permanent and seasonal water bodies were found to have decreased from 1990 to 2020 by 19.58% and 42.5% on average respectively. The reason behind this may be illegal encroachments and increased urbanization leading to a rise in human settlements that eventually resulted in the filling up of the permanent water bodies. This would have a negative impact on the fisheries sector because of the disturbance caused to the habitats and breeding grounds of fishes and other aquatic animals. The seasonal water bodies increased between 2000 and 2005, after which it started decreasing slightly. Increasing trends of seasonal water bodies found from the satellite images analysis may be the aftermath of gradual sea level rise and consequent increase of intertidal area, which usually create temporary waterlogged areas in low lying regions. Overall, this assessment reveals increased saline or brackish water habitat and decreased freshwater habitat, therefore, adaptation in fish farming practices will need to be planned accordingly.

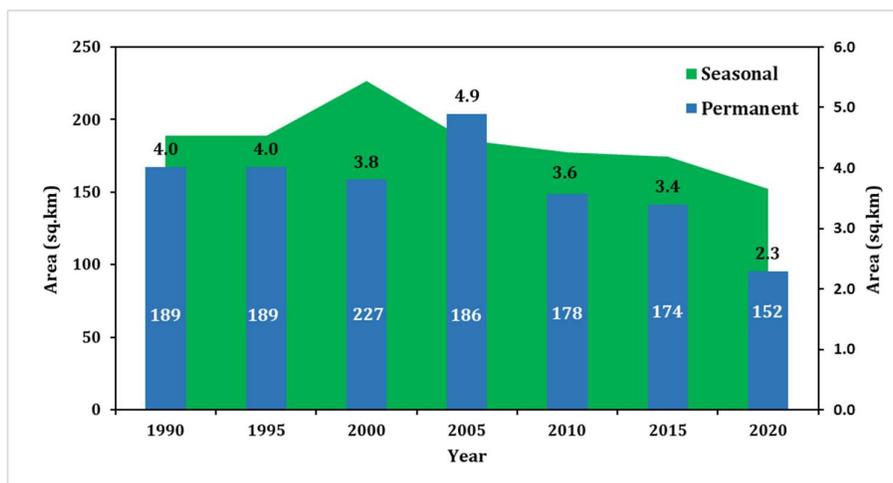


Figure 4.1: Water body changes in Jagannathpur Upazila

Disruption of ecosystem services

The aquatic ecosystem of the study area provides numerous ecosystem services as reported by the communities during FGDs and KIIs. Local people extract fish, fuel wood, medicinal plants, sand and gravel, plant parts along with grass from the river, haor and pond ecosystems. River and haor water is also used for bathing, transport and other non-consumptive use. The pond dyke, haor and river bank is suitable for cultivating vegetables like Sweet Pumpkin, Bottle gourd, Cucumber, Hyacinth bean, etc. People normally plant trees and cultivate vegetables around the pond to support the ecosystem. Haor provides direct and indirect livelihood benefits to nearly 200,000 peoples (Rana et.al. 2009) who are mainly involved in farming and fishing.

Aquatic ecosystem is diversified with fresh water species, which facilitate carbon sequestration, heat absorption, nutrient cycling, sediment retention, groundwater replenishment, and most importantly act as barriers against flood and storm surges. The study area receives an abundant amount of rainfall every year. A number of vegetation is observed on the torus and along the riverside and haor toe of the embankment. The major perennial wetlands inside the haor area are beels and khals which have important roles to support numerous water dependent birds, fishes and other wild animals, which have a tremendous influence on the maintenance of food-web and ecosystems. Khals contribute connectivity between rivers and beels. Beels of this haor area hold water round the year and support as migratory bird habitat and as the last refuge/shelter for the indigenous fishes. Gaidala Beel, Hondal Beel, Rua Beel and Hortazur Beel are the major perennial wetlands those were important for the fishes and other water dependent wild faunal communities. A number of khals performed connectivity between internal water bodies and surrounding rivers -- Kusiara, Dahuka, Naljor and Kamarkhali. The haor area except settlement platforms has been converted as a seasonal wetland in monsoon and triggered lush growth of water lilies, water hyacinths, water lettuce especially at the shallow portions of the haor. These aquatic floras were, and still are, the abode of local fishes and source of feeds for water birds. Among the mollusks, freshwater snails were abundant and consumed by migratory ducks. The most common tree species of the wetlands are *Barringtonia acutangula* (Hijol), *Diospyros cordifolia* (Tamal), *Erythrina variegata* (Mandar), *Lagerstroemia speciosa* (Jarul), *Ficus religiosa* (Ashwathwa), *Pongamia pinnata* (koroach), etc. The most commonly occurred shrub species are *Datura stramonium* (Dhutura), *Ipomoea carnea* (Dholkalmi), *Phragmites karka* (Nal), *Saccharum spontaneum* (Kash), *Schumannianthus dichotomus* (Pati-pata) etc. Herb species that commonly occur in the haor area are *Asparagus racemosus* (Satamuli), *Centella asiatica* (Thankuni), *Colocassia esculenta* (Kochu), *Cynodon dactylon* (Durba), *Enhydra flactuans* (Helenca), *Marsilea quadrifolia* (Sushnishak), *Nymphaea nouchali* (Shapla), etc. But survey results indicate that the number of vegetation in haor areas is decreasing and dead decaying tree mortality increasing from earlier. This is may be due to changes of rainfall extremes and long term flood causes death and decay of root system of flood prone trees as a result of reduction of concentration of oxygen in soil, altering pH, sedimentation and impediments on roots. Seasonal flooding also impacts the growth and population of all aquatic plants.

A higher proportion of the rainfall is infiltrated as ground water, which supports flow of water in the streams and withdrawal of water for irrigation or daily use. Ponds accumulate organic matter in their sediments and therefore bury or sequester carbon. The plants surrounded by rivers, haors, ponds, internal khal and ditches also support the storage of rainwater in canopy, balance the fish production and its food system through oxygen supply and fish waste uptake by algal bloom and its photosynthesis in daytime, support for other aquatic flora and fauna, food, fuel, cosmetics, folk medicine and building materials.

Apart from providing, regulating and supporting services as described above, local communities reported that aquatic ecosystem in Jagannathpur upazila also provides opportunities for cultural services such as recreation, aesthetic value and inspirational values. Naluar haor is the largest Haor in Jagannathpur upazila, which is not only a source of enormous biodiversity but also a source of natural beauty. Its versatile beauty figured out individually in every season. Especially, in rainy season it takes youthful and significance looks. Winter provides good opportunity for travelling. It refreshes mind and body together. Observing the scenic beauty, serenity, unique and diversified animals and, landscape aesthetics, people get both mental and physical health benefits. According to the community people, fishermen of Jagannathpur upazila have been celebrating the fishing festival for hundreds of years. The festival is an occasion of enjoyment for the fishermen. But sometimes it poses threats to the fish habitat and ecosystem.

All these four categories of ecosystem services are being disrupted by climate change in combination with non-climatic factors opined by communities. A SWOT analysis (**Figure 4.2**) performed for **provisioning, regulating, supporting and cultural** revealed that river ecosystem has more weaknesses and threats than the haor and pond ecosystem under climate change scenarios.

The result (**Figure 4.2**) shows strength, weakness, opportunities and threats with score of 0-15 representing low value, 16-30 representing medium value and 31-45 representing high value. The result also showed that all the components within these three major ecosystems have sufficient strength to provide ecosystem services due to their unique features. The results also showed that the river has more weaknesses and high threats than haor and pond due to rapid urbanization and environmental pollution. There are good opportunities for ecosystem services from river and haor, but pond ecosystem has higher strength and opportunities because of their natural and manmade land-cover types. From the statement of the respondent's habitat degradation, climate change, and human activities are found to be responsible for ecosystem disruption and biodiversity loss in the river. The existing Haor ecosystem is also subject to a variety of threats and pressures, such as loss of reed land and swamp forest areas due to conversion for agriculture and the removal of trees for building and firewood. On the other hand, the pond ecosystem is modified with the existing nature based solution, planted and naturally regenerated with diversified species.

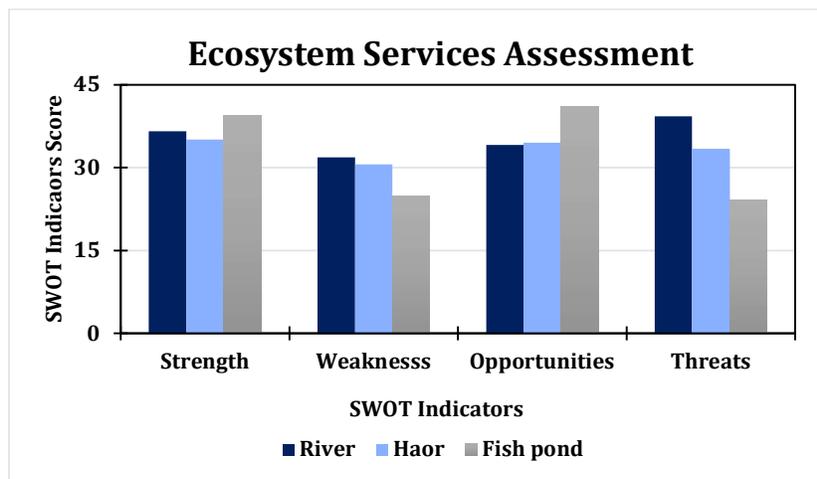
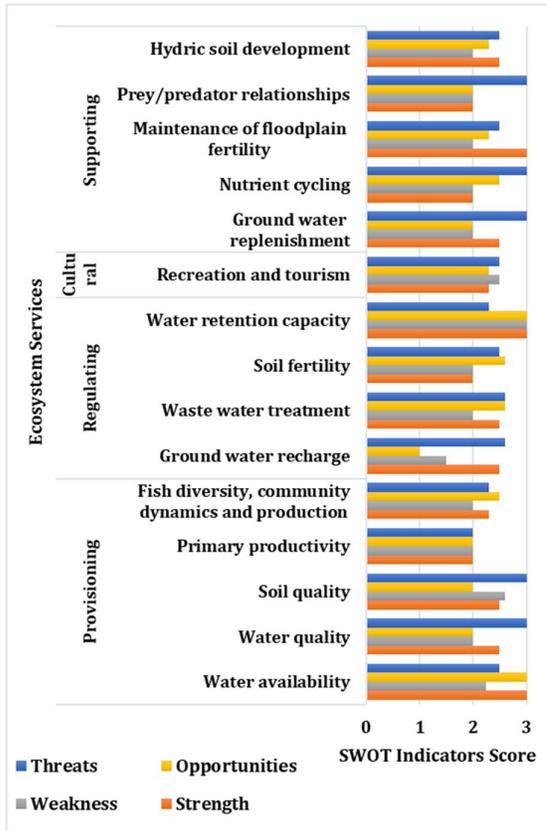


Figure 4.2: SWOT results of aquatic ecosystem services

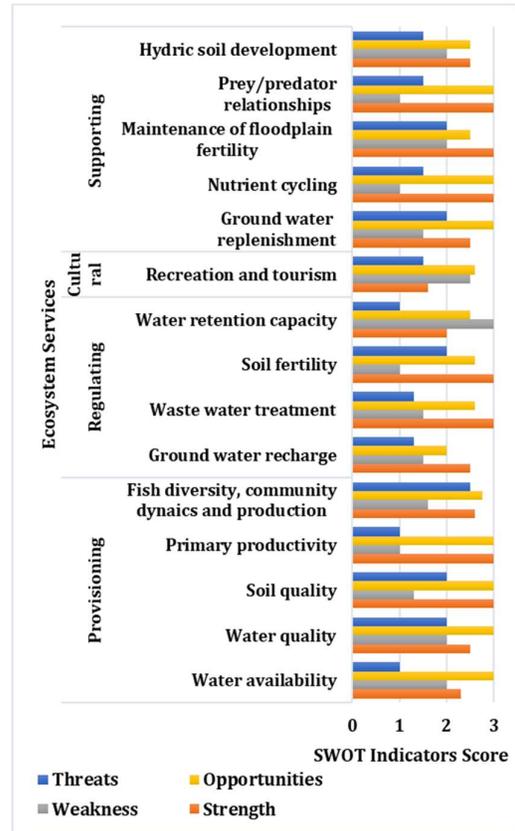
To enhance the ecosystem services from rivers, haors and ponds ecosystem, identified weakness and threats will need to be addressed to increase the related benefits sustainably. Therefore, Ecosystem

Approaches for Aquaculture (EAA) or Ecosystem Approach to Fisheries (EAF) should be followed to manage fishery ecosystem and its climate sensitivity in a sustainable way. Integration of fishery ecosystem during structural or non-structural intervention design for adaptation and resilient building is needed to be mainstream widely to harness the desired level of the ecosystem services combating negative impacts exert by climate and non-climatic factors.

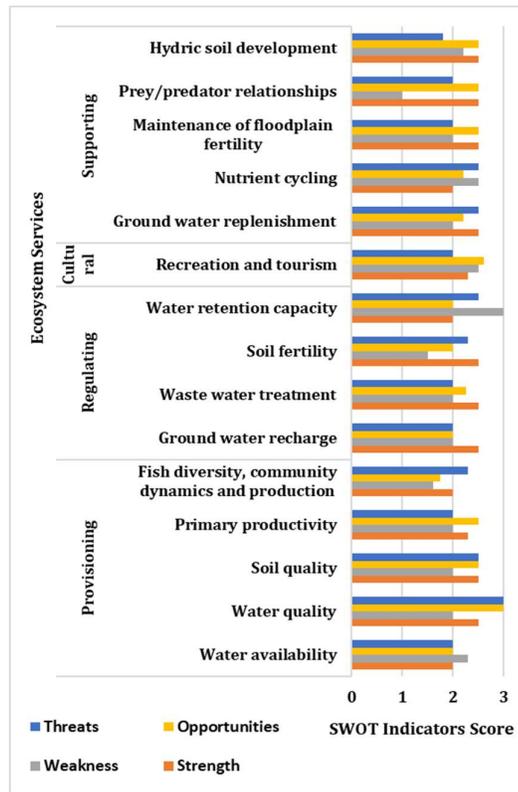
The graph below (Figure 4.3-a, b & c) shows the aggregated score of strength, weaknesses, opportunities and threats indicator of the ecosystem services under the four categories for river, pond and haor. All the indicators were ranked as per their scores obtained from field visit (i.e. scores per respondent: 1=Less/Poor condition, 2=Medium/Good condition, 3=High/Better condition). Detailed outcomes of SWOT analyses are given in Annex II.



a) SWOT outcomes of ES for Rivers



b) SWOT outcomes of ES for Fish pond



c) SWOT outcomes of ES for Haor

Figure 4.3: SWOT outcome for river, haor and fish pond ecosystem

Aquatic habitat condition

Similar to ecosystem services disruption by climate change, in situ and laboratory tests of water quality also indicated the ecosystem sensitivity to be deteriorating due to climate change. DO, COD, EC, TDS, pH and Nitrate were found suitable and within the thresholds reference value for all ecosystem. Temperature and BOD in Representative River and pond water are found to exceed the thresholds reference value of ECR'97 and different studies (marked in Brown color as shown in **Table 4.1**).

Water temperature is the most important physical variable affecting the metabolic rate of fish and is therefore one of the most important water quality attributes in aquaculture (Kane et al., 2015)². Temperature of the representative sample in pond and haor was found around 33.4°C and 34.1°C respectively. According to EQS (1997)³ and De (2005)⁴, the optimum temperature of water for fish culture ranges from 20 to 30°C. Shyamala et al. (2008)⁵ also reported that the range of temperature between 24.75 to 28.5°C was suitable for commercial fish production. So, the temperature was found slightly high for fish habitat. The minimum amount of DO is 5 mg l⁻¹ for survival aquatic animals and level <4 mg/l causes killing

² Kane, S.F.; Quarri, P.; Lazo and Bekteshi, L. 2015. The effect of physicochemical parameters and nutrients on fish growth in Narta Lagoon, Albania. *Journal of Hygienic Engineering and Design* 10 62-68.

³ EQS (Environmental Quality Standard). 1997. Bangladesh Gazette, registered nr. DA-1, Ministry of Environment, Government of Bangladesh.

⁴ De, A.K. 2005. *Environmental chemistry*. 5th Edition, New Age International (Pvt.) Ltd., Daryagan, New Delhi, India. pp. 187.

⁵ Shyamala, R.; Shanthi, M. and Lalitha, P. 2008. Physicochemical analysis of bore well water samples of Telungupalayam area in Coimbatore District, Tamilnadu, India. *Journal of Chemistry* 5 (4) 924-929.

of fish and other animals of water kingdom. Thirupathaiah et al. (2012)⁶ reported a range of DO in between 5.18 to 9.72 mg l⁻¹ is good for survival of aquatic organism.

Present study found DO in Kushiya River at Jagannathpur union to be 4.9 & 4.5 mg l⁻¹, which is below the threshold level and can harm aquatic organism and biodiversity health. BOD is the indicator of organic matter in water. According to The Environment Conservation Rules, 1997 optimum BOD level for fisheries should be less than 6 mg/L. The BOD of all collected water samples were varied between 19 and 48 mg/L, which is extremely high. Chowdhury (2009) recommended that optimum BOD level for aquaculture should be less than 6 mg/L. On the basis of measured BOD all water samples were beyond the acceptable range. So, from the observation of river, pond, and haor, it is seen that the BOD level was not suitable for fish production and environment. It was observed during the field visit and communities during surveys reported occurrence of frequent algal blooms due to increased water temperature and fish mortalities specialty during summer. In addition, siltation, tornado, rising trend of flash flood, especially during the monsoon period usually result in the alteration of aquatic habitat and disappearance of local species from the water bodies. Apart from climatic factors, farmers reported water quality fluctuation for flood and decreased water levels due to drought reducing habitat and production of fish. Beds of the rivers, haor, ponds and nearby canals have been silted up, and this has reduced the water carrying capacity of rivers. Excessive sediment loads are deposited in the rivers and their tributaries that cause floods during monsoon. These water quality conditions will be exacerbated under climate change condition.

Table 4.1: Surface water quality in Jagannathpur Upazila

Sample ID & Unit	Physical and Aggregate Properties of Surface Water Resource						
	pH	Temp	DO	EC	TDS	BOD	COD
-	-	°C	mg/l	µS/cm	mg/l	mg/l	mg/l
Homestead pond in Jagannathpur Pouroshova	8.14	31.1	6.3	140	70		
Fishery pond in Jagannathpur Pouroshova	7.8	33.4	5.7	60	30	19	80
Noiljhor River Jagannathpur Pourashava	7.28	30.4	6	70	33		
Kalni/Khushiyara River, Jagannathpur	7.52	31	4.9	70	40		
Khushiyara River, Jagannathpur	7.39	30.6	5	70	30		
Khushiyara River, Jagannathpur	7.48	30.5	4.5	70	30	16	68
Nolua Haor, Jagannathpur	8.36	34.1	7.1	60	30	48	100
Pond in Haldipur Union	7.93	32	5.9	70	30		
Bangladesh Standard for Surface Water Quality (ECR'97)	6.5 – 8.5	20°C - 30°C	≥5.0	1200	2100	6 or less for fisheries	

⁶ Thirupathaiah, M.; Samatha, C.H. and Chintha, S. 2012. Analysis of water quality using physicochemical parameters in lower man air reservoir of Karimnagar district, Andhra Pradesh. International Journal of Environmental Sciences 3 (1) 172-180.

Sample ID & Unit	Physical and Aggregate Properties of Surface Water Resource						
	pH	Temp	DO	EC	TDS	BOD	COD
	-	°C	mg/l	µS/cm	mg/l	mg/l	mg/l
Study reference value	(6.5-9) ⁷	(25-32°C) ⁸	(5.18-9.72) ⁹	(30-5000 µs/cm) ¹⁰	(< 160-200 mg/l) ¹¹	(<6 mg/l) ¹²	(<200 mg/l) ¹³

*Green colors indicate standard reference value of water quality parameters as per ECR'97 and different study source and Red color shows the parameters which exceed the standard reference value or threshold

The combined sensitivity analysis (**Table 4.2**) using the habitat extent, condition and ecosystem services related indicators, it has been found that Haldipur, Mirpur and Raniganj unions were highly sensitive ecosystem, whereas Pailgaon union was found to have moderately sensitive ecosystem.

4.1.3 Capacity of aquatic ecosystem to adapt

Rapid restoration and regeneration of plankton and vegetation; abundance of flora and animals; soil health; decomposition of leafs and plant parts and co-management of biodiversity; non-destructive katha or brush piling fishing; expanding the forest cover on newly char land; enhancing primary productivity; a good capacity for retaining and transporting water; and medium turbidity are some key inherent adaptive capacities of river and haor observed during field visits. Because rivers are by nature dynamic systems continually modifying the depth, width, and sinuosity, a healthy river responds to changes in the environment and the climate regime by going through these changes. In connection with aquatic ecosystems, riparian vegetation performs a number of crucial tasks, such as evapotranspiration, and shade. As a result, it generates a buffer zone that serves as a filter for sediments and nutrients, and source of food and habitat. Nollahr haor is the most important freshwater wetland located in the Jagannathpur Upazila, which supports plentiful flora, wildlife, and aquatic resources. On the other hand, pond ecosystems also have some inherent ability to change, like coping with climate hazards. Apart from the system's inherent ability to cope with the nature, the field survey revealed that people generally use fencing and netting around ponds to prevent the escape of stocked fish as well as invasion of predator fish during floods. Local people harvest rainwater with storage facilities for aquaculture in the dry season. Using rainwater for fish culture and pond-dike cropping increases water use efficiency. According to KIIs survey, pond-dike cropping can help to cope with increased water temperature. Plantation of suitable trees on pond-dikes can provide shade on water for fish and stabilize soil. Local people are practicing Ecosystem-based Adaptations (EbAs) in the pond ecosystem. Floating aquatic vegetation's are used for shed or shelter of fishes in the kathas in rivers and haor. Among them, *Enhydra fluctuans*, *Ipomoea aquitica* and *Eichhornia crassipes* are mostly used. Long bamboos and nylon rope were used to encircle and fix that vegetation's. For shelter of bottom dweller fishes and prawns, branches and roots of different trees were put under water before set up of katha. *Barringtonia acuitangula* (Hijal), *Tamarindus indica* (Tetul), *Enterolobium saman* (Eucheliptus), *Mangifera indica* (Am), *Psidium guajava* (Peyara) and other locally available tree branches were used for this purpose. To increase the primary productivity of the ponds, local people normally use Urea; Triple Super Phosphate (TSP); Murate of Potash (MP); Gypsum, and Zinc Sulphate

⁷ <https://www.fisheriesjournal.com/archives/2020/vol8issue1/PartD/8-1-33-780.pdf>

⁸ Das, 1997. Das, B. 1997. Fisheries and Fisheries Resources Management. Bangla Academy, Dhaka, Bangladesh, 153-155p

⁹ Thirupathaiah, M.; Samatha, C.H. and Chintha, S. 2012. Analysis of water quality using physicochemical parameters in lower man air reservoir of Karimnagar district, Andhra Pradesh. International Journal of Environmental Sciences 3 (1) 172-180.

¹⁰ Stone, N.M. and Thomforde, H.K. 2004. Understanding your fish pond water analysis report. Cooperative extension program, University of Arkansas at Pine Bluff Aquaculture/Fisheries.

¹¹ Huq, S.M.I. and Alam, M.D. 2005. A handbook on analysis of soil, plant and water. BACER-DU, University of Dhaka, Bangladesh. pp. 246

¹² Ahmed, G.; Uddin, M. K.; Khan, G. M.; Rahman, M. S. and Chowdhury, D. A. 2009. Distribution of trace metal pollutants in surface water system connected to effluent disposal points of Dhaka Export Processing Zone (DEPZ), Bangladesh: A statistical approach, Journal of Nature Science and Sustainable Technology, 3(4): 293-304.

¹³

(ZnSO₄). Lime (CaO), Ca(OH)₂ and CaCO₃ are being used to improve biological activity, oxygen, maintain pH and remove turbidity.

Union wise adaptive capacity assessment (**Table 4.2**) based on different indicators (listed in Annex I) demonstrates the overall status of coping mechanism of the ecosystems. It is found that aquatic ecosystem in Kalkalia union had high adaptive capacity whereas the rest of the unions had low adaptive capacity. Adaptive capacity of the ecosystem of these unions can be increased through wetland conservation, pollution control through regular monitoring and maintenance. A reserved wetland could be a sanctuary for the fauna and other aquatic habitat, it may work as a safe haven for their reproduction purpose.

4.1.4 Vulnerability of aquatic ecosystem

Vulnerability of ecosystem is obtained through analyzing the adaptive capacity and sensitivity of the system. From the assessment (**Table 4.2**) it is found that Haldipur, Mirpur and Raniganj unions were highly vulnerable to climate change induced hazards. These unions have high sensitivity and low adaptive capacity to cope with the hazards. On the other hand, Pailgaon union was found to be moderately vulnerable and other unions' ecosystems were found to be low vulnerable to climate change induced hazards.

Table 4.2: Summary of climate vulnerability assessment for aquatic ecosystem in Jagannathpur Upazila

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Asharkandi	High	Low	Low	Low
Haldipur	High	High	Low	High
Kalkalia	Low	Low	High	Low
Mirpur	High	High	Low	High
Pailgaon	High	Medium	Low	Medium
Patali	High	Low	Low	Low
Raniganj	Low	High	Low	High
Syed Pur	High	Low	Low	Low
Jagannathpur	High	Low	Low	Low

4.1.5 Risk of aquatic ecosystem

Climate change risk (**Figure 4.4**) on ecosystem in Jagannathpur Upazila has been calculated for both base period and 2050s following the CRVA framework (attached in Annex I). The unions Kalkalia and Asharkandi are highly exposed to multi-hazard risk in both present and future time periods and Haldipur, Pailgaon, unions and Jagannathpur Pourshava are highly exposed to multi hazard risk in the future which affects aquatic ecosystem negatively throughout the year in these unions. Both the permanent and seasonal waterbody in Jagannathpur have been reported to decrease in recent years which may be due to increased urbanization and filling up of waterbodies. Decrease in waterbody poses threat to the fresh water aquatic ecosystem within. Apart from that each year flash flood destroy or heavily damage the ecosystem. Siltation in Nolijur River and Nollahr haor decreases water availability in winter and threatens biodiversity. The inland waterbodies i.e ponds, gheras are affected by extreme heat and drought, due to extreme heat natural habitat condition is degrading though DO depletion, water temperature increase, extensive algae bloom.

From the risk analysis considering extreme climate change scenarios, Mirpur, Haldipur, Jagannathpur Pourashava, Pailgaon and Asharkandi unions are found under high risk in both time slices. In the base period, Patali and Syed Pur unions were under moderate risk. In future Kalkalia falls under moderate risk along with the moderate risk unions in the base period. Raniganj union is found under low risk in both time slices.

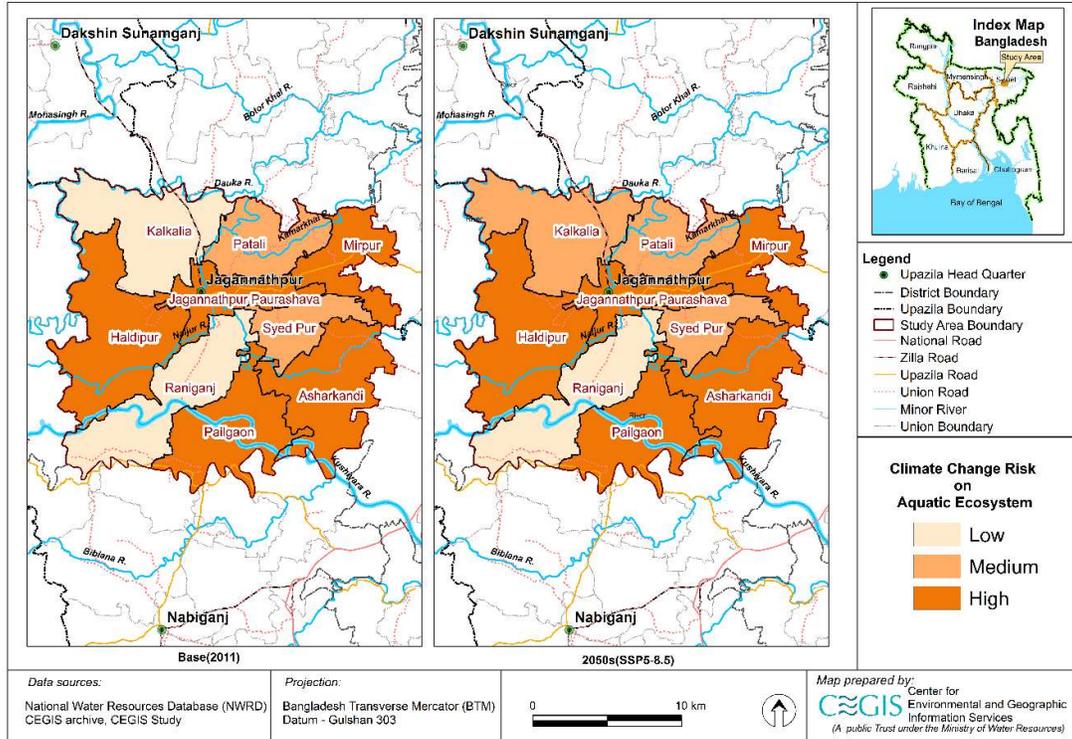


Figure 4.4: Climate risk of aquatic ecosystem in Jagannathpur Upazila

4.2 Capture fisheries

4.2.1 Exposure

The open water fisheries resources are dominated by the riverine ecosystem. This section focuses on the spatial distribution of the available ecosystem (detailed description is given in the ecosystem section) and fish diversity in respect to the exposure indicators of this ecosystem.

Fish habitat area

The Upazila possesses in total 1,207 ha of riverine habitat and 1,312 ha of beel habitat. Union-wise distribution of the habitat is given in the **Table 4.3** below.

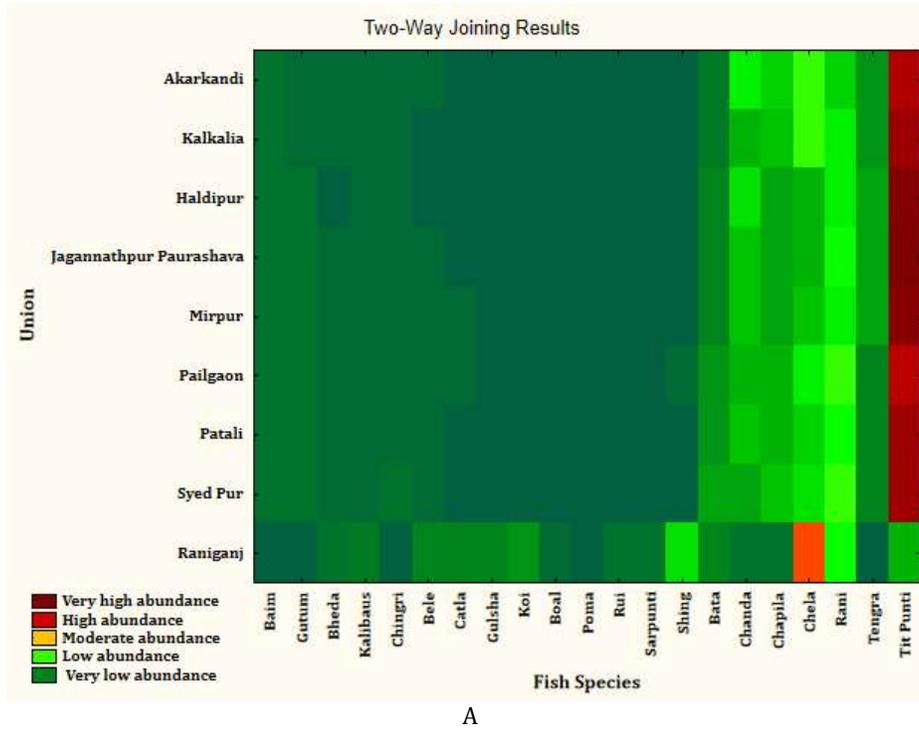
Table 4.3: Area of River and Beel habitat in different unions of Jagannathpur Upazila

Unions	Habitat area (ha)		
	River	Beel	Total
Asharkandi	226	457	683
Haldipur	181	-	181
Jagannathpur Paurashava	68	-	68
Kalkalia	98	42	140
Mirpur	16	159	175
Pailgaon	257	223	480
Patali	50	30	80
Raniganj	274	401	675
Syed Pur	37	-	37
Total	1,207	1,312	2,519

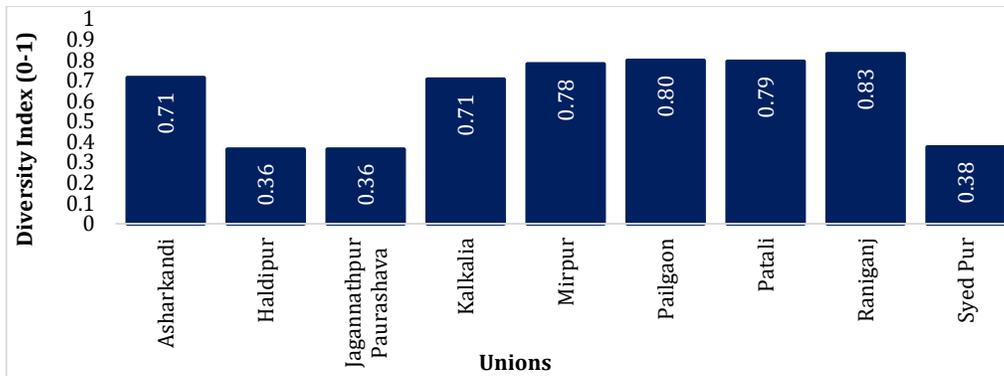
Satellite image LandSat8, 2019

Fish diversity

The riverine and beel ecosystem is characterized by various fresh water fish species. The Two-way Cluster Analysis was applied in this study to present the distribution pattern of available fish species found in the instantaneous catch among the unions under the Jagannathpur Upazila. The present study found that the instantaneous catch is highly dominated by Tit Punti. (**Figure 4.5-A**). The colors in the following figure denote the composition of fish species. Very high dominance where the composition has 80%-100%, high dominance indicates the composition of 60%-79%, moderate dominance indicates the composition of 40%-59%, low dominance indicates 30-39% and very low dominance indicates less than 30% of species in the composition.



A



B

Figure 4.5: Species composition and biodiversity index (species evenness) of the instantaneous catch of different unions in Jagannathpur Upazila

This study also analyses the Shannon-Weiner Index (Bio-diversity Index) in order to assess the species evenness in the riverine ecosystem (**Figure 4.5-B**). The values of this index range from 0 to 1. The fractal intervals of the index values can be used to characterize the various magnitude of evenness in distribution, i.e., the value of less than or equal to 0.2 indicates uneven distribution (only one species is highly dominated in a particular habitat), 0.21- 0.4 indicates low evenness (very few species are highly dominated), 0.41-0.6 indicates moderate evenness (a number of species are in similar composition), 0.61-0.8 indicates high

evenness (maximum number of species are in similar composition), and above 0.8 indicates very high evenness (all species are more or less evenly distributed). The index showed that the fish species in all unions are evenly distributed in Jagannathpur Upazila.

Livelihoods

Field findings show that about BDT. 15,000-20,000 is earned by the capture fisher's household monthly. As women are not involved in fishing, the average monthly income is very negligible as they mostly catch fish to support their families. After the family's needs are met, they sell the surplus in the local market and make a small profit. According to the fishermen, the availability of fish is decreasing day by day. The reason behind this is the decreasing navigability of water, lack of rainfall, increased temperature, embankment and water contamination etc. Apart from this, Jalmahal is now leased out in haor, due to which fishermen cannot catch fish in open areas. This results in disruption of the income of fishermen.

For Jagannathpur Upazila, union wise exposure for capture fisheries was also assessed. In this regard indicators formulated from impact chains were identified. These impact chains and indicators were validated by DoF officials. Indicators like abundance of species in open water bodies, migratory route, and number of endangered species etc. were considered for exposure assessment. A complete list of indicator for exposure assessment is attached in the (Annex I). From the exposure assessment (**Table 4.8**) it was found that Asharkandi, Mirpur, Patali and Syedpur are highly exposed to climate change induced hazards, which may be due to high presence of river ecosystem within this Upazila. Kalkalia, Pailgaon, Raniganj has moderate exposure, and the rest of the unions have comparatively lower exposure for capture.

4.2.2 Sensitivity

Habitat under threshold

The present study calculated the sensitivity scores ranging from 0 (low sensitive-deep green in **Figure 4.6**) to 1 (very high sensitive-deep red)) for habitat condition to support biological activities of different fish species (particularly resident fishes) in respect of temperature variability (TSE: Temperature Sensitive Environment), and to influence spawning, growth, maturation and even migration pattern and extent of river/beel resident, seasonal migrant and adventitious visitor fishes sensitivity to rainfall variability under different scenarios (Base scenario (1983-2010), SSP5-8.5 (2050), SSP5-8.5 (2100), SSP1-2.6 (2050) and SSP1-2.6 (2100)). The study predicted that the magnitude of temperature induced stress environment for the river's seasonal migratory fishes will be increased in the 2036-2065 and 2070-2100 average years under SSP1-2.6 scenario by about 0.41% and 0.22% with increasing 1°C mean water temperature.

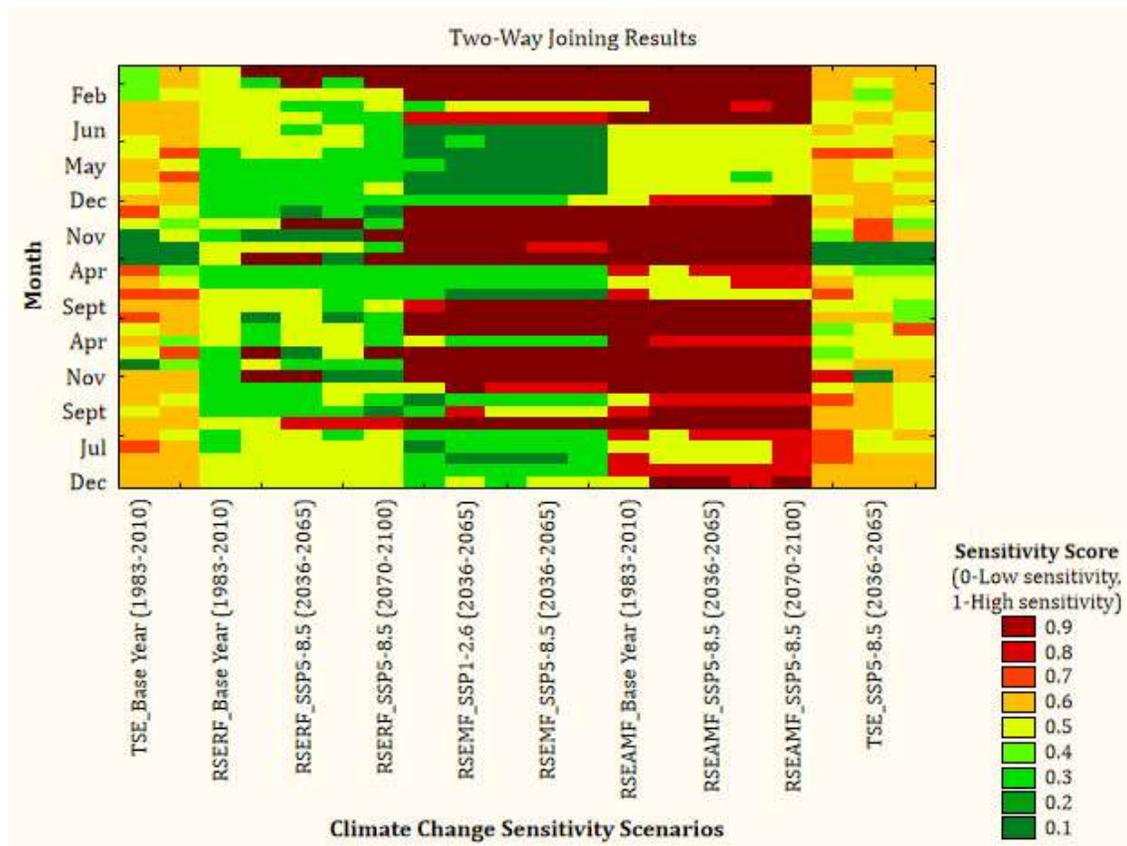


Figure 4.6: Habitat sensitivity to natural mortality in the Ssp1-2.6 and SSP5-8.5 scenarios

Sensitivity analysis, CEGIS (2022). TSE: Temperature Sensitive Environment; RSERF: Rainfall Sensitive Environment for Resident Fishes; RSEMF: Rainfall Sensitive Environment for Migratory Fishes; 1-12: Months per Year

Fish breeding/spawning

Most species use river as breeding and spawning ground. Breeding season of Chapila is from April to October and the spawning season is from March to September. Breeding season of Boal is in July-September and the spawning season is July-August. Aire start to breed in June and continue up to September, and spawns in July to August. Bele has two breeding and spawning seasons (Table 4.4). During the rainy season, fish migrates from one place to another for spawning and breeding purposes. Timing of rainfall is a crucial factor for gonadal development which may trigger the freshwater species for successful spawning and breeding. Climate change may have altered the timing of rainfall, so fish spawning time may also shift which can result in decreased fertilization rate.

Table 4.4: Breeding and spawning season of the available fish species in the instantaneous catch

Species	Locality	Breeding season	Spawning Season
Chapila	River, Beel	April-October	March-September
Boal	Beel	July-September	July-August
Chela	River	June-September	August
Baim	River	March-June	July - September
Bele	River	<ul style="list-style-type: none"> • March-April • September- October 	<ul style="list-style-type: none"> • May-June • October- November
Tengra	Beel	June-September	July and August
Punti	River, Beel	March-July	March-July
Aire	River	June-September	July and August

Literature review and CEGIS Field Survey, 2022

These studies indicated that maximum fluctuations from the optimum ranges might result in lowering chances for fertilization success, and thus reducing breeding and spawning success. The present study predicted that the changing scenario of water temperature and rainfall pattern plays an important role in changing the phenological events of different fish groups, including fishes of euphotic, despotic, and aphotic zones, river residents, and also migratory fish groups. It has been found that the magnitude of breeding/spawning success might be significantly decreased in the case of Bata, Boal, Galda, and other available inland fishes in the SSP1-2.6 scenario (Figure 4.7).

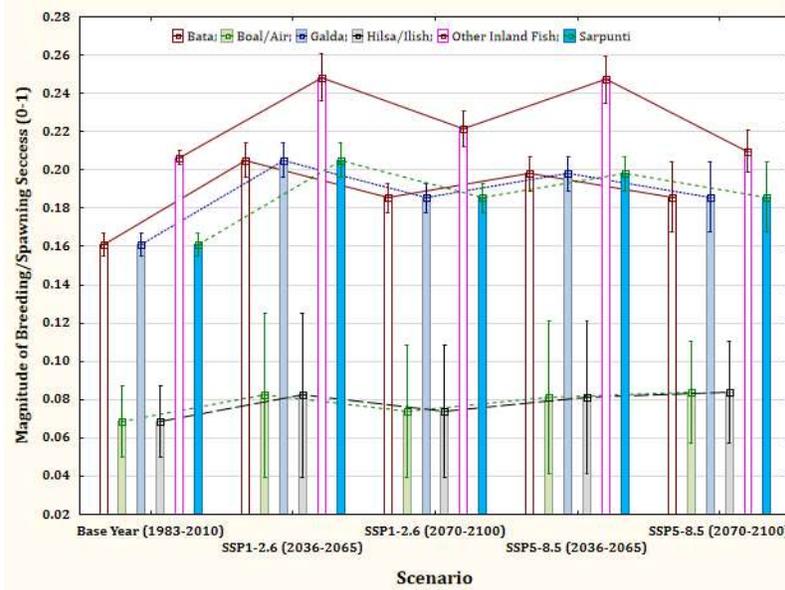


Figure 4.7: Magnitude of Breeding/Spawning success of the available fish species

CEGIS Field Survey, 2022

Fish migration

The rivers in the unions of Jagannathpur Upazila can provide necessary ecological demand for feeding, breeding/spawning and nursing of fries and juvenile fishes of different migratory fish species. According to the local fishermen and Upazila Fisheries Officials, major longitudinal migratory fishes in the rivers are Chapila (*Gudusia chapra*), Ilish (*Tenulosa ilisha*), Rui (*Labeo rohita*), and Kalibaus (*Labeo kalbasu*). The lateral migration occurs mostly for small fishes like Tengra (*Mystus bleekeri*), Punti (*Puntius spp.*) Bele (*Glossogobius giuris*) and small shrimp/prawn which are mostly limited between the rivers and khals. This study analyzed the magnitude of the migration extent for available fishes from the instantaneous catch among the unions of the upazila (Figure 4.8-A). The values ranging from 0 to 1 are divided into five (05) fractal intervals. The value of less than or equal to 0.2 indicates very strict migration (available in only one particular habitat condition), 0.21-0.4 indicates strict migration (favor to migrate to one particular habitat condition, but migrate adventitiously to other habitat condition), 0.41-0.6 indicates moderate migration extent (frequently migrate to different habitat conditions, but in limited unions), 0.61-0.8 indicates wide migration extent (frequently migrate to different habitat conditions among the unions), and above 0.8 indicates very wide migration extent (very frequently migrate to different habitat conditions among the unions). It has been found that Chela have a very high migration extent and Tit Punti, Bele, and Baim have medium migration extent distributing all the rivers in all unions (Figure 4.8-A). According to the SSP5-8.5 (2036-2065) scenario, the migration rate for Hilsa, Aire, Bata, Sarpunti, and Galda will expand (Figure 4.8-B). The future scenarios, however, would not affect the migratory rates of the inland fishes.

Fish migration may be affected by various climatic factors such as, salinity ingress, erratic rainfall, changes of flooding seasonality, temperature fluctuation, etc. Salinity ingress may pose threats to freshwater fish assemblages and their habitats. The migration length may be decreased in the riverine ecosystem due to salinity ingress because of sea level rise. During the rainy season, fish migrates from one place to another for spawning and breeding purposes. The timing of rainfall is a crucial factor for

gonadal development—as it triggers successful spawning and breeding among freshwater species. Climate change may have altered the timing of rainfall, impacting fish spawning time that may result into decreased fertilization rate. Fish migration occurs for quality habitat and available food. Food availability i.e., phytoplankton, zooplankton, benthos-particle is one of the major determiners for fish migration and this mainly depends on temperature. The primary productivity decreases following temperature fluctuations which hampers fish migration rate in the riverine ecosystem. On the other hand, excess rainfall causes floods, leading into water turbidity and siltation, which may block the migration route.

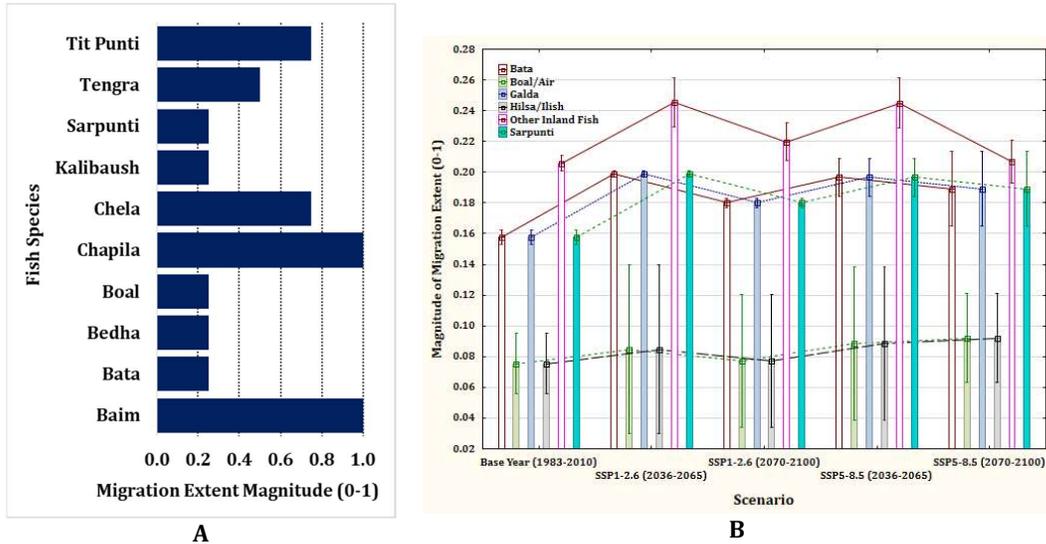


Figure 4.8: Migration extent of different migratory fish species

CEGIS Field Survey, 2022

Growth coefficient and natural mortality

Koi has a higher growth coefficient (about 1.8), whereas the majority of fish species have a lower growth coefficient (0.4) (Figure 4.9). This suggests that given the quality and health of the current environment, some fish species may develop more slowly. In the examined riverine system, the current study also discovered that Rani and Chela have the highest mortality rates, losing more than three generation cohorts per year, while other fish were reported to lose two generation cohorts annually.

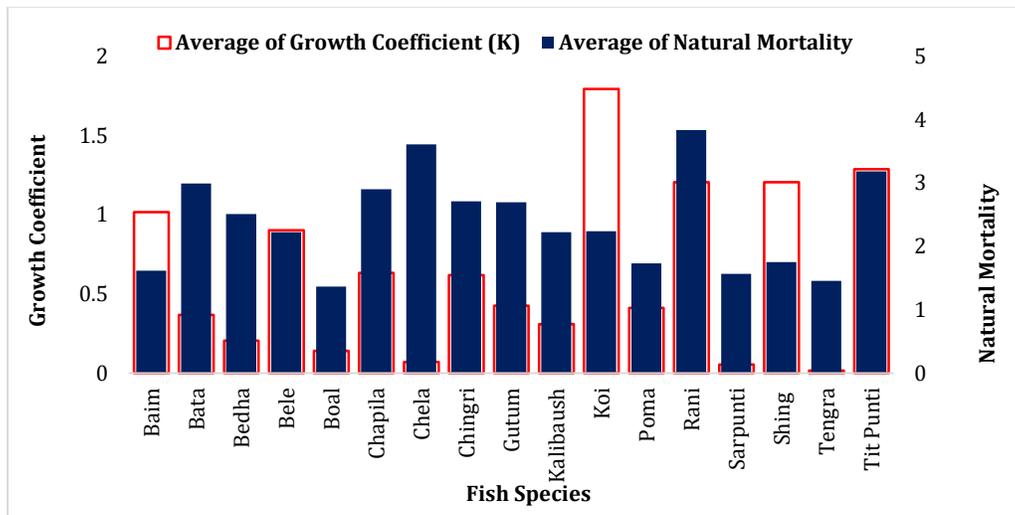


Figure 4.9: Growth coefficient and natural mortality of the available fish species in the instantaneous catch

CEGIS Catch Assessment Survey, 2022; FishBase Life-History Data

This study found that under the SSP1-2.6 scenario, the magnitude of growth performance may also be reduced for Bata, Boal, Galda, Sarpunti and other readily accessible inland fishes (**Figure 4.10**). Future possibilities for Aire would not result in any noticeable changes from the base year. And this magnitude would be greatly impacted by an increase in mean temperature of roughly 10% for Sarpunti, Galda, and other inland fishes in the SSP1-2.6 scenario, but amplified in the SSP5-8.5 scenario. It suggests that the growth rate of these fish may be slower under the SSP1-2.6 future scenario but faster in the SSP5-8.5 future scenario.

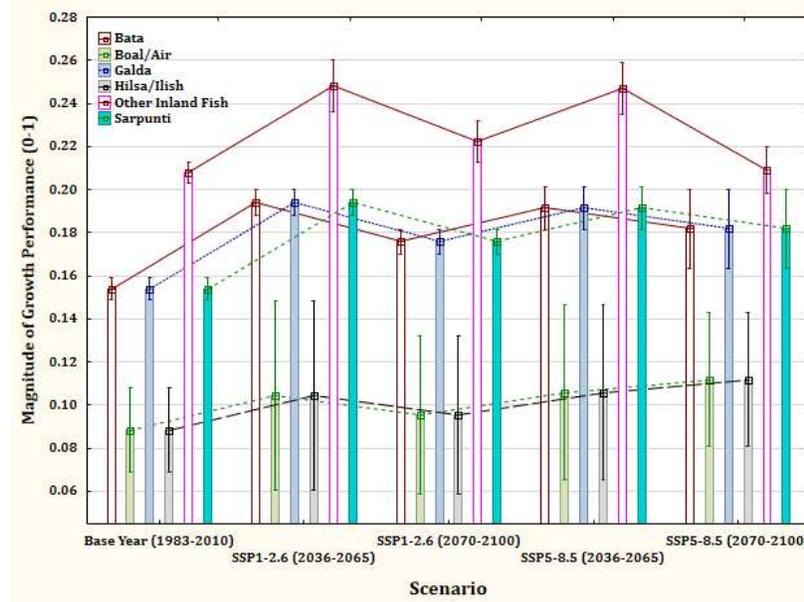


Figure 4.10: Magnitude of growth performance of the available fish species

Impact Chain Analysis, CEGIS (2022)

Fish production

The above-mentioned changes in habitat condition, fish diversity, fish migration, and fish biology in respect of different climate change scenarios, total river fish production in different unions of Jagannathpur Upazila would be about 186 MT, 192 MT, 192 MT, and 215 MT in SSP1-2.6 (2050), SSP1-2.6 (2100), SSP5-8.5 (2050) and SSP5-8.5 (2100) scenarios respectively as shown in **Table 4.5**.

Table 4.5: Capture fish production under different climate change scenario

Union	Fish Production (MT)				
	Base Year	SSP1-2.6 (2050)	SSP1-2.6 (2100)	SSP5-8.5 (2050)	SSP5-8.5 (2100)
Asharkandi	36	35	36	36	40
Haldipur	29	28	29	29	32
Jagannathpur Paurashava	11	10	11	11	12
Kalkalia	16	15	16	16	17
Mirpur	2	2	2	2	3
Pailgaon	41	40	41	41	46
Patali	8	8	8	8	9
Raniganj	44	42	44	44	49
Syed Pur	6	6	6	6	7
Total =	193	186	192	192	215

Impact Chain Analysis, CEGIS (2022)

The total fish production from beels in different unions of Jagannathpur Upazila would be about 1500 MT, 1549 MT, 1548 MT, and 1732 MT respectively in SSP1-2.6 (2050), SSP1-2.6 (2100), SSP5-8.5 (2050) and SSP5-8.5 (2100) scenarios as shown in **Table 4.6**.

Table 4.6: Beel fish production under different climate change scenario

Union	Fish Production (MT)				
	Base Year	SSP1-2.6 (2050)	SSP1-2.6 (2100)	SSP5-8.5 (2050)	SSP5-8.5 (2100)
Asharkandi	542	522	540	539	604
Haldipur	-	-	-	-	-
Jagannathpur Paurashava	-	-	-	-	-
Kalkalia	50	48	49	49	55
Mirpur	188	142	188	187	210
Pailgaon	265	255	264	264	295
Patali	35	34	35	35	39
Raniganj	476	459	474	473	530
Syed Pur	-	-	-	-	-
Total =	1,556	1,500	1,549	1,548	1,732

Livelihoods

Sensitivity of fishing-based livelihoods due to climate change is determined by their dependency on fishing resources in terms of unavailability of alternative livelihoods, lack of financial capital, lack of institutional support for the diversification of income sources, and a lack of human capital to engage in AIGAs. Due to seasonal variability, post harvesting loss and low income of fishermen made them highly sensitive to the climatic shocks. Field findings from Jagannathpur indicates that a considerable percentage of fishermen, particularly small farmers, rely upon various alternative sources balancing their financial demands such as shop keeping, small business, labor, part time jobs, auto rickshaw driving, carpenter etc. Additionally, they are receiving training related to alternative income from various government and private institutions. Besides, many of them take loans from various NGOs and banks for balancing their livelihoods.

Sensitivity of capture fisheries was assessed (**Table 4.8**) through indicator-based analysis. A list of indicators is attached to the (Annex I) which were used to identify union wise sensitivity in Jagannathpur Upazila. Kaikhali, Mirpur, Patali, Syedpur, and Jagannathpur unions are highly sensitive to climate change induced hazard and Halidipur union is in medium state of sensitivity but rest of the unions were in low sensitive zone for capture fisheries. Because of extreme climatic events, the duration of fishing season has reduced, which has considerable impacts on the fishermen's income by reducing fishing days. Dependency on the fishing makes the livelihoods of fishermen highly sensitive to climate change as fishing and fish processing have a high exposure to climate change induced hazards, such as, droughts, lightning, flash floods etc. This climate sensitivity will pose serious impacts particularly on low income fishermen.

4.2.3 Fishers adaptive capacity

Mechanized boats

The fishers face increased frequency of climate induced hazardous events like cyclone, storm surge, etc. in carrying out fishing activities. In this context, they have limited capacity to adapt with the mentioned climatic events as most of the fishers are poor and have narrow scope of coping with the hazardous situation. However, the fishers usually undertake various initiatives to cope with such environmental stress for reducing health and economic risk. Among the initiatives, they profoundly use the mechanized boat for operating the fishing gears. Along with other multiple benefits, they can return to safe place from fishing within the shortest possible time being noticed/informed about any hazardous event. According to the local people, a good number of fishers possesses mechanized boat in this Upazila for catching fish. Availability of fishing boats by unions in Jagannathpur Upazila is shown in **Figure 4.11**.

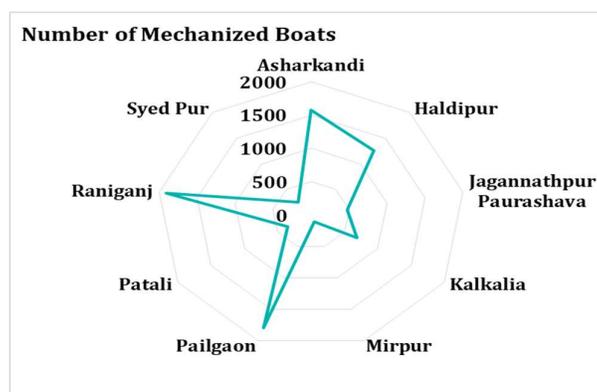


Figure 4.11: Availability of mechanized boats

CEGIS Field Survey, 2022

Fishing gear

In the Upazila, various types of fishing gear are used to catch maximum fish within the shortest period of time for strengthening their economic capability and reduce socio-economic vulnerability. In this study, different types of fishing gears and catch have been observed during the field investigation. The gear specific detail information of catch and catch per unit effort (CPUE) are shown in **Table 4.7**.

Table 4.7: CPUE of mostly available fishing gears during the study period

Gear Name	Within 10 Years				Before 10 Years			
	Haul Number	Haul Duration (Hr.)	Catch (kg)	CPUE (Kg/hr.)	Haul Number	Haul Duration (Hr.)	Catch (kg)	CPUE (Kg/hr.)
Dharma Jal	37	6.5	8.8	1.35	37	6.5	8.85	1.35
Ber Jal	6	12	3.5	0.29	6	12	3.5	0.29
Current Jal	9	6.5	5.5	0.85	9	6.5	5.5	0.85

CEGIS Field Survey, 2022

4.2.4 Vulnerability

Vulnerability of Capture fisheries of Jagannathpur Upazila was obtained through validated impact chain analysis. Generally high vulnerability occurs when for particular union sensitivity is high but adaptive capacity is low. From the assessment (**Table 4.8**) Haldipur, Kalkalia, Mirpur, Patali, Syed Pur and Jagannathpur Paurashava unions were found to be in medium vulnerability. These unions had high to moderate sensitivity and moderate to high adaptive capacity. Asharkandi, Pailgaon and Raniganj unions were found to be in low vulnerable zone.

Table 4.8: Summary of climate vulnerability assessment for capture fisheries in Jagannathpur Upazila

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Asharkandi	High	Low	Low	Low
Haldipur	Low	Medium	Medium	Medium
Kalkalia	Medium	High	High	Medium
Mirpur	High	High	High	Medium
Pailgaon	Medium	Low	Low	Low
Patali	High	High	High	Medium
Raniganj	Medium	Low	Low	Low
Syed Pur	High	High	High	Medium
Jagannathpur Paurashava	Low	High	Low	Medium

4.2.5 Risk

The study also assessed the risk associated to capture fisheries for the base and 2050s time period. The unions Kalkalia and Asharkandi are highly exposed to multi-hazard risk in both present and future time periods and Haldipur, Pailgaon, unions and Jagannathpur Pourshava are highly exposed to multi hazard risk in the future which affects capture fisheries activities negatively throughout the year in these unions. Rivers Kushiyara, Kamarkhal, Naljur and Dauka run through unions Raniganj, Pailgaon, Haldipur, Asharkandi, Kalkalia, Patali and Jagannathpur Pourashava which creates capture fisheries opportunity in these unions but also leave them exposed to flood, wave action, erosion etc. Due to lack of proper early warning system, fishermen often get caught up in heavy rainfall, lightning and flash flood while fishing in these rivers and lose their boats, nets, fishing gear, catch and even their lives. Their conventional fishing boats and other equipment are not adequate to cope with the changing climatic threats. Siltation in Nolijur River and Nollahr haor decreases water availability and hampers fish production. Due to increasing temperature, the water temperature is also rising, affecting the water quality adversely. Lack of oxygen in the water lead to hampered growth rate and increased mortality of fish. Moreover, the fishermen in the region lack for appropriate freezing, storage and transportation facility hence often loose a considerable amount of their catch.

From risk analysis of capture fisheries, Kalkalia union was found to be in high risk in the base period and will be continued to be the same in 2050s. Haldipur and Asharkandi unions, which were found to be under moderate risk zone in the base period, will change into high risk zone in the future. Pailgaon union was found to be in low risk in the base period and will change to moderate risk zone in the 2050s. The rest of the unions i.e, Patali, Mirpur, Syed Pur, Raniganj unions and Jagannathpur Pourashava were found to be in low risk for both periods. The income and livelihoods of high risk unions will face more losses and damages due to recurrent climatic extreme event. Following **Figure 4.12** shows the risk of capture fisheries in Jagannathpur Upazila.

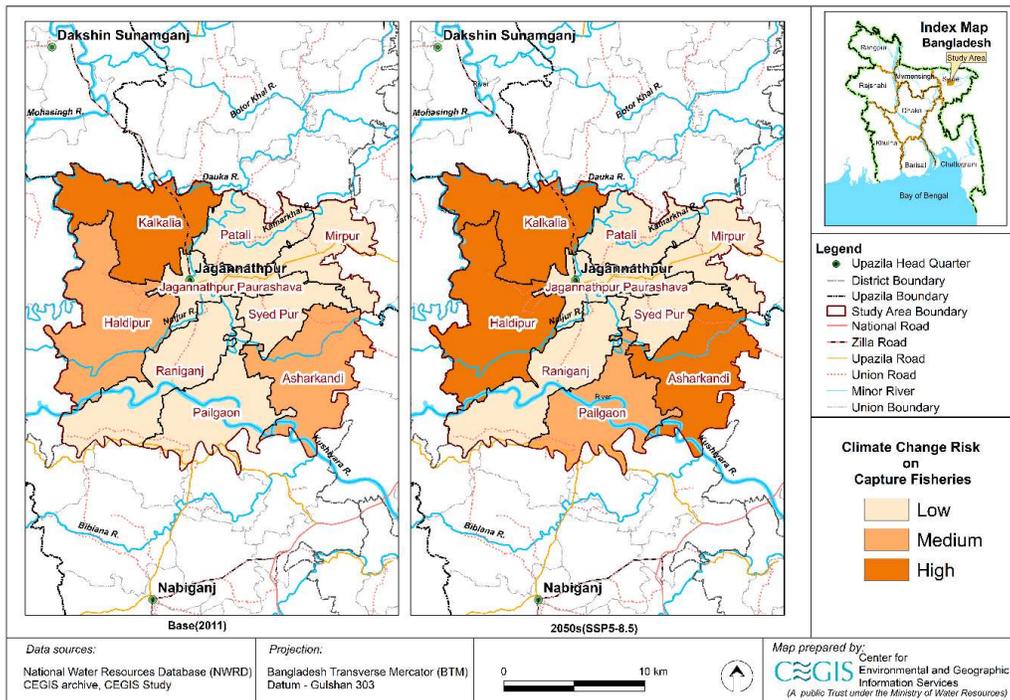


Figure 4.12: Climate risk of capture fisheries in Jagannathpur Upazila

4.3 Culture fisheries

4.3.1 Exposure

The aquaculture sector in Jagannathpur Upazila includes different culture technology adopted for commercial ponds and homestead ponds. Assessment of the aquaculture habitat and cultivable fish species are briefly described in respect of the exposure indicators in the following sections.

Habitat

About 721 ha area of fish pond including extensive and semi-intensive ponds were found in Jagannathpur Upazila. Most of the ponds are seasonal and aquaculture is practiced there during the wet season adopting extensive technology. Major carp, exotic carp and other fast-growing fish species are cultured in the ponds following poly-culture technology. Extent of aquaculture habitats by unions in Jagannathpur Upazila are shown in **Table 4.9**.

Table 4.9: Extent of aquaculture habitats by unions in Jagannathpur Upazila

Unions	Water area (ha)
Asharkandi	30
Haldipur	14
Jagannathpur Paurashava	13
Kalkalia	341
Mirpur	20
Pailgaon	183
Patali	68
Raniganj	28
Syed Pur	24
Total	721

Satellite image LandSat8, 2019

Cultured fish species

Tilapia was found to be a highly cultivable fish species in Jagannathpur Upazila (**Figure 4.10**). The pond owners mainly cultivate major carp and other fast-growing fish as these fish species have high market demand and low mortality rate due to temperature and other climatic stress conditions.

Table 4.10: Composition of cultured fish species in fish ponds and Bio-folio in the unions

Species name	Species composition (%)
Catla	4.0
Gonia	0.3
Grass carp	2.6
Kalbasu	3.6
Mrigal	3.3
Pabda	1.8
Pangas	19.3
Rui	6.6
Sarpunti	3.3
Shing	2.1
Tilapia	53.1
Total	100

CEGIS Field Survey, 2022

Livelihoods

In recent past fish farming is gradually increasing in the study area. The average monthly income of fish farmer is about BDT 15,000 -20,000 (monthly) from fish farming. Whereas female's income from fish farming is also very low because most of the women help their husbands in fish farming and do not own ponds, so they do not get any remuneration for this. After dealing with all the social challenges, the women who are involved in culture fisheries and own fish farm earn an average of BDT. 6000-7000 monthly.

Besides, wage paid to women in this area is usually significantly lower than what their male counterpart earns for doing the same job.

Income from fish farming depends on the weather conditions, if favorable or not, and the production. Respondents stated that there was not much surplus after meeting the household needs from only paddy farming earlier, but now the farmers are getting more profit from fish farming. Additionally, road communication has become developed so that is also increasing the possibilities of higher income for fish farmers, although, fish farming is affected almost every year due to natural calamities which adversely affects their income. Pond fish farmer faced various types of problems during culture period such as economical, technical, social and environmental problem. Flash floods, landslides, droughts etc. make the livelihood of the pond fish farmers more exposed due to lack of money for pond management, insufficient water in dry season, non-availability of fish fry, and fish disease.

An indicator-based assessment was also made to understand the culture fisheries exposure to climate change induced hazards in Jagannathpur Upazila. In this regard, eleven exposure indicators were selected (Annex I) and mapped after analyzing through impact chain. **Table 4.17** below shows the exposure status of Jagannathpur Upazila. From the assessment, Kalkalia union was found to be in high exposure while Pailgaon union had moderate exposure and the rest of the unions were exposed at a low rate for culture fisheries.

4.3.2 Sensitivity

The aquaculture production becomes vulnerable when different sensitivity and adaptive capacity indicators are seen. The condition of other sensitivity indicators and adaptive capacity are briefly described in the following sections.

Habitat condition

Pond water quality starts to degrade when temperature reaches higher than 33°C and results in slow growth and reduced feeding efficiency (A. Adey et. Al., 2015, M. Shahjahan, 2021). Temperature higher than 36°C is the lethal limit for most fish species. Temperature less than 22 °C can also cause less feed intake and less body weight (Singh, 2019). Moreover, pH ranges from 6.8 to 8.5 is the optimum preferable for most fish species and 3.8 is the lethal limit to which most fishes cannot survive within 12 hours (G. L. Allan and G. B. Maguire, 1992). It has been found that, in the study area, pH, TDS and DO are in optimum range but BOD exceed slightly in all unions. (**Table 4.11**). It has been found that the fish ponds have more or less stress environment in respect of water temperature and DO (**Table 4.11**). Exceeding BOD can cause stress, suffocation or death of fish. It has also been predicted that extreme temperatures coupled with erratic rainfall patterns have a direct impact on fish physiology, growth, feeding behavior and mortality in aquaculture. Moreover, excessive rainfall will breach the dyke of the fish pond and increase the natural mortality due to depletion of pH.

Table 4.11: Stress magnitude of the shrimp/prawn/fish farm ecosystem in the Jagannathpur upazila

Unions	PH	TDS (gm/l)	Water Temperature (°C)	DO (mg/l)	BOD (mg/l)
Asharkandi	7.8	30	33.4	5.7	5.8
Haldipur	8	31	33	5.6	6
Jagannathpur Paurashava	7.9	30	32	5.9	5.5
Kalkalia	8	31	33.5	6	8
Mirpur	8	28	33	5.7	6.2
Pailgaon	8.2	27	32	5.5	5.8
Patali	8.5	29	32.5	6.2	5.9
Raniganj	8	30	33	6	5.6
Syed Pur	7.8	26	33.5	5.8	5
Acceptable Range of Fish Community including Crustaceans	Growth Limit: 6.8-8.5 Lethal Limit: 3.8	0.3-120	Lethal Limit: 36 °C Optimum Range: 25-30°C Significantly Lower Growth Rate (<1%/day SGR*): <15°C and > 33°C	>5	<50

The study has found that the average water depth of the fish pond is above the minimum required water depth (1m) in all unions of Jagannathpur Upazila. Furthermore, more than 50% vegetation coverage (considering both floating and sub-merged vegetation) was found in the fish ponds in most of the unions (**Figure 4.13**). The ponds having higher coverage of submerged vegetation (>50%), are expected to produce high abundance of methanotrophs, which can act as a biological sink for the greenhouse gas methane. According to L. Fan et al. (2019), the present study has predicted that the submerged vegetation potentially may influence methanotrophs in two ways: by increasing the alpha diversity of the methanotrophic community or by increasing methanotrophic abundance through inducing anaerobic root zone conditions, thereby increasing methane oxidation potential.

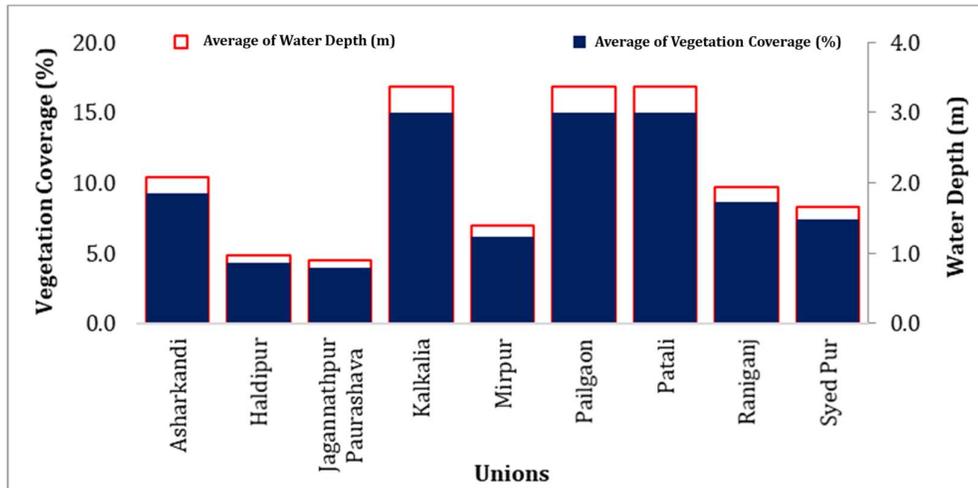


Figure 4.13: Average water depth and vegetation coverage in the fish ponds in different unions of the Jagannathpur Upazila

Growth coefficient and natural mortality

The growth coefficient and natural mortality of fishes, which have been exposed to extreme climate change events, were selected as the major sensitivity factor for aquaculture production. It has been found that the highest growth rate in aquaculture is among the Tilapia (nearly 0.18 cm per day). However, the highest mortality has been found in case of Catla (**Figure 4.14**). From the survey, this is mainly a result of viral infection accelerated by increasing temperatures.

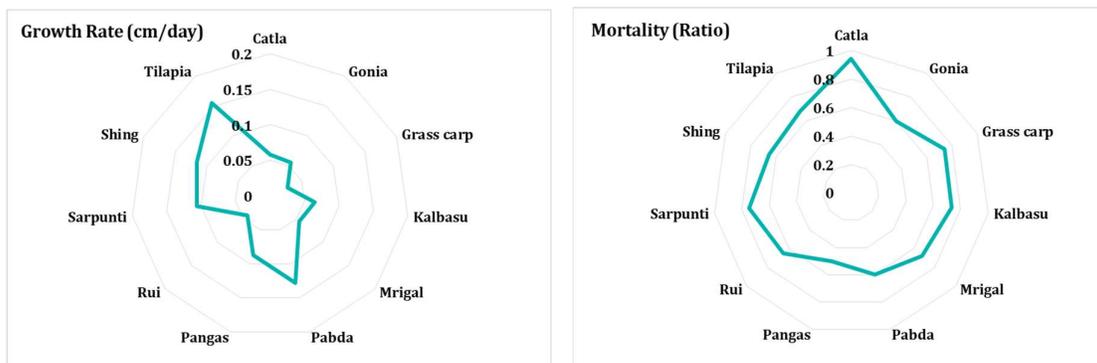


Figure 4.14: Exposure of fin fishes to major climate induced hazards

CEGIS Field Survey, 2022

Production loss due to climate-induced disease

Different unions of Jagannathpur Upazila were estimated to lose fish production due to climate-induced disease and different extreme events (**Table 4.12**). During field survey, three climate induced diseases have been identified, among them antenna cut and White Spot Syndrome (WSS) are caused due to extended days of extreme high temperature and, Epizootic Ulcerative Syndrome (EUS) is happened because of extended days of severe cold temperature.

Table 4.12: Production loss due to climate-induced disease

Unions	Fish production loss (MT)
Asharkandi	4.2
Haldipur	2.0
Jagannathpur Paurashava	1.8
Kalkalia	47.8
Mirpur	2.8
Pailgaon	25.6
Patali	9.5
Raniganj	3.9
Syed Pur	3.4
Total	101

CEGIS Field Survey, 2022

Fish production

The changes mentioned above in habitat condition and fish biology with growth co-efficient and natural mortality in respect of different climate change scenarios, total fish production in the unions of Jagannathpur Upazila would be about 4,525 MT, 2,433 MT, 2,513 MT, 2,513 MT and 2,811 MT in SSP1-2.6 (2050), SSP1-2.6 (2100), SSP5-8.5 (2050) and SSP5-8.5 (2100) scenarios respectively as shown in **Table 4.13**.

Table 4.13: Aquaculture fish production under different climate change scenario

Union	Fish Production (MT)				
	Base Year	SSP1-2.6 (2050)	SSP1-2.6 (2100)	SSP5-8.5 (2050)	SSP5-8.5 (2100)
Asharkandi	104	100	103	103	115
Haldipur	48	47	48	48	54
Jagannathpur Paurashava	48	46	47	47	53
Kalkalia	1195	1152	1190	1189	1331
Mirpur	70	68	70	70	78
Pailgaon	639	616	636	636	712
Patali	239	230	237	237	266
Raniganj	98	95	98	98	109
Syed Pur	84	81	83	83	93
Total	2525	2433	2513	2513	2811

Impact Chain Analysis, CEGIS (2022)

Livelihoods

Field findings found that the aquaculture sector is suffering every year due to adverse weather condition, climate change, increasing natural calamities etc. Whereas flash flood is major problem for agriculture which does not disrupt aquaculture production every year. As a result, people in this region are interested in fish farming. Besides, during monsoon most of the people who were involved in agriculture earn their livelihood by catching fish. However, due to extreme weather conditions and various natural calamities, the farmers are not being able to profit as expected in fish farming.

Due to adverse weather conditions and natural calamities, the fish farmers are unable to make the expected profit. Due to frequent flash floods, the ponds are washed away and the bank of the pond as well as fish production are damaged. Small farmers who cultivate small areas or taking lease are the most affected. Many of them tried to support their families through a subsistence economy. Now if the fish ponds are damaged due to extreme weather condition, they have no other means of livelihood. As a result, it becomes very difficult for them to make a living in this situation.

An indicator-based sensitivity analysis (**Table 4.17**) was also made to identify sensitive unions of Jagannathpur Upazila. A total of 13 (thirteen) indicators were used to represent the sensitivity of ecosystem in Jagannathpur. A list of indicators is attached to the (Annex I). According to the sensitivity analysis,

Kalkalia union was found to be highly sensitive while Pailgaon union was moderately sensitive and the rest of the unions are low in terms of sensitivity for culture fisheries.

4.3.3 Adaptive capacity

There are three types of adaptive measures found to be adopted by the pond owners in order to adapt with the extreme climatic events in the unions of Jagannathpur Upazila. These include aquaculture production system, farm management against natural hazards and disease control measures as discussed below.

Aquaculture production system

The study has found that pond owners in all unions take about 48 days (from December to January) to prepare the pond for aquaculture. The farmers adopt mainly semi-intensive culture technology. They use about 240kg of fertilizer and 123 kg of lime per hectare on average for their pond management (**Table 4.14**). Stocking rate of these ponds mainly depends on the pond area and water depth. Vegetation coverage also have an influence on the pond management. Union wise fertilizer and lime use in the Upazila is given in the **Table 4.14**.

Table 4.14: Aquaculture production system in different unions of Jagannathpur Upazila

Union	Land Preparation (Days)	Fertilization (kg/ha)	Lime (kg/ha)
Jagannathpur Municipality	48	245	115
Asharkandi		220	110
Haldipur		250	125
Kalkalia		240	120
Mirpur		255	130
Pailgaon		235	120
Patali		230	130
Raniganj		240	130
Sayedpur-Saharpara		245	125

CEGIS Field Survey, 2022

Farm management against natural hazards

The present study found that the local aquaculture farm owners have very limited adaptive capacity against the extreme climate induced events. They frequently take only two measures to tackle the extreme hot days, including irrigation in the ponds and use of water hyacinth in the ponds to make shade. During the drought period, they mainly use groundwater (**Table 4.15**). They use fine nets surround their pond to protect fishes from overtopping during flood, heavy rainfall and erratic rainfall. In this study, a survey was conducted on 60 participants where 32% took no adaptive measure for heavy rainfall, erratic rainfall and wet days.

Table 4.15: Adaptive measures for farm management

Hazard	Adaptive Measures	Response (%)
Extreme Hot Days	<ul style="list-style-type: none"> ● Pumping water ● Use of water hyacinth in the ponds to make shade 	19
Flash Flood	<ul style="list-style-type: none"> ● Using Groundwater ● Farmers irrigate water to the ponds to maintain water level at least 1.0 meter in the dry season ● Fish farmers fenced their ponds with Nylon net or bamboo made mat (Bana) around the pond to prevent fish from escaping ● The farmers heighten the pond dyke to prevent fish from escaping ● The farmers harvest fish at premature stage before flooding to some extent 	25
Heavy Rainfall	Fish farmers usually do not take any measure in case of these hazards	56
Erratic Rainfall		
Wet Days		

CEGIS Field Survey, 2022

Climate-induced disease control measures

Four climate induced diseases were identified during the field survey, among them eye disease, argulosis and gill damage are caused due to extended days of extreme high temperature and, Epizootic Ulcerative Syndrome (EUS) is happened because of extended days of severe cold temperature. The local aquaculture farm owners frequently use aqua medicine and liming for eye disease, argulosis and gill damage and aqua-medicine and liming and salt for controlling EUS (**Table 4.16**).

Table 4.16: Adaptive measures for disease control

Climatic Cause	Disease	Disease Control Measures	Response (%)
Extended days of extreme high temperature	Eye disease	Using Aqua-medicine, Lime and Salt	18
	Argulosis		32
	Gill damage		10
Extended days of severe cold temperature	EUS	Using Aqua-medicine, Liming and Salt	11
		No measures	29

CEGIS Field Survey, 2022

Union wise adaptive capacity was also assessed (**Table 4.17**) through different indicator-based impact chain. These indicators mainly demonstrate the coping mechanism of the culture fisheries in hostile condition induced by climate change. However, the culture fisheries scenario assessment in this study followed 17 adaptive capacity indicators. Although due to study limitation, the study team could cover only three unions during field visit. The study team assessed union wise condition by consulting SUFOs, key informants, secondary data sources and expert judgment. The set of indicator lists are attached (Annex I). From the adaptive capacity assessment of the culture fisheries in Jagannathpur Upazila it was found that Asharkandi, Haldipur, Kalkalia, Mirpur and Syed Pur unions were highly adaptive to culture fisheries, whereas Pailgaon union was moderately adaptive and the rest of the unions had low adaptive capacity for culture fisheries.

4.3.4 Vulnerability

Vulnerability of culture fisheries (**Table 4.17**) of Jagannathpur Upazila was also obtained through validated impact chain analysis. Generally, high vulnerability occurs when for any particular union sensitivity is high but adaptive capacity is low. From the assessment Kalkalia, Mirpur, Pailgaon, Patali and Syed Pur unions were found to be moderately vulnerable. These unions had low to moderate sensitivity and moderate to high adaptive capacity. Asharkandi, Haldipur, Raniganj and Jagannathpur Paurashava unions were found to be in low vulnerable zone.

Table 4.17: Summary of climate vulnerability assessment for culture fisheries in Jagannathpur Upazila

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Asharkandi	Low	Low	High	Low
Haldipur	Low	Low	High	Low
Kalkalia	High	High	High	Medium
Mirpur	Low	Low	High	Medium
Pailgaon	Medium	Medium	Medium	Medium
Patali	Low	Low	High	Medium
Raniganj	Low	Low	Low	Low
Syed Pur	Low	Low	High	Medium
Jagannathpur Paurashava	Low	Low	Low	Low

4.3.5 Risk

Climate change induced hazard risk (**Figure 4.15**) for culture fisheries was obtained through impact chain analysis for base and 2050s time period. Kalkalia and Pailgaon unions contain the highest number of aquaculture farms in Jagannathpur. However, these unions also faced highest amount of production loss. During flood events the western portion of Jagannathpur including Kaikhali, Haldipur and Jagannathpur Pourashava gets inundated due to its low lying topography and lack of proper flood protection infrastructure. During floods fish being washed out of ponds and predator fish entering in the ponds are common occurrences. Hence fish farmers often elevate the banks of their ponds to prevent flood water intrusion. Low water availability during the dry season poses difficulty for fish farmers who often need irrigation to maintain adequate water level for fish culture. Lack of proper storage and transportation facility result in considerable production loss. The increasing temperature also increase the oxygen demand of water in the fish farms and lead to reduced fish growth rate and death of fish fry and juvenile fish. The farmers often use banana leaf, coconut leaf, palm leaf and bamboo baskets to maintain optimum water temperature and quality of water as adaptive techniques during summer.

The culture fisheries risk assessment found Kalkalia union to be in high risk for the base period. Haldipur, Asharkandi unions and Jagannathpur Pourashava which were in the moderate risk zone in the base period will be in high-risk zone in 2050s. Pailgaon union was in moderate risk at the base period and will be continued to be the same in 2050s. Initially Raniganj union was in low-risk zone in the base period, but due to increased impact of climate change it will be in moderate risk zone in 2050s. Unions Patiali, Syed Pur and Mirpur stays in low-risk zone for both the time slices.

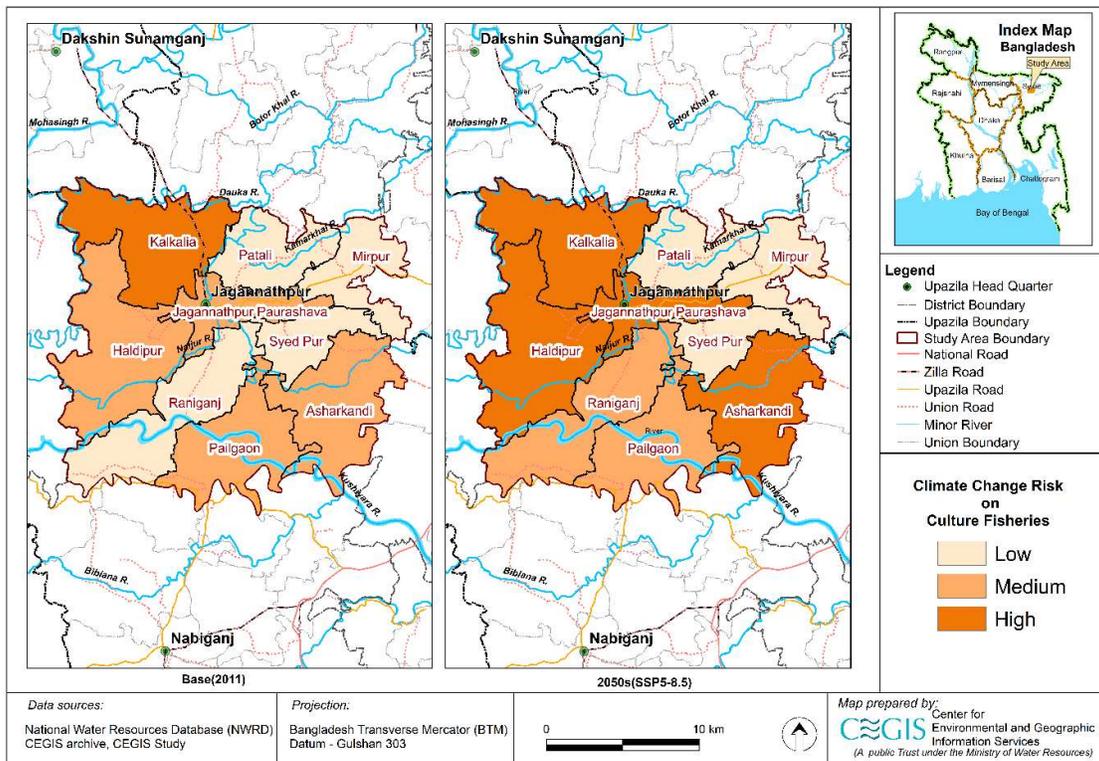


Figure 4.15: Climate risk for culture fisheries in Jagannathpur Upazila

4.4 Gender

Gender equality and women’s empowerment agenda for the 8FYP is based on pursuing strategies and actions, not only enhance women’s capabilities, and access to resources, and opportunities, but also address the barriers in structures and institutions including the changing practice of social norms and protecting their rights are critical to integrate within the plan. The vulnerability of women to climate change is

different from men in different aspects (e.g. accessibility and control over resources, limited work opportunity, social status etc.). Its sensitivity is not equal for all. Women do most of the reproductive and part of the productive work, while men are only responsible for the productive work. Women (43.1%) participate in the labor market but gender-based inequalities are found in wage rate, access to the market, and decision-making power.

Jagannathpur upazila is an administrative unit situated in the Northeast region of Bangladesh. Natural disasters (extreme heat, flooding, lightening, drought) are a very common phenomenon in this region. The livelihood of the people of this upazila is dependent on the haor. These people are marginalized and dependent on threatened natural resources. Fisheries and aquaculture is one of the main income-generating sources in this area. Women are also involved in these activities, especially in the post harvesting period such as cleaning weeds, carrying soil up pond bank, pond cleaning, testing water quality (color), applying fish feed, fertilizer, lime etc. In the broader sense, women cannot contribute much to decision-making, though they are involved much in the production processes. Mainly the women are directly related to traditional gender roles. Women have a minimal impact on the planning and decision-making process. Both qualitative and quantitative data has been collected to identify the risks, risks mitigation action and future adaptation measures.

This section analyzes climatic risks on gender. Besides, it analyzes the mitigation and adaptation measures which is linked to climate change impacts to highlight these issues into policy, plans and programs to promote gender sensitive resilience in fisheries sector.

4.4.1 Exposure

The impact of climate change has increased the number of various hazards that have adverse effects on fisheries and aquaculture. In fisheries and aquaculture sector, exposure determines the risks to be exposed on fisheries resources (i.e. ponds, fishing gear) and vulnerable communities who are prone to become affected due to the climate change. In Jagannathpur upazila fish farming is one of the most important occupations. Women are also involved in fish farming. But their main roles are to support the male members in doing that. This upazila is geographically situated in a haor area which resulted to create an impact on the fisheries and aquaculture sector. Moreover, the suffering has increased due to the fragile infrastructures, lack of training, lack of capital, lack of time to be involved in this activity instead of household chores. Women are disproportionately affected by climate change.

Women are not involved in fishing even though the region is dominated by haor. It is found that most women do not, or are not permitted to work outside the home. However, they involve in agricultural work such as crop threshing, processing and storing along with household work but are not involved in fishing. However, some women sometimes catch fish near the house to meet their family's needs. According to Upazila Fisheries Office information, the total number of fishers is 12,100. Among those, the number of registered fishers is 8420. It can be seen that the number of women fishers in this region is negligible compared to their male counterparts.

Women are mainly involved in household work, but also, women assist men in all activities related to fish farming such as pond preparation, feeding, harvesting, fertilizer application, take care of the pond etc. Women who are involved in such activities spend about 2/3 hours daily for these activities. Due to the disasters, reduced working hour and decreased fish production in the fish farms impact household income which is higher for female owning or leasing out ponds.

The following **Table 4.18** shows the engagement of gender in Fish activities and the family members' dependency (dependent population belong to the age group of 0-14 and above 60).

Table 4.18: Distribution of engagement in fish related activities with family members dependency

Name of the Unions	Male (% of fish related occupants)	Female (% of fish related occupants)	Dependent members (%)
Syedpur	98	2	46.2
Raniganj	97	3	48.9
Patali	98	2	48.2
Pailgaon	97	3	48.9

Name of the Unions	Male (% of fish related occupants)	Female (% of fish related occupants)	Dependent members (%)
Mirpur	98	2	46.1
Kalkalia	98	2	49.3
Haldipur	97	3	50.3
Asharkandi	97	3	47.1

BBS 2012 and estimated through Field Survey, 2022

During flash floods the entire area gets suddenly washed out along with the ponds. It adversely affects houses, crop fields, infrastructure as well as culture fishing, homestead vegetation, income generating activities. With the regular increase of hazards, the access roads, ponds, tube-wells get damaged, which impact women much more severely than it does to the men. Women endure sufferings because of the exposure of houses, roads, ponds and IGAs due to the climatic hazards in this upazila (based on the people's perspective from different unions). Thus, from the gender perspectives, the women of this upazila are facing worse impact than their male counterparts as the fish ponds, access roads, fresh water sources, growth centers and IGA get exposed to the hazards which have been occurring on a greater rate in recent years, in this Upazila.

Based on the indicators of exposed elements by combining all data of exposed elements, it is found that Haldipur unions are highly exposed by the climatic hazards in comparison with other unions (**Table 4.21**). Besides, Jagannathpur Pourashava and Syed Pur union were moderately exposed and rest of the unions were found as comparatively less exposed by the risks of flash flood, wave action, siltation and other hazards occurred in this area.

4.4.2 Sensitivity

Different parameters as health, physical condition, working opportunity, income, poverty become more sensitive due to the impacts of natural hazards. Women, the aged, children, and physically challenged people cannot move to the health centers or flood shelters easily during disasters. In the flood shelters the women do not have separate accommodation, thus they often do not feel at ease to stay there or move comfortably within the shelter, which are aspects that also increase their vulnerability. Another more concerning issue is, women have little access and control over land, labor and development resources including credit, technology, training and information. From this perspective, they are more sensitive than the male members of their community, at any given time. Thus poverty, dependence on male members, socially determined skewed power relations, lack of access to productive resources make women more sensitive to hazardous situations particularly in changing climate situations.

Following **Figure 4.16** shows the monthly average income by gender in fish farming and related activities in Jagannathpur. Facing all sorts of the social challenges, women involved in fish farms earn on an average BDT. 6,000-7,000 monthly, which is much lower than the monthly income of their male counterparts, which ranges between BDT 14000 to BDT 16000. Altogether, respondents from the different unions in Jagannathpur Upazila stated that their average income is not sufficient to maintain their daily life. At times of crisis, if not on a regular basis, the women involved in fishing hand over money to the male family members, which creates constraints on their journey to be self-reliant. Apart from this, religious bindings also make it difficult, and sometimes impossible, for women to work outside, especially in this region. They often do not have, or cannot take advantage of, the opportunities to be involved in alternative income-generating activities which are offered through NGOs and government programs. As a result, poor conditions and fewer income opportunities continue, which make them more sensitive to the changing climatic conditions.

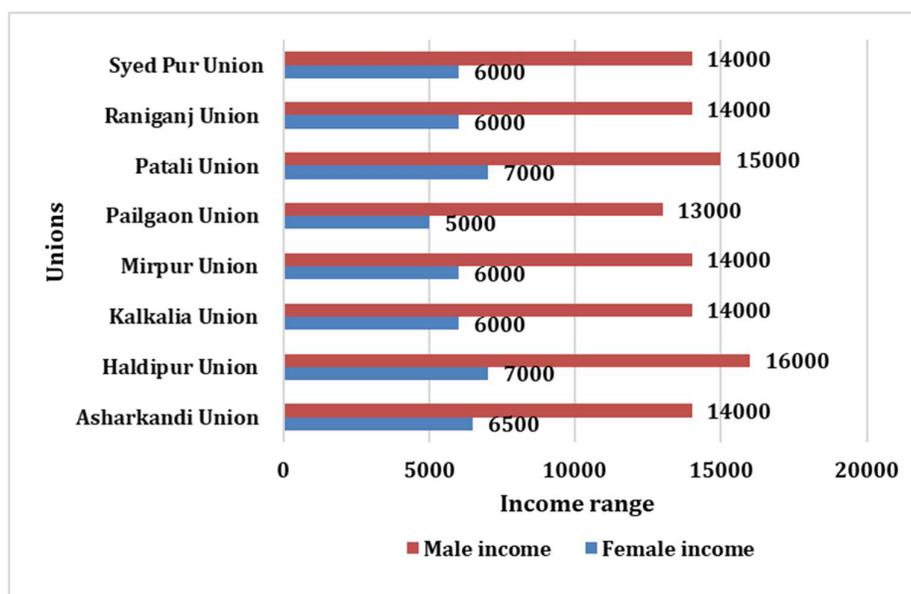


Figure 4.16: Monthly average income in fish related activities

Women wage rate is lower than the wage rate of their male counterparts. It has been found during the field visit that, for the same work, women were paid BDT 250 to 300 taka whereas the male workers were paid BDT 400 to 550, per day. Less income is a reason that makes them more sensitive to the changing climatic condition. In some remote areas of Jagannathpur upazila, the people especially women and the aged people suffer a lot due to a lack of sufficient health facilities. Moreover, fragile infrastructures make the situation more sensitive. Following **Table 4.19** shows the different indicators and their impacts on women that will make them more sensitive.

Table 4.19: Impacts of hazards on women

Indicators	Impacts
Loss of income, savings and employment	Different hazards in this area affect the income sector. Employment and income generation are disrupted due to natural calamities. It makes women's income lower than their male counterparts. The net loss in income leads to a loss of savings, thus making it even harder for households to cope with disasters. During the flash flood, water enters and washes out the ponds. In this way, women farm owners have to face great loss that make them more vulnerable. At the same time, the lack of savings and income loss make them more vulnerable since they have very little say in decision making at households, pond management, and market level.
Impact on pond management and homestead production	Women have less control over the resources especially ownership of the ponds. Women usually work at nearby ponds. Due to floods etc., their pond-base activities get disrupted. Women who earn homestead-based livelihoods, like growing vegetables and crops, or rearing poultry and/or livestock are more affected by disasters. After any natural calamity, vegetation and crops are destroyed, their work opportunities are curtailed, and shortage of loans or other facilities together make it more difficult for them to recover from this situation. And when poverty strikes, women tend to feed their husbands and children first, before taking any food themselves, and usually eat leftovers. This social and cultural practice tends to make women susceptible to chronic nutritional deficiency.

Sickness and disease	The frequency of sickness has increased in the region. Women who are involved in fish culture and fish processing have to work for a long time. Women and adolescent girls are usually required to work hard even in pregnancy period. In most of the cases, women need to go to cities for treatment, which is a financial burden for their household. Also, they cannot travel on their own, and often they are not taken to hospitals or medical facilities when needed. For all these reasons, premature birth, abortion and still birth (blue-baby syndrome) are reported in alarmingly high numbers in these areas. Apart from this, flood related deaths are often caused by drowning and snake bites, which tend to occur in increasing numbers for children, followed by adult women. There is a health center situated in the Upazila headquarter and community clinic at the union level. Access to hospital and lack of medical officers and modern equipment create problems to get health service perfectly. During the period of disaster, critical patient and pregnant suffer a lot to receive treatment from the hospital and community clinic because of the remoteness and vulnerable communication system.
Social security	Women's involvement in household activities is not counted as economic activity in the study area. They do not get social dignity. Employed women sometimes face social stigma, and many problems. There is no separate facility for working women in the local market which is dominated by men, and flood shelters also do not have separate rooms or toilet facilities for women, which also makes their situation more vulnerable.

According to the **table 4.21** the union named Asharkandi, Kalkalia, Mirpur, Pailgaon and Raniganj were found highly sensitive due to the moderate condition of domestic violence, moderate accessibility to income opportunities, post harvesting loss and working hour according to the results on sensitivity indicators on Gender.

4.4.3 Adaptive capacity

Following **Table 4.20** shows the status of people's contribution or access toward the adaptive indicators. Field finding shows that, 67% of women respondent know about climate change. The percentage of having knowledge of fisheries techniques and the percentage of having knowledge about pests and diseases is 75% and 58% accordingly. About 58% of the respondents have received training on alternative livelihoods. The adaptive capacity scorecard shows that they are getting the facilities to be adaptive and fighting against the challenge of climate change-induced problems. But they feel that they have insufficiency in obtaining training facilities on alternative livelihoods, climate change adaptation, climate resilient housing, pond management and infrastructures.

Based on the adaptive capacity score card, it is clear that the women in the Jagannathpur Upazila requires to be more enlightened on climate change adaptation and alternative livelihood. Arranging more trainings, seminars on the climate change and its impacts and possible alternative earning sources can play a crucial part to educate the women more. Involving the males of the area will also help them to understand the importance of women's engagement in earning activities can be very helpful for the family. This can help the males to allow their wives of house females to work outside and earn.

Table 4.20: Status of adaptive capacity of women involved in fishing

Adaptive capacity indicators	Status (%)
Understanding of climate change impact	67
Knowledge of fisheries techniques	75
Knowledge of pests and diseases in fish	58
Receive early warning message regularly	67
Watching news/informative programs on television or social media	67

Adaptive capacity indicators	Status (%)
Having cell phone	50
Having smart phone without internet	0
Having smart phone with internet	0
Watching television once in a week	58
Accessibility to shelter during cyclone/floods	100
Knowledge on hygiene and menstrual health during disaster	75
Knowledge on drinking water boiling or chlorination	58
Training received on climate change	67
Training on alternative livelihood	58
Training on climate change impact and adaptation	50
Knowledge on reducing the salinity from drinking water	33
Training on climate resilient housing, pond management and infrastructures	0

Adaptive capacity assessment (**Table 4.21**) showed that all the rest of the unions had low adaptive capacity for gender specific fisheries livelihoods.

4.4.4 Vulnerability

Vulnerability for gender-based livelihood was also assessed for Jagannthpur Upazila using impact chains developed for the Southwest region. Vulnerability assessment (**Table 4.21**) showed Asharkandi, Kalkalia, Mirpur, Pailgaon and Raniganj unions were highly vulnerable. Unions with high vulnerability have low adaptive capacity and high sensitivity level. The rest of the unions were found to be in low vulnerability level.

Table 4.21: Summary of climate vulnerability assessment for gender-specific livelihood in Jagannathpur Upazila

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Asharkandi	Low	High	Low	High
Haldipur	High	Low	Low	Low
Kalkalia	Low	High	Low	High
Mirpur	Low	High	Low	High
Pailgaon	Low	High	Low	High
Patali	Low	Low	Low	Low
Raniganj	Low	High	Low	High
Syed Pur	Medium	Low	Low	Low
Jagannathpur Paurashava	Medium	Low	Low	Low

4.4.5 Risk

The study assessed union-wise risk on gender-based livelihood due to climate change induced hazard for two-time period. In Jagannathpur, the women have low involvement in fisheries related activities along with a little to no ownership of fish farms and decision-making powers which makes them exposed to hazards and climate change. Even for women involved in fishing and aquaculture, the wage rate is significantly lower. Specially in Pailgaon, Mirpur, Syedpur, Raniganj and Kalkalia the wage rate of women is shockingly low than men. Changing climatic condition, lack of proper hygiene knowledge and WASH facility also impact their health adversely.

Risk assessment shows that Kalkalia, Haldipur and Asharkandi unions are in high risk for gender-based livelihood for both the base period and 2050s. Raniganj, Pailgaon unions and Jagannathpur Pourashava are in moderate risk at the base period and continue to do so in the future. Initially Mirpur union was in low risk at the base period, but in 2050s due to increased impact of climate change induced hazards it showed to be in moderate risk category. Patali and Syedpur unions stay in low-risk zone for both time slices. Following **Figure 4.17** shows the gender specific risks on fisheries livelihood sector in Jagannathpur Upazila.

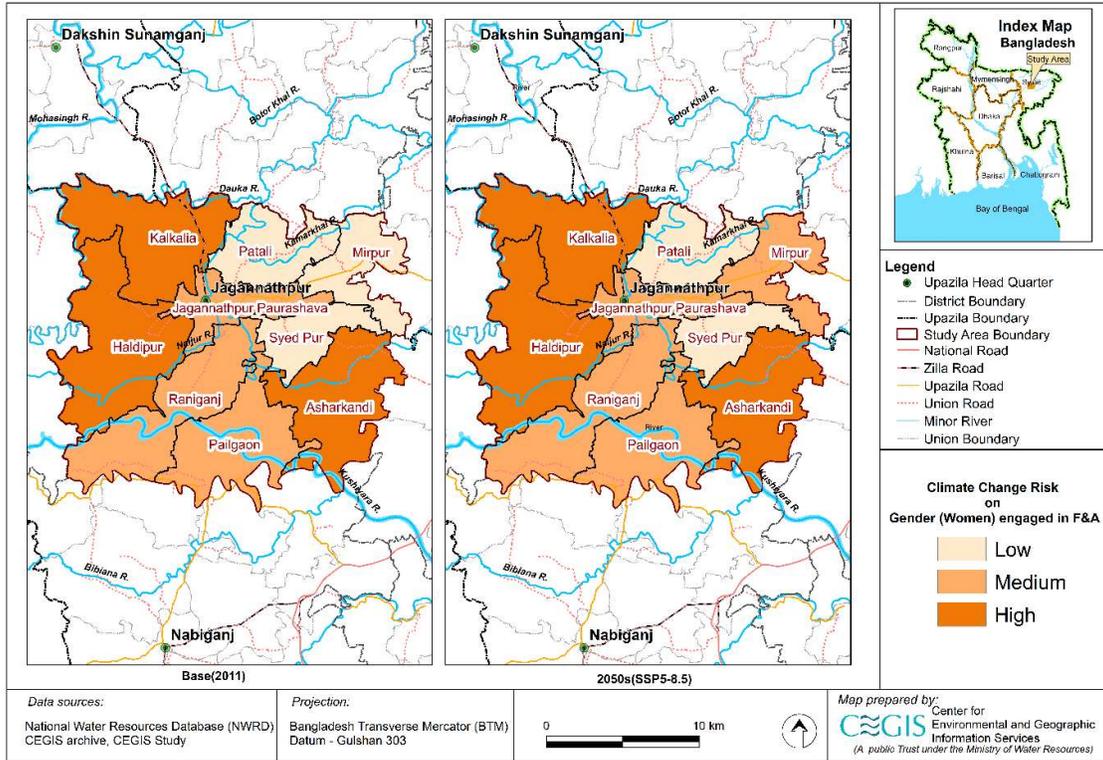


Figure 4.17: Climate Risk of Gender engaged in F&A in Jagannathpur Upazila

5 Climate Resilience Action Plan

Climate risk reduction and resilience development among society, institutions, and ecosystem is key to adapting against adversities of climate change. This chapter focuses on developing a climate resilience action plan for reducing assessed risk and vulnerabilities for the F&A sector in Jagannathpur Upazila. A resilient framework can apply to improve F&A-based livelihoods focusing on gender and boosting aquatic ecosystem health. Livelihoods diversification; human skills and institutional capacity development; sustainable development of human and ecosystem well-being through Ecosystem Approaches to Fisheries (EAF) or Ecosystem Approaches to Aquaculture (EAA); gender-responsive local led actions, etc., are among outlined priorities towards development of the resilience action plan.

This section elaborates on the implementation strategies of the developed climate-resilient adaptation plan for Jagannathpur Upazila. The approach undertaken was to group related hazards which may have similar adaptations or risk reduction options. Following tables present adaptation options for hazards prominent in Jagannathpur Upazila and identified their risk.

Open water fisheries

The **Table 5.1** below outlines the risks related to flood, flash flood and wave action on capture fisheries and gives potential adaptations and risk reduction options that should be undertaken or promoted by different stakeholders under capture fisheries.

Table 5.1: Risk of flood, flash flood and wave action on capture fisheries with adaptation options

Flood, Flash Flood and Wave Action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder(s)	When to Implement
1	Fisher's life may be at risk during fishing in the sea/river or large open waterbodies due to floods, flash floods and wave action	<ul style="list-style-type: none"> Develop and strengthen EWS and its dissemination for F&A 	<ul style="list-style-type: none"> Protect fishers' life, livelihoods and ensure social security through pre-informed early warning messages 	DoF, BFRI, FFWC, MoDMR, BMD, SPARRSO, LGED, LGIs, NGOs, Electronic, web and print media	Within 3 years
		<ul style="list-style-type: none"> Introduce index-based risk recovery mechanism or insurance scheme for the fishing communities 	<ul style="list-style-type: none"> Improve financial stability of family to recover sudden loss of family member 	DoF, BFRI, MoF, MoDMR, MoEFCC, Insurance companies	Within 3 years
		<ul style="list-style-type: none"> Training for emergency disaster response and risk management 	<ul style="list-style-type: none"> Increase adaptive capacity and know how to respond on disaster 	DoF, BFRI, MoDMR, LGD, DSS, MOWCA, NGOs, Training and Knowledge Institutes	Within 3 years
		<ul style="list-style-type: none"> Awareness raising program and behavioral change 	<ul style="list-style-type: none"> Protect fishers' life, livelihoods and ensure social security 	DoF, BFRI, MoDMR, DSS, MoWCA, LGD, NGOs, Training and Knowledge Institutes	Within 3 years
2	Fishing boats and gear may be lost or damaged due to extreme waves or current	<ul style="list-style-type: none"> Develop and strengthen EWS and its dissemination for F&A to facilitate emergency safeguard of boats or fishing gears 	<ul style="list-style-type: none"> Safeguard the fishing gears and boats against hazards Reduce economic loss of the fishermen 	DoF, BFRI, FFWC, MoDMR, BMD, SPARRSO, LGED, Electronic, web and print media	Within 3 years
		<ul style="list-style-type: none"> Introduce index-based risk recovery mechanism or insurance scheme for fishers' community 	<ul style="list-style-type: none"> Improve financial stability of fishermen to recover any losses incurred from damages Ensure sustainability of income and livelihoods 	DoF, BFRI, MoF, MoDMR, MoEFCC, Insurance companies	Within 3 to 5 years
		<ul style="list-style-type: none"> Provide climate resilience funds for repair or purchase of boats of gears 	<ul style="list-style-type: none"> Improve financial stability of fishermen to recover any losses incurred from damages 	DoF, BFRI, MoF, MoDMR, MoEFCC, LGIs, NGOs	Within 3 years

Flood, Flash Flood and Wave Action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder(s)	When to Implement
		<ul style="list-style-type: none"> Repair fishing gears before every monsoon 	<ul style="list-style-type: none"> Protection of boats or gears and economic loss through proactive adaptation 	Fishing communities	Within 3 years and continue
		<ul style="list-style-type: none"> Construction of storage areas for fishing tools 	<ul style="list-style-type: none"> Ensure support to prevent fishing gear and safety equipment damages during disasters 	DoF, BFRI, MoF, MoDMR, MoEFCC, LGIs, NGOs	Within 3 years
		<ul style="list-style-type: none"> Awareness raising program and behavioral change 	<ul style="list-style-type: none"> Enhance adaptive capacity and resilience 	DoF, BFRI, MoDMR, DSS, MoWCA, LGD, Training and Knowledge Institutes	Within 3 years and continue
3	Reduced river, haor and beel habitats due to siltation and habitat condition degradation after floods/flash floods	<ul style="list-style-type: none"> Regular dredging of all large, medium and small rivers, beels and haors 	<ul style="list-style-type: none"> Revitalization of rivers, beels and haors and restoration of fisheries habitat Reduce aquatic ecosystem vulnerability 	BWDB, MoS, DoE, NRCC, DoF, WARPO, DBHWD	Annual and periodic
		<ul style="list-style-type: none"> Maintaining connectivity of khals, beel and rivers 	<ul style="list-style-type: none"> Revitalization of rivers, beels and restoration of fisheries habitat Reduce aquatic ecosystem vulnerability 	BWDB, MoS, DoE, NRCC, DoF, WARPO, DBHWD	Within 3 to 5 years
		<ul style="list-style-type: none"> Restoration of fish habitats and breeding grounds 	<ul style="list-style-type: none"> Increase productivity of fisheries 	DoF, BFRI, DoE, MoS, NRCC, WARPO, DBHWD	Within 3 to 5 years
		<ul style="list-style-type: none"> Delay fishing activities until river/beel water become clean 	<ul style="list-style-type: none"> Reduce production losses 	DoF, BFRI, MoLJPA, LGIs	Within 3 years and continue
4	Overall fishing activities may be hampered due to extreme weather, floods/ flash floods or wave actions	<ul style="list-style-type: none"> Awareness raising and capacity building for enhancing coping mechanism 	<ul style="list-style-type: none"> Increase adaptive capacity and resilience, income generation activities and improve living standard 	DoF, BFRI, MoDMR, DSS, MoWCA, LGD, NDOs, Training and Knowledge Institutes	Within 3 years and continue
		<ul style="list-style-type: none"> Arrangement of opportunities and skill development for alternative livelihoods generation 	<ul style="list-style-type: none"> Increase adaptive capacity and resilience, income generation activities and improve living standard 	DoF, BFRI, LGIs, DSS, MoWCA, MoDMR, MoEFCC, Training and Knowledge Institutes, Private Sectors	Within 3 years and continue

Flood, Flash Flood and Wave Action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder(s)	When to Implement
		<ul style="list-style-type: none"> Introduce index-based risk recovery mechanism or insurance scheme for fishermen community 	<ul style="list-style-type: none"> Improve financial stability of fishermen to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, Insurance companies	Within 3 to 5 years
		<ul style="list-style-type: none"> Strengthen flood management measures 	<ul style="list-style-type: none"> Reduce disruptions in fishing activities and economic losses 	BWDB, LGED, DoF, WARPO	Within 3 to 5 years
		<ul style="list-style-type: none"> Climate sensitive zoning, plan and regulate fishing activities accordingly 	<ul style="list-style-type: none"> Reduce disruptions in fishing activities and economic losses 	DoF, BFRI, MoLJPA, LGIs	Within 3 years and continue
5	Migration disruptions, diseases outbreak, hampered and decreased mortality of fish leading to production loss due to floods and flash floods	<ul style="list-style-type: none"> Stock enhancement of threatened fish species 	<ul style="list-style-type: none"> Enhance resilience of fish species, increase adaptive capacity of fisheries ecosystem and reduce production losses 	DoF, BFRI, LGD, DBHWD, Knowledge Institutes, Academia	Within 3 years and continue
		<ul style="list-style-type: none"> Research and monitoring of migration extent and diseases of major fish species 	<ul style="list-style-type: none"> Innovate stress tolerant technologies, halt outbreak of diseases, reduce production losses and plan accordingly for fisheries risk reduction 	DoF, BFRI, Knowledge Institutes, Academia, DoE	Within 3 years and continue
		<ul style="list-style-type: none"> Innovate and release stress tolerant fish species 	<ul style="list-style-type: none"> Innovate stress tolerant technologies, halt outbreak of diseases, reduce production losses and plan accordingly for fisheries risk reduction 	DoF, BFRI, LGIs, Knowledge Institutes, Academia	Within 3 years and continue
		<ul style="list-style-type: none"> Conservation of freshwater sanctuaries, beel nursery and breeding ground 	<ul style="list-style-type: none"> Spawning and breeding of healthy fisheries and enhance fisheries production, boost income 	DoF, BFRI, NRCC, WARPO, LGIs, DoE, MoLJPA, DBHWD	Within 3 years and continue
		<ul style="list-style-type: none"> Provide subsidies and skill development for alternative livelihoods ensuring women's participation 	<ul style="list-style-type: none"> Reduce gender vulnerability, income loss and living standard 	DoF, BFRI, LGIs, DSS, MoWCA, DYD, MoDMR, MoEFCC, MoF, Training and Knowledge Institutes, Private Sectors	Within 3 years and continue

Flood, Flash Flood and Wave Action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder(s)	When to Implement
			<ul style="list-style-type: none"> Enhance adaptive capacity and resilience to combat disproportionate impacts on gender 		
		<ul style="list-style-type: none"> Training on gender and youth inclusive CC&DRR and EWS for fish farmers 	<ul style="list-style-type: none"> Enhance adaptive capacity and resilience to combat climate disasters 	DoF, BFRI, LGIs, DSS, MoWCA, DYD, MoDMR, MoEFCC, MoF, NGOs, Training and Knowledge Institutes, Private Sectors	Within 3 years and continue
6	Loss of livelihoods, shifting occupation and increased poverty with disproportionate impact on women	<ul style="list-style-type: none"> Introduction of zero interest or low interest-based credit facilities to recover disaster risk 	<ul style="list-style-type: none"> Improve financial stability of fishermen to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, Insurance companies, Bangladesh Banks and Private Sectors	Within 3 years and continue
		<ul style="list-style-type: none"> Introduce index-based risk recovery mechanism or insurance scheme for fishermen community specially focusing on women 	<ul style="list-style-type: none"> Improve financial stability of women to recover any losses incurred from damages due to climate hazards Reduce gender indiscrimination and inequality 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, Insurance companies	Within 3 to 5 years
		<ul style="list-style-type: none"> Provide climate resilience funds specially focusing on marginal women 	<ul style="list-style-type: none"> Improve financial stability of women to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, LGIs	Within 3 years and continue
		<ul style="list-style-type: none"> Monitoring of water quality after the disaster and refrain from fishing activities 	<ul style="list-style-type: none"> Information about the habitat condition and plan fishing activities accordingly 	DoF, BFRI, Knowledge Institutes, Academia, DoE, LGIs, MoLJPA	Within 3 years and continue
		<ul style="list-style-type: none"> Regular dredging of rivers and beels 	<ul style="list-style-type: none"> Allow natural cleansing of water and improve water quality 	BWDB, MoS, DoE, NRCC, DoF, WARPO, DBHWD	Annually
7	Aquatic habitat degradation and decreased water quality due to floods/flash floods	<ul style="list-style-type: none"> Conservation and expansion of coverage of different indigenous aquatic plants 	<ul style="list-style-type: none"> Allow natural cleansing of water and improve overall habitat condition 	DoF, BFRI, DoE, BFD, LGIs, LGD, DBHWD	Within 3 years and continue
		<ul style="list-style-type: none"> Conservation of freshwater sanctuaries, beel nursery and breeding ground 	<ul style="list-style-type: none"> Spawning and breeding of healthy fisheries and 	DoF, BFRI, NRCC, WARPO, LGIs, DoE, MoLJPA, DBHWD	Within 3 years and continue

Flood, Flash Flood and Wave Action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder(s)	When to Implement
			enhance fisheries production, boost income		
		<ul style="list-style-type: none"> Ensure proper and smooth drainage of water after the floods through effective and integrated water management and operational infrastructures with fish pass 	<ul style="list-style-type: none"> Reduce chances of water quality degradation after floods 	BWDB, LGED, RHED, MoS, WARPO, DoF, BFRI, DBHWD	Within 3 to 5 years
		<ul style="list-style-type: none"> Development of climate proofed post-harvest storage management, communication infrastructures and marketing facilities in gender inclusive way 	<ul style="list-style-type: none"> Reduce post-harvest losses and economic losses Reduce recurrent cost of government for O&M 	LGED, RHD, LGD, DoF, BFRI, MoEFCC, MoDMR, private sectors, MoWCA, DSS, DYD	Within 3 to 5 years
		<ul style="list-style-type: none"> Rehabilitation of post-harvest storage management, communication infrastructures and marketing facilities in climate resilient way 	<ul style="list-style-type: none"> Reduce post-harvest losses and economic losses Reduce recurrent cost of government for O&M 	LGED, RHD, LGD, DoF, BFRI, MoEFCC, MoDMR, private sectors, MoWCA, DSS, DYD	Within 3 to 5 years
8	Disruption in post-harvest storage management, damage of infrastructures and communication facilities due to floods/flash floods	<ul style="list-style-type: none"> Climate sensitive planning and extend F&A post-harvest storage facilities and relevant infrastructures 	<ul style="list-style-type: none"> Reduce post-harvest losses and economic losses Reduce recurrent cost of government for O&M 	LGED, RHD, LGD, DoF, BFRI, MoEFCC, MoDMR, private sectors, MoWCA, DSS, DYD	Within 3 to 5 years

The **Table 5.2** below outlines the risks related to drought, lightning, and heat stress on capture fisheries and gives potential adaptations and risk reduction options that should be undertaken or promoted by different stakeholders under capture fisheries.

Table 5.2: Risk of drought, lightning, and heat stress on capture fisheries with adaptation options

Drought, Lightning, Heat and Cold Stress					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
1	Low water availability and drying up of aquatic habitat during drought	<ul style="list-style-type: none"> Regular dredging of all large, medium and small rivers, beels 	<ul style="list-style-type: none"> Revitalization of rivers, beels and restoration of fisheries habitat Reduce aquatic ecosystem vulnerability 	BWDB, MoS, DoE, NRCC, DoF, WARPO, DBHWD	Annual and periodic
		<ul style="list-style-type: none"> Maintaining connectivity of khals, beel and rivers 	<ul style="list-style-type: none"> Revitalization of rivers, beels and restoration of fisheries habitat Reduce aquatic ecosystem vulnerability 	BWDB, MoS, DoE, NRCC, DoF, WARPO, DBHWD	Within 3 to 5 years
2	Rise of water temperature, algae bloom and reduction in dissolved oxygen due to heat stress	<ul style="list-style-type: none"> Coverage of selective aquatic vegetation in the water body e.g. water hyacinth, improve habitat suitability and biochemical treatment of water 	<ul style="list-style-type: none"> Establishment of selective fish sanctuaries with brush shelters. 	DoF, BFRI, LGIs, Knowledge Institutes, Academia	Within 3 years and continue
3	Post-harvest storage management may get disrupted due to extreme heat and crisis of ice/cold storage facilities	<ul style="list-style-type: none"> Development and rehabilitation of climate proofed post-harvest storage management, communication infrastructures and marketing facilities in gender inclusive way 	<ul style="list-style-type: none"> Reduce post-harvest losses and economic losses Reduce recurrent cost of government for O&M 	LGED, RHD, LGD, DoF, BFRI, MoEFCC, MoDMR, private sectors, MoWCA, DSS, DYD	Within 3 to 5 years
		<ul style="list-style-type: none"> Climate sensitive planning and extend F&A post-harvest storage facilities and relevant infrastructures 	<ul style="list-style-type: none"> Reduce post-harvest losses and economic losses Reduce recurrent cost of government for O&M 	LGED, RHD, LGD, DoF, BFRI, MoEFCC, MoDMR, private sectors, MoWCA, DSS, DYD	Within 3 to 5 years
4	Food intake behavior change, disruptions in growth & migration and increased mortality due to cold wave and excess rain	<ul style="list-style-type: none"> Development of stress tolerant species, improve habitat suitability and enhance aquatic biodiversity 	<ul style="list-style-type: none"> Innovate stress tolerant technologies, halt outbreak of diseases, reduce production losses and plan accordingly for fisheries risk reduction 	DoF, BFRI, LGIs, Academic Institutes, Academia	Within 3 years and continue

Drought, Lightning, Heat and Cold Stress					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
5	Loss of fishermen lives due to lightning	<ul style="list-style-type: none"> Strengthening Gender inclusive ICT based EWS for the Fisheries and aquaculture sector 	<ul style="list-style-type: none"> Protect fishers' life, livelihoods and ensure social security through pre-informed early warning messages 	DoF, BFRI, FFWC, MoDMR, BMD, SPARRSO, LGED, LGIs, Electronic, web and print media	Within 3 years
		<ul style="list-style-type: none"> Installation of lightning arresters or resting sheds nearby to large open waterbodies 	<ul style="list-style-type: none"> Protect fishers' life, livelihoods and ensure social security 	DoF, BFRI, LGED, LGD, MoDMR	Within 3 years
		<ul style="list-style-type: none"> Awareness raising and capacity building for enhancing coping mechanism 	<ul style="list-style-type: none"> Increase adaptive capacity and resilience, income generation activities and improve living standard 	DoF, BFRI, MoDMR, DSS, MoWCA, LGD, Training and Knowledge Institutes	Within 3 years and continue
		<ul style="list-style-type: none"> Introduce index-based risk recovery mechanism or insurance scheme for fishermen community 	<ul style="list-style-type: none"> Improve financial stability of fishermen to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, Insurance companies	Within 3 to 5 years
6	Loss of livelihoods, shifting occupation and increased poverty with disproportionate impact on women	<ul style="list-style-type: none"> Provide subsidies and skill development for alternative livelihoods ensuring women's participation 	<ul style="list-style-type: none"> Reduce gender vulnerability, income loss and living standard Enhance adaptive capacity and resilience to combat disproportionate impacts on gender 	DoF, BFRI, LGIs, DSS, MoWCA, DYD, MoDMR, MoEFCC, MoF, Training and Academic Institutes, Private Sectors	Within 3 years and continue
		<ul style="list-style-type: none"> Training on gender and youth inclusive CC&DRR and EWS for fish farmers 	<ul style="list-style-type: none"> Enhance adaptive capacity and resilience to combat climate disasters 	DoF, BFRI, LGIs, DSS, MoWCA, DYD, MoDMR, MoEFCC, MoF, Training and Academic Institutes, Private Sectors	Within 3 years and continue
		<ul style="list-style-type: none"> Introduction of zero interest or low interest-based credit facilities to recover disaster risk 	<ul style="list-style-type: none"> Improve financial stability of fishermen to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, Insurance companies, Bangladesh Banks and Private Sectors	Within 3 years and continue

Drought, Lightning, Heat and Cold Stress					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
		<ul style="list-style-type: none"> Introduce index-based risk recovery mechanism or insurance scheme for fishermen community specially focusing on women 	<ul style="list-style-type: none"> Improve financial stability of women to recover any losses incurred from damages due to climate hazards Reduce gender indiscrimination and inequality 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, Insurance companies	Within 3 to 5 years
		<ul style="list-style-type: none"> Provide climate resilience funds specially focusing on marginal women 	<ul style="list-style-type: none"> Improve financial stability of women to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, LGIs	Within 3 years and continue

Culture fisheries

The **Table 5.3** below outlines the risks related to flood, flash flood and wave action on culture fisheries and gives potential adaptations and risk reduction options that should be undertaken or promoted by different stakeholders under culture fisheries.

Table 5.3: Risk of flood, flash flood and wave action on culture fisheries with adaptation options

Flood, Flash Floods & Wave action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
1	Pond and farms dykes may get damaged and overflowing of fishes due to floods or flash floods or wave action	<ul style="list-style-type: none"> Construction of climate proofed dykes or wave control structures or use of nets 	<ul style="list-style-type: none"> Reduce production losses and income losses 	DoF, BFRI, LGED, LGIs, BWDB	Within next 3 years
		<ul style="list-style-type: none"> Plantation of native species, fruit trees or vegetable farming and mangroves as natural barrier over the pond dykes 	<ul style="list-style-type: none"> Reduce production losses and income losses Boost vegetable and fruit production and income 	DoF, BFRI, LGED, LGIs, BFD, DAE	Within next 3 years
		<ul style="list-style-type: none"> Strengthening Gender inclusive ICT based EWS for the Fisheries and aquaculture sector 	<ul style="list-style-type: none"> Protect fisheries related infrastructures and assets through pre-informed early warning messages 	DoF, BFRI, FFWC, MoDMR, BMD, SPARRSO, LGED, LGIs, Electronic, web and print media	Within 3 years
2	Fishing and fishing assets (boats, nets and gear) may get damaged due to floods or flash floods	<ul style="list-style-type: none"> Strengthening Gender inclusive ICT based EWS for the Fisheries and aquaculture sector 	<ul style="list-style-type: none"> Protect fisheries related infrastructures and assets through pre-informed early warning messages 	DoF, BFRI, FFWC, MoDMR, BMD, SPARRSO, LGED, LGIs, Electronic, web and print media	Within 3 years
		<ul style="list-style-type: none"> Construction of storage areas for fishing tools 	<ul style="list-style-type: none"> Protect fisheries related infrastructures and assets Reduce economic losses and income 	DoF, BFRI, LGED, LGIs, RHD, Private Sectors	Within 3 years
		<ul style="list-style-type: none"> Introduce index-based risk recovery mechanism or insurance scheme for fishermen community specially focusing on women 	<ul style="list-style-type: none"> Improve financial stability of women to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, Insurance companies	Within 3 to 5 years

Flood, Flash Floods & Wave action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
			<ul style="list-style-type: none"> Reduce gender discrimination and inequality 		
		<ul style="list-style-type: none"> Provide climate resilience funds specially focusing on marginal women 	<ul style="list-style-type: none"> Improve financial stability of women to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, LGIs	Within 3 years and continue
3	Habitat degradation, disease outbreak, disruptions in growth, due floods and flash floods	<ul style="list-style-type: none"> Development of stress tolerant species, improve habitat suitability and enhance aquatic biodiversity 	<ul style="list-style-type: none"> Innovate stress tolerant technologies, halt outbreak of diseases, reduce production losses and plan accordingly for fisheries risk reduction 	DoF, BFRI, LGIs, Academic Institutes, Academia	Within 3 years and continue
		<ul style="list-style-type: none"> Deepening of the ponds/shrimp farms to retain water >1.0 meter 	<ul style="list-style-type: none"> Improvement of habitat condition Control of disease outbreak Increase in fish production Increase of income 	DoF, BFRI, LGIs, Academic Institutes, private sectors	Within 3 years and continue
		<ul style="list-style-type: none"> Application of aerator for oxygenation, aqua-medicine use in the aquaculture farms 	<ul style="list-style-type: none"> Reduce/neutralize environmental effects Reduce disease outbreak Increase fish production 	DoF, BFRI, LGIs, Academic Institutes	Within 3 years and continue
		<ul style="list-style-type: none"> Identify and select simultaneous cultures of fish or shellfish along with other culture systems in light of integrated fish farming (IFF) 	<ul style="list-style-type: none"> Fish production increase Income increase 	DoF, BFRI, LGIs, Academic, Academia, private sectors	Within 3 years and continue
		<ul style="list-style-type: none"> Facilitate in development and extension of stress-tolerant functional aqua-feed 	<ul style="list-style-type: none"> Improve habitat condition Facilitate boosting fisheries nutrients 	DoF, BFRI, LGIs, Academic, Academia	Within 3 years and continue
		<ul style="list-style-type: none"> Heighten dikes of freshwater retention ponds to halt flood water ingress 	<ul style="list-style-type: none"> Safeguard fish species and production Secure income 	DoF, BFRI, LGIs, Academic, Academia	Within 3 years and continue

Flood, Flash Floods & Wave action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
		<ul style="list-style-type: none"> Introduce IoT based water quality monitoring such as pH/DO/water temperature in the aquaculture farms 	<ul style="list-style-type: none"> Risk informed decision making by fishermen themselves Reduce habitat and production loss 	DoF, BFRI, LGIs, Academic, Academia, Fishing Communities	Within 3 years and continue
		<ul style="list-style-type: none"> Pond rehabilitation to improve water quality with Urea, TSP, lime etc. 	<ul style="list-style-type: none"> Improve habitat condition Facilitate boosting fisheries nutrients 	DoF, BFRI, LGIs, Academic, Academia	Within 3 years and continue
4	Mortality of fry/Juvenile of fish due to floods or flash floods	<ul style="list-style-type: none"> Extension of resilient climate technology for combating climate-related stresses in Aquaculture Development of stress tolerant species of commercially important fish and species diversification 	<ul style="list-style-type: none"> Innovate stress tolerant technologies, halt outbreak of diseases, reduce production losses and plan accordingly for fisheries risk reduction 	DoF, BFRI, LGIs, Academic, Academia	Within 3 years and continue
5	Pond habitats degradation due to siltation after floods	<ul style="list-style-type: none"> Excavation or re-excavation of dighi, pond, reservoir or construction-relevant infrastructure for freshwater harvesting 	<ul style="list-style-type: none"> Good quality, healthy and improved pond ecosystems to increase productivity and profit. Protect ecosystem to increase production and reduce vulnerability of the local community. 	DoF, BFRI, BFD, WARPO, BWDB, MoS, DoE, DBHWD	Within 3 to 5 years
		<ul style="list-style-type: none"> Restoration of fish habitats and breeding grounds 	<ul style="list-style-type: none"> Improve the fish habitat condition 	DoF, BFRI, BFD, WARPO, BWDB, MoS, DoE, DBHWD	Within 3 to 5 years
6	Loss of livelihoods, shifting occupation and increased poverty & internal displacement with disproportionate impact on women	<ul style="list-style-type: none"> Provide subsidies and skill development for alternative livelihoods ensuring women's participation 	<ul style="list-style-type: none"> Reduce gender vulnerability, income loss and living standard Enhance adaptive capacity and resilience to combat disproportionate impacts on gender 	DoF, BFRI, LGIs, DSS, MoWCA, DYD, MoDMR, MoEFCC, MoF, Training and Academic Institutes, Private Sectors	Within 3 years and continue
		<ul style="list-style-type: none"> Training on gender and youth inclusive CC&DRR and EWS for fish farmers 	<ul style="list-style-type: none"> Enhance adaptive capacity and resilience to combat climate disasters 	DoF, BFRI, LGIs, DSS, MoWCA, DYD, MoDMR, MoEFCC, MoF, Training and	Within 3 years and continue

Flood, Flash Floods & Wave action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
				Academic Institutes, Private Sectors	
		<ul style="list-style-type: none"> • Introduction of zero interest or low interest based credit facilities to recover disaster risk 	<ul style="list-style-type: none"> • Improve financial stability of fishermen to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, Insurance companies, Bangladesh Banks and Private Sectors	Within 3 years and continue
		<ul style="list-style-type: none"> • Introduce index based risk recovery mechanism or insurance scheme for fishermen community specially focusing on women 	<ul style="list-style-type: none"> • Improve financial stability of women to recover any losses incurred from damages due to climate hazards • Reduce gender indiscrimination and inequality 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, Insurance companies	Within 3 to 5 years
		<ul style="list-style-type: none"> • Provide climate resilience funds specially focusing on marginal women 	<ul style="list-style-type: none"> • Improve financial stability of women to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, LGIs	Within 3 years and continue

The **Table 5.4** below outlines the risks related to drought, lightning and heat stress on culture fisheries and gives potential adaptations and risk reduction options that should be undertaken or promoted by different stakeholders under culture fisheries.

Table 5.4: Risk of drought, lightning and heat stress on culture fisheries with adaptation options

Drought, Lightning, and Heat Stress					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
1	Low water availability and drying up of ponds/ farms, overall culture habitat reduction due to drought	<ul style="list-style-type: none"> Regular dredging of all connected river reaches with fish farms or ponds 	<ul style="list-style-type: none"> Revitalization of rivers, beels and restoration of fisheries habitat Reduce aquatic ecosystem vulnerability 	BWDB, MoS, DoE, NRCC, DoF, WARPO, DBHWD	Annual and periodic
		<ul style="list-style-type: none"> Digging or excavation of ponds/dighi or reservoirs to store more water 	<ul style="list-style-type: none"> Reduce disruptions in migrations 	MoWR, NRCC, LGED, MoS, WARPO, JRC	Within 3 to 5 years
		<ul style="list-style-type: none"> Identification of vulnerable fish farms in respect of water availability and arrange for irrigation measures 	<ul style="list-style-type: none"> Reduce climate risks due to drought 	DoF, BFRI, LGIs, MoWR, BMDA, DAE	Within 3 years and continue
2	Rise of water temperature, algae bloom, reduction in dissolved oxygen and reduced fish production due to heat wave	<ul style="list-style-type: none"> Development of stress tolerant species Improve habitat suitability and enhance aquatic biodiversity 	<ul style="list-style-type: none"> Innovate stress tolerant technologies, halt outbreak of diseases, reduce production losses and plan accordingly for fisheries risk reduction 	DoF, BFRI, LGIs, Knowledge Institutes, Academia	Within 3 years and continue
3	Occurrence of death for fry/Juvenile of fish due to extreme heat or cold	<ul style="list-style-type: none"> Extension of resilient climate technology for combating climate-related stresses in Aquaculture Development of stress tolerant species of commercially important fish and species diversification 	<ul style="list-style-type: none"> Innovate stress tolerant technologies, halt outbreak of diseases, reduce production losses and plan accordingly for fisheries risk reduction 	DoF, BFRI, LGIs, Knowledge Institutes, Academia	Within 3 years and continue

Drought, Lightning, and Heat Stress					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
4	Food intake behavior change, disruptions in growth & migration and increased mortality due to cold wave and excess rain	<ul style="list-style-type: none"> Development of stress tolerant species, improve habitat suitability and enhance aquatic biodiversity 	<ul style="list-style-type: none"> Innovate stress tolerant technologies, halt outbreak of diseases, reduce production losses and plan accordingly for fisheries risk reduction 	DoF, BFRI, LGIs, Knowledge Institutes, Academia	Within 3 years and continue
5	Post-harvest storage management during extreme heat	<ul style="list-style-type: none"> Development and rehabilitation of climate proofed post-harvest storage management, communication infrastructures and marketing facilities in gender inclusive way 	<ul style="list-style-type: none"> Reduce post-harvest losses and economic losses Reduce recurrent cost of government for O&M 	LGED, RHD, LGD, DoF, BFRI, MoEFCC, MoDMR, private sectors, MoWCA, DSS, DYD	Within 3 to 5 years
		<ul style="list-style-type: none"> Climate sensitive planning and extend F&A post-harvest storage facilities and relevant infrastructures 	<ul style="list-style-type: none"> Reduce post-harvest losses and economic losses Reduce recurrent cost of government for O&M 	LGED, RHD, LGD, DoF, BFRI, MoEFCC, MoDMR, private sectors, MoWCA, DSS, DYD	Within 3 to 5 years
		<ul style="list-style-type: none"> Construction of sheds over the ponds or farms 	<ul style="list-style-type: none"> Protection of fisheries and reduce production losses 	DoF, BFRI, LGD, LGED, LGIs, Private Sectors	
6	Loss of livelihoods, shifting occupation and increased poverty & internal displacement with disproportionate impact on women	<ul style="list-style-type: none"> Provide subsidies and skill development for alternative livelihoods ensuring women's participation 	<ul style="list-style-type: none"> Reduce gender vulnerability, income loss and living standard Enhance adaptive capacity and resilience to combat disproportionate impacts on gender 	DoF, BFRI, LGIs, DSS, MoWCA, DYD, MoDMR, MoEFCC, MoF, Training and Knowledge Institutes, Private Sectors	Within 3 years and continue
		<ul style="list-style-type: none"> Training on gender and youth inclusive CC&DRR and EWS for fish farmers 	<ul style="list-style-type: none"> Enhance adaptive capacity and resilience to combat climate disasters 	DoF, BFRI, LGIs, DSS, MoWCA, DYD, MoDMR, MoEFCC, MoF, Training and Knowledge Institutes, Private Sectors	Within 3 years and continue
		<ul style="list-style-type: none"> Introduction of zero interest or low interest-based credit schemes to recover from disaster risks 	<ul style="list-style-type: none"> Improve financial stability of fishers to recover from any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, NGOs, Insurance companies, Bangladesh Banks and Private Sectors	Within 3 years and continue

Drought, Lightning, and Heat Stress					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
		<ul style="list-style-type: none"> Introduce index-based risk recovery mechanism or insurance scheme for fishermen community specially focusing on women 	<ul style="list-style-type: none"> Improve financial stability of women to recover any losses incurred from damages due to climate hazards Reduce gender discrimination and inequality 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, Insurance companies	Within 3 to 5 years
		<ul style="list-style-type: none"> Provide climate resilience funds specially focusing on marginal women 	<ul style="list-style-type: none"> Improve financial stability of women to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, LGIs	Within 3 years and continue

Gender

The **Table 5.5** below outlines the risks related to drought, lightning and heat stress on culture fisheries and gives potential adaptations and risk reduction options that should be undertaken or promoted by different stakeholders under culture fisheries.

Table 5.5: Risk on women with adaptation options

ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
1	Lack of awareness, empowerment and capacity building	<ul style="list-style-type: none"> • Arrangement for awareness building on Climate change and its impacts 	<ul style="list-style-type: none"> • Improving Capacity on CCA 	DoF, MoWCA, NILG, MoLGRDC and MoSW with relevant organizations/ institutes, CBO, NGOs, CSOs	Before and After Disaster
			<ul style="list-style-type: none"> • Improving knowledge on CCA 		
			<ul style="list-style-type: none"> • Ensure empowerment and access to resources 		
		<ul style="list-style-type: none"> • Training on optimum usage of resources for homestead and livelihoods development 	<ul style="list-style-type: none"> • Improving knowledge on CCA 		
		<ul style="list-style-type: none"> • Resilient Livelihoods and Infrastructures 	<ul style="list-style-type: none"> • Improving Capacity on CCA 		
<ul style="list-style-type: none"> • Training on safety and security management of livelihood and homestead for pre, during and after disasters 	<ul style="list-style-type: none"> • Ensure empowerment and access to resources 				
		<ul style="list-style-type: none"> • Training on handling the necessary tech-based devices for ensuring early warning 	<ul style="list-style-type: none"> • Ensure empowerment and access to resources 		
2	Lack of infrastructure dedicated for women	<ul style="list-style-type: none"> • Training on Understanding the necessity of using civic facilities during disaster 	<ul style="list-style-type: none"> • Understanding the necessity of using civic facilities during disaster 	DoF, MoWCA, MoLGRDC, MoSW, NILG with relevant	Before and After Disaster

ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
		<ul style="list-style-type: none"> • Training on management of civic facilities in emergencies during disaster 	<ul style="list-style-type: none"> • Capacity building on the management of these civic facilities in emergencies during disaster 	organizations/ institutes, CBO, NGOs, CSOs	
		<ul style="list-style-type: none"> • Building cyclone shelter with separate accommodation, hygiene and WASH facilities for women 	<ul style="list-style-type: none"> • Ensure mobility and accessibility to the cyclone and flood centre • Reducing gender base violence during and post disaster period 		
		<ul style="list-style-type: none"> • Construction of separate market shed for women 	<ul style="list-style-type: none"> • Ensure accessibility to the market and Growth Centre • Ensuring safety - security during and post disasters 		
3	Disasters hampering income generating activities	<ul style="list-style-type: none"> • Creation of alternative IGAs and training on IGAs for livelihood management due to impact of disaster • Training on IGAs with diseases management of livestock and poultry products • Training on cow fattening and multi farming approach 	<ul style="list-style-type: none"> • Ensuring support in livelihood during disasters • Ensuring sustainability of income and livelihood • Ensuring support in livelihood during disasters • Ensuring sustainability of income and livelihood • Ensuring support in livelihood during disasters • Ensuring sustainability of income and livelihood 	MoWCA, DoF, DDM, MoSW, DYD, NILG, CreLIC, CBOs, NGOs and CSOs.	During and after Disaster
4	Violence and accidental occurrences towards women	<ul style="list-style-type: none"> • Required training for emergency response team from Community, NGOs and GOs Level • Training on handling the gender sensitive issues during disaster and post disaster 	<ul style="list-style-type: none"> • Stopping violence and accidental occurrence during and after disaster period 	MoWCA, DoF, DDM, MoSW, DYD, NILG, CreLIC, CBOs, NGOs and CSOs.	During and after Disaster
5	Inadequate lead time in early warning	<ul style="list-style-type: none"> • Instant and direct dissemination of early warning to women staying at home 	<ul style="list-style-type: none"> • Safe evacuation before disaster 	DoF, BMD, FFWC, DDM	Before and during Disaster

ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
			<ul style="list-style-type: none"> • Protection of livestock and property 		
		<ul style="list-style-type: none"> • Transmitting early warning through digital medium i.e mobile SMS, megaphone announcement etc. 	<ul style="list-style-type: none"> • Safe evacuation before disaster • Protection of livestock and property 		

6 Conclusions and Recommendations

This study assessed the key risks and vulnerabilities of F&A sectors, specifically fishers' livelihoods, with special focus on gender and aquatic ecosystem in the project area of Jagannathpur Upazila through a comprehensive assessment. Blended participatory appraisal techniques such as FGDs, KIIs and representative community surveys; scientific analysis based on latest available data and information were utilized for the assessment. The assessed risk and vulnerabilities are mapped through geo-spatial analysis following indicator-based approach of the approved CRVA framework for the F&A sector in Bangladesh. Impact chains analyses for capture fisheries, culture fisheries, aquatic ecosystem and gender-based F&A livelihoods were used to prioritize indicators, collect data through participatory and scientific approach and then did a weighted aggregation of multiple indicators using geo-spatial tools. The risk and vulnerability maps were prepared with risk severity or vulnerabilities for each of the unions of the Jagannathpur Upazila. In situ and laboratory tests of rivers, haors and ponds/ghers were performed, followed by the SWOT analysis of ecosystem services to analyze the climate sensitivity of aquatic ecosystem.

Flash flood, wave action, extreme hot days, river bank erosion, lightning and drought were found to have severely affected the people lives in this region. The region experiences flash flood almost every year which inundates ponds and fish farms. Fish farmers in Jagannathpur Upazila are faced with a number of difficulties as a result of the dramatic increase in perceived temperature in the north-eastern region, most notably significant decrease in water oxygen as well as various viral, bacterial, and fungal infections. Additionally, the natural mortality rate has been increasing with increasing hot days and other climatic hazards. Climate change sets to increase the frequency of lightning strikes which affects the spawning and breeding of fisheries as well. During the dry/drought period, ponds, rivers, canals, and beels dry up or retain insufficient water, affecting fishing production in open water systems in some localities of Jagannathpur Upazila. Fish and/or other aquatic species migration, reproduction, and growth are also being impacted by the drought conditions usually experience in the area.

Climate change induced hazard risk for both capture and culture fisheries impact chain analysis showed Kalkalia union was in high risk for the base period. In 2050s Haldipur and Asharakandi unions will be in high risk along with the high-risk unions at the base period. The SWOT analysis shows the river has more weaknesses and high threats than haor and pond due to rapid urbanization and environmental pollution. There are good opportunities for ecosystem services from river and haor, but pond ecosystem has higher strength and opportunities because of their natural and manmade land-cover types. From the statement of the respondent's habitat degradation, climate change, and human activities are found to be responsible for ecosystem disruption and biodiversity loss in the river.

A climate resilience action plan has been prepared following the principles of climate resilience framework, ecosystem approaches to fisheries and aquaculture. Community preferences of actions for the climate risk reduction are considered for the resilience action plan. Key stakeholders were mapped to implement the action plan. Necessary capacity development initiatives and institutional management measures are suggested to boost the motivation of stakeholders to implement locally-led resilience action plan of the Jagannathpur smoothly. Different ecosystem-based adaption options, technical/financial incentives, and alternative livelihoods generation for fishermen, required policy reforms or nonstructural solutions like human skill development and capacity building of institutions are considered under this plan. Particular emphasis is given to creating an enabling environment for women's participation in climate adaptation process for the F&A, raising women's voices from micro level to macro level, creating gender-specific disaster risk reduction policies, and promoting women's empowerment through capacity building to combat pre, during and post disaster period. The implementation of the locally-led climate resilience action plan would significantly reduce the risk and vulnerabilities of climate change and build resilience for F&A-based livelihood, women fishers and climate sensitive aquatic ecosystem. The fisheries and aquaculture production would be revamped in the region, and sustainable economic development will be achieved.

Collection of union-wise data and information for different indicators of risk, vulnerabilities, and adaptive capacities, and particularly, sex, age, and disability-specific F&A data for each of the unions within the given limited resources were major challenges and limitations of the study. Although the study consulted with multiple respondents from the fisheries and fisheries-related communities residing in 2-3 vulnerable unions and organizations in the Jagannathpur Upazila, consultations and validation in each of the unions would improve the study outcome. Further, a comprehensive assessment of such information may improve the study outcome, making it more specific and locally evidence-based, which may be undertaken in the future considering the fundamental and unique framework developed in this study.

References

- Akber, M.A., Islam, M.A., Ahmed, M., Rahman, M.M., Rahman, M.R., 2017. Changes of Shrimp Farming In Southwest Coastal Bangladesh. *Aquac. Int.* 25 (5), 1883–1899.
- Banerjee SM. Water Quality and Soil Condition of Fishponds in States of India in Relation to Fish Production. *Indian Journal of Fisheries.* 1967; 14:115-144
- Barange M, Perry RI (2009) Physical and Ecological Impacts of Climate Change Relevant To Marine and Inland Capture Fisheries and Aquaculture. In: Cochrane K, De Young C, Soto D Et Al (Eds) *Climate Change Implications For Fisheries and Aquaculture: Overview of Current Scientific Knowledge.* FAO Fisheries and Aquaculture Technical Paper No. 530, Pp 7–106
- Brown, C. J., O'Connor, M I., Poloczanska, E. S., Schoeman D. S 2016. Ecological and Methodological Drivers of Species' Distribution and Phenology Responses To Climate Change, *Global Change Biology* 22(4):N/A-N/ADDOI:10.1111/Gcb.13184
- Brown, S. (1997). *Estimating Biomass and Biomass Change of Tropical Forests: A Primer* (Vol. 134). Food & Agriculture Org
- Chakroborty, T., & Rahman, M. M. (2017). An Introductory Study of Fish Biodiversity and Fishing Practices In The Betna River of Southwestern Bangladesh, *Academic Journal of Life Sciences* ISSN(E): 2415-2137, ISSN(P): 2415-5217 Vol. 3, No. 4, Pp: 18-23
- Chave, J., Réjou-Méchain, M., Búrquez, A., Chidumayo, E., Colgan, M. S., Delitti, W. B., ... & Vieilledent, G. (2014). Improved Allometric Models to Estimate the Aboveground Biomass of Tropical Trees. *Global Change Biology*, 20(10), 3177-3190
- Ciais P, Reichstein M, Viovy N Et Al (2005) Europe-Wide Reduction In Primary Productivity Caused By The Heat and Drought In 2003. *Nature* 437:529–533. Doi:10.1038/Nature03972
- Cowardin, Carter, Golet and Laroe (1979). *Classification of Wetlands and Deepwater Habitats of the United States*, Wetlands Subcommittee, Federal Geographic Data Committee
- Darlington, PJ, Jr. *Zoogeography: The Geographical Distribution of Animals.* New York: John Wiley & Sons; 1957
- Das S, Bhattacharya BK, Goswamy UCJ. *Inland Fish. Soc. India.* 1995; 27(2):105-109
- Das, 1997. Das, B. 1997. *Fisheries and Fisheries Resources Management.* Bangla Academy, Dhaka, Bangladesh, 153-155p
- Dudgeon D, Arthington A, Gessner M, Kawabata Z-I, Knowler D, Lévêque C, Naiman R, Prieur-Richard A-H, Soto D, Stiassny M, Sullivan C (2006) *Freshwater Biodiversity: Importance, Threats, Status and Conservation Challenges.* *Biol Rev Camb Philos Soc* 81:163–182
- Erwin, K. L. (2009). Wetlands and Global Climate Change: The Role of Wetland Restoration In A Changing World. *Wetlands Ecology and Management*, 17(1), 71-84
- Espírito-Santo, H. M. V., Magnusson, W. E., Zuanon, J., Mendonça, F. P., & Landeiro, V. L. 2009. Seasonal Variation In The Composition of Fish Assemblages In Small Amazonian Forest Streams: Evidence For Predictable Changes. *Freshwater Biology*, 54(3), 536–548. DOI: 10.1111/J.1365-2427.2008.02129.X
- FAO Fisheries management. *The ecosystem approach to fisheries, FAO Technical Guidelines for Responsible Fisheries, 2003, vol. 4 Suppl. 2, 112 pp*
- Ficke AD, Myrick CA, Hansen LJ (2007) Potential Impacts of Global Climate Change On Freshwater Fisheries. *Rev Fish Biol Fish* 17:581–613. Doi:10.1007/S11160-007-9059-5
- Gain, A. K. Et Al., 2008. Impact of River Salinity On Fish Diversity in The South-West Coastal region of Bangladesh, *International Journal of Ecology and Environmental Sciences* 34 (1): 49-54
- Garcia S.M., Zerbi A., Aliaume C., Do Chi T., Lasserre G. *The ecosystem approach to fisheries, 2003, Issues, terminology, principles, institutional foundations, implementation and outlook.* FAO Fisheries Technical Paper, 443. 71 pp

-
- GED. (2018). Bangladesh Delta Plan 2100. Dhaka: General Economics Division (GED), Planning Commission, Government of The People's Republic of Bangladesh
- Hossain, M.A.R., Hasan, M.R., 2017. An Assessment of Impacts From Shrimp Aquaculture In Bangladesh and Prospects For Improvement, 618. FAO Fisheries and Aquaculture Technical Paper No, P. 96.
- Huq, S., 2001: Climate Change and Bangladesh. *Science*, 294, Doi:10.1126/Science.294.5547.1617. Crossref, Search Google Scholar, Export Citation
- Jadhav U (2008) Aquaculture Technology and Environment. PHI Learning Private Limited, New Delhi
- James, M. E. 2000. Water Quality and Recalculating Aquaculture Systems. Aquaculture Systems Technologies, LLC. New Orleans, LA. 16- 17p, 28p
- Jeppesen E, Meerhoff M, Holmgren K Et Al (2010) Impacts of Climate Warming On Lake Fish Community Structure and Potential Effects On Ecosystem Function. *Hydrobiologia* 646:73–90. Doi:10.1007/ S10750-010-0171-5
- Jerin, J.N., Islam, A.R.M., Mamun, M.A.A., Mozahid, M.N., Ibrahim, S. M.(2021). Climate Change Effects On Potential Evapotranspiration In Bangladesh, Saudi Society of Geosciences
- Kieran, C., Sproule, K., Doss, C., Quisumbing, A., & Kim, S. M. (2015). Examining Gender Inequalities In Land Rights Indicators In Asia. *Agricultural Economics*, 46(S1), 119-138.
- Kirtman, B., and Coauthors, 2013: Near-Term Climate Change: Projections and Predictability. *Climate Change 2013: The Physical Science Basis*, T. F. Stocker Et Al., Eds., Cambridge University Press, 953–1028, [Http://Www.Ipcc.Ch/Pdf/Assessment-Report/Ar5/Wg1/WG1AR5_Chapter11_FINAL.Pdf](http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/wg1ar5_chapter11_final.pdf)
- Macdicken, K. G. (1997). A Guide To Monitoring Carbon Storage In Forestry and Agroforestry Projects
- Mccarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S.E., 2001. Climate change 2001: Impacts, Adaptation, and Vulnerability. Cambridge Universitypress, UK, P. 1000
- Mccarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S.E., 2001. Climate change 2001: Impacts, Adaptation, and Vulnerability. Cambridge Universitypress, UK, P. 1000
- McInnes, R. J., & Everard, M. (2017). Rapid Assessment of Wetland Ecosystem Services (RAWES): An Example From Colombo, Sri Lanka. *Ecosystem Services*, 25, 89-105
- Mitchell, P., & Borchard, C. (2014). Mainstreaming Children's Vulnerabilities and Capacities Into Community-Based Adaptation To Enhance Impact. *Climate and Development*, 6(4), 372-381
- Moefcc. (2018). Nationwide Climate Vulnerability Assessment In Bangladesh. Dhaka: Ministry of Environment, Forest and Climate Change, Government of The People's Republic of Bangladesh. [https://Moef.Gov.Bd/Sites/Default/Files/Files/Moef.Portal.Gov.Bd/Notices/D31d60fd_Df55_4d75_Bc22_1b0142fd9d3f/Draft%20NCVA.Pdf](https://moef.gov.bd/sites/default/files/files/moef.portal.gov.bd/notices/D31d60fd_Df55_4d75_Bc22_1b0142fd9d3f/Draft%20NCVA.Pdf)
- Munang R, Thiaw I, Alverson K, Mumba M, Liu, J and Rivington, M (2013). Climate Change and Ecosystem-Based Adaptation: A New Pragmatic Approach To Buffering Climate Change Impacts. *Current Opinion In Environmental Sustainability* 2013: 5: Xx–Yy. [www.Sciencedirect.Com](http://www.sciencedirect.com)
- Ormerod SJ (2009) Climate Change, River Conservation and The Adaptation Challenge. *Aquatic Conservation: Marine and Freshwater. Ecosystems* 19:609–613
- Palmer MA, Bernhardt ES, Allan JD, Lake PS, Alexander G, Brooks S, Carr J, Clayton S, Dahm CN, Shah JF (2005) Standards Forecologically Successful River Restoration. *Journal of Applied Ecol-Ogy* 42:208–217
- Pazin, V. F. V., Magnusson, W. E., Zuanon, J., & Mendonça, F. P. 2006. Fish Assemblages In Temporary Ponds Adjacent To "Terra-Firme" Streams In Central Amazonia. *Freshwater Biology*, 51(6), 1025–1037. DOI: 10.1111/J.1365-2427.2006.01552.X
- Peterson MS, Meador MR (1994) Effects of Salinity On Freshwater Fishes In Coastal Plain Drainages In The Southeastern U.S. *Reviews In Fisheries Science* 2: 95–121, [https://Doi.Org/10.1080/ 10641269409388554](https://doi.org/10.1080/10641269409388554)
- Rabbani, M. G., Rahman, S. H., & Munira, S. (2018). Prospects of Pond Ecosystems As Resource Base Towards Community Based Adaptation (CBA) To Climate Change In Coastal Region of Bangladesh. *Journal of Water and Climate Change*, 9(1), 223-238

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- Rahman, A.Z 2019. Study On Climate Anomalies of Bangladesh Using Statistically Downscaled Climate Projections For Representative Concentration Pathways (Rcps) of Ipcc Fifth Assessment Report, Department of Water Resources Engineering, Bangladesh University of Engineering and Technology
- Rajib, M. A, Mortuza, M. R, Selmi S., Ankur, A. R, Rahman M. M (2011). Increase of Heat Index Over Bangladesh: Impact of Climate Change, World Academy of Science, Engineering and Technology 58
- Richardson DM, Holmes PM, Esler KJ, Galatowitsch SM, Stromberg JC, Kirkman SP, Pysek P, Hobbs RJ (2007) Riparian Vegetation: Degradation, Alien Plant Invasions, and Restoration Prospects. *Divers Distrib* 13:126–139
- Rimi, R. H, Rahman S.H, Karmakar, S., Hussain, S. G. (2009). Trend Analysis of Climate Change and Investigation On Its Probable Impacts On Rice Production At Satk Hira, Bangladesh, *Pakistan Journal of Meteorology*, Vol.6
- Rocha AV, Goulden ML (2010) Drought Legacies Influence The Long term Carbon Balance of A Freshwater Marsh. *J Geophys Res* 115: G00H02. Doi:10.1029/2009JG001215
- Rodgers JH (2008) Algal Toxins In Pond Aquaculture. Southern Regional Aquaculture Center, USA
- Soto D., Aguilar-Manjarrez J., and Hishamunda N., 2008a: Building an Ecosystem Approach to Aquaculture, FAO/Universitat de les Illes Balears Expert Workshop (7–11 May 2007, Palma de Mallorca, Spain), FAO Fisheries and Aquaculture Proceedings. No. 14, FAO, Rome, 221pp
- Standard, B. (1997). The Environment Conservation Rules 1997. Government of The People's Republic of Bangladesh, Dhaka
- Tabacchi E, Correll DL, Hauer R, Pinay G, Planty-Tabacchi AM, Wissmar RC (1998) Development, Maintenance and Role of Riparian Vegetation In The River Landscape. *Freshw Biol* 40:497–516
- Tucker CS, Hargreaves JA (2004) Pond Water Quality. In: Tucker CS, Hargreaves JA (Eds) *Biology and Culture of Channel Catfish*. Elsevier, Amsterdam, Pp 216–278
- Wang, X., M, GUO., XU, X., Jun, W., (2012); Changing Trends of Reference Crop Evapotranspiration and impact Factors in Yunnan Mengzhi Plain in Recent 50 Years, international Conference On Structural Computation and Geotechnical Mechanics, *Procedia Earth and Planetary Science* 5 (2012) 326 – 334
- Wisser, D., Frolking, S., Douglas, E. M., Fekete, B. M., Schumann, A. H., & Vorosmarty, C. J. (2010). The Significance of Local Water Resources Captured in Small Reservoirs For Crop Production—A Global-Scale Analysis. *Journal of Hydrology*, 384(3-4), 264-2

Glossary

Adaptation strategy	An adaptation strategy is a program, project or approach that has been developed to respond to anticipated climate change impacts in a specific area of potential concern.
Adaptive capacity	The general ability of institutions, systems, and individuals to adjust to potential damage, to take advantage of opportunities, or to cope with the consequences.
Aquaculture	Aquaculture is the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Aquaculture occurs in both inland (freshwater) and coastal (brackish water, seawater) areas.
Aquatic ecosystem	A water-based environment, wherein, living organisms interact with both physical and chemical features of the environment.
Biodiversity	Biological diversity means the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (UN, 1992)
Biomass	The total mass of living organisms in a given area or volume; recently dead plant material is often included as dead biomass. The quantity of biomass is expressed as a dry weight or as the energy, carbon or nitrogen content.
BOD	Biochemical oxygen demand (BOD) is the amount of dissolved oxygen (DO) needed (i.e., demanded) by aerobic biological organisms to break down organic material present in a given water sample at a certain temperature over a specific period.
Capture fisheries	Capture fishery refers to harvesting naturally occurring living resources in both marine and freshwater environments.
Climate change	Climate change refers to any change over time, whether due to natural variability or due to human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which defines 'climate change' as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods.
Climate Change Adaptation	Climate change adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.
Climate change impacts	The effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health status, ecosystems, economic, social and cultural assets, services (including environmental) and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific period and the vulnerability of an exposed society or system.
Climate change risk	The potential for climate change impacts where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as the probability of occurrence of hazardous climate

	<p>events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability and hazard.</p>
Climate sensitivity	<p>Climate sensitivity refers to the change in the annual global mean surface temperature in response to a change in the atmospheric CO₂ concentration or other radiative forcing.</p>
Climate vulnerability	<p>The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and the variation to which a system is exposed, its sensitivity and its adaptive capacity.</p>
COD	<p>Chemical oxygen demand (COD) is the amount of oxygen needed to oxidize the organic matter present in water.</p>
Community based Organization	<p>Community-based organization means a public or private nonprofit organization of demonstrated effectiveness that— is representative of a community or significant segments of a community; and provides educational or related services to individuals in the community.</p>
Culture fisheries	<p>Culture fisheries is the cultivation of selected fishes in confined areas with utmost care to get maximum yield.</p>
Disaster	<p>Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.</p>
Disaster risk reduction (DRR)	<p>Disaster risk reduction is aimed at preventing new and reducing existing disaster risks and managing residual risks, all of which contributes to strengthening resilience and therefore to the achievement of sustainable development.</p>
Early warning systems (EWS)	<p>The set of technical, financial and institutional capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss. Dependent upon context, EWS may draw upon scientific and/or Indigenous knowledge. EWS are also considered for ecological applications e.g., conservation, where the organization itself is not threatened by hazard but the ecosystem under conservation is (an example is coral bleaching alerts), in agriculture (for example, warnings of ground frost, hailstorms) and in fisheries (storm and tsunami warnings). [UNISDR (2009)]</p>
Ecologically Critical Area	<p>Areas or ecosystems affected adversely or endangered to reach a critical condition by the changes brought through various human activities.</p>
Ecosystem services	<p>Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food or fiber, (3) regulating services such as climate regulation or carbon sequestration, and (4) cultural services such as tourism or spiritual and aesthetic appreciation.</p>
Epizootic Ulcerative Syndrome	<p>Epizootic ulcerative syndrome (EUS) is considered to be an infection with the oomycete known as <i>Aphanomyces</i> invades.</p>
Equity	<p>A principle that ascribes equal worth to all human beings, including equal opportunities, rights, and obligations, irrespective of origins.</p>

Exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected. See also Hazard, Risk and Vulnerability.
Gender	Gender refers to the characteristics of women, men, girls and boys that are socially constructed. This includes norms, behaviors and roles associated with being a woman, man, girl or boy, as well as relationships with each other.
Global Circulation Model	Global Circulation Model (GCM) is a model that simulates general circulation of planetary atmosphere or oceans. The term general circulation is used to indicate large-scale atmospheric or oceanic motions with its persistent as well as transient features on various scales.
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.
Land use	Land use refers to the total of arrangements, activities and inputs undertaken in a certain land cover type (a set of human actions). The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction, conservation and city dwelling). In national greenhouse gas inventories, land use is classified according to the IPCC land use categories of forest land, cropland, grassland, wetland, settlements, other.
Livelihood	The resources used and the activities undertaken in order to live. Livelihoods are usually determined by the entitlements and assets to which people have access. Such assets can be categorized as human, social, natural, physical or financial.
Mean Sea Level	Mean Sea Level (MSL) is the datum for measurement of elevation and altitude. Mean Sea Level is the equipotential surface of the Earth as described by the World Geodetic System.
Muriate of Potash	Potassium Chloride (KCl) used chiefly of fertilizer grades.
Resilience	The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation.
Risk assessment	The qualitative and/or quantitative scientific estimation of risks.
Sensitivity	The degree to which climate variability or change affects a system or species adversely or beneficially. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).
Total Dissolved Solids	Total dissolved solids (TDS) is a measure of the dissolved combined content of all inorganic and organic substances present in a liquid in molecular, ionized, or micro-granular (colloidal sol) suspended form.

Annex I: CRVA Framework and Selected Indicators

CRVA Framework

Steps	Activities	Agenda	National Level	Local Level
1	Preparing the CRVA	<ul style="list-style-type: none"> Understand context of CRVA, define objectives and possible outcome Define scope (sector, topic), extent (geographic level or vertical level) and timeframe (current and future) Assess resources and stakeholders' involvement requirement Stocktake available information Prepare implementation plan 	<ul style="list-style-type: none"> Capture and Culture Fisheries CRVA on Fisheries Livelihood and Ecosystem Base (2000s) and Future (2050s and 2085s) Climate Change Scenarios (SSP1-2.6 and SSP5-8.5) Up to district level Separate assessment for selected 6 regions National level stakeholders Review and stocktake 	<ul style="list-style-type: none"> Capture and Culture Fisheries CRVA on Fisheries Livelihood and Fish Ecosystem Base (2000) and Future (2050s and 2085s) Climate Change Scenarios (SSP1-2.6 and SSP5-8.5) Up to union level Separate assessment for each project site or Upazila Local level stakeholders, community and gender Review and stocktake
2	Developing Impact Chains	<ul style="list-style-type: none"> Identify climate impacts and risks affecting the system Determine hazards (climate signal and direct impacts) and intermediate impacts Determine vulnerability (i.e. sensitivity and lack of adaptive capacity which are contributing to risk) 	<ul style="list-style-type: none"> Brainstorming among study team experts based on draft NCVA impact chain Develop initially conceptualized impact chain for selected 6 regions and as per defined scope for F&A Identify recommended adaptation measures including Ecosystem based Adaptation (EbA) considering gender inclusion and sustainable livelihoods 	<ul style="list-style-type: none"> Bring the national level impact chain for the respective region under which project site located Conduct FGDs, KIIs and Community Survey Update or modify the impact chain including the weight through Budget Allocation Approach

Steps	Activities	Agenda	National Level	Local Level
		<ul style="list-style-type: none"> Determine exposures or elements at risk Brainstorm adaptation measures to reduce the risk 	<ul style="list-style-type: none"> Share with relevant stakeholders and client Get feedback and assign weights of identified CRVA elements through Budget Allocation Approach Finalise the impact chain for next step 	<ul style="list-style-type: none"> Identify recommended adaptation measures including EbA considering gender inclusion and sustainable livelihoods Compile Field based Outcome Brainstorming among study team experts Finalise the impact chain for each project site
3	Identifying and Selecting Indicators	<ul style="list-style-type: none"> Select indicators for hazards Select indicators for vulnerability and exposure based on functional relationship with risk Identify proxy indicators, if any List all indicators and discard redundant or repeated indicators for same CRVA components 	<ul style="list-style-type: none"> Compiling data and information availability Selecting indicators of CRVA components based on data and information availability at desired level from secondary sources Identify proxy indicators Deduct redundant data 	<ul style="list-style-type: none"> Compiling data and information availability from FGDs, KIIs and Community Survey, Water Quality test Selecting indicators of CRVA components based on data and information availability at desired level from both secondary and primary sources Identify proxy indicators Deduct redundant data
4	Data Acquisition and Management	<ul style="list-style-type: none"> Data collection, database construction and linking relevant data to chosen indicators 	<ul style="list-style-type: none"> Data collection and processing Gender disaggregation which are possible Threshold or intensity identification from trend, frequency and indices analysis Climate data downscaling for each region for future projections from CORDEX CMIP5 datasets for South Asia along with national level projections from recent CMIP6 dataset. Land cover or water bodies change assessment Inventory preparation with unit for each indicator 	<ul style="list-style-type: none"> Data collection and processing Gender disaggregation which are possible Threshold or intensity identification from trend, frequency and indices analysis through both secondary sources and using feedback from local stakeholders and community Climate data downscaling for each region for future projections from CORDEX CMIP5 datasets for South Asia along with national level projections from recent CMIP6 dataset. Land cover or water bodies change assessment

Steps	Activities	Agenda	National Level	Local Level
				<ul style="list-style-type: none"> Inventory preparation with unit for each indicator
5	Normalisation of Indicator Data	<ul style="list-style-type: none"> Transfer different data sets into unit-less values on a common scale (i.e., 0 to 1) based on functional relationship and standard normalisation formula 	<ul style="list-style-type: none"> Normalisation of indicator data based on functional relationship 	<ul style="list-style-type: none"> Normalisation of indicator data based on functional relationship
6	Weighting and Aggregating Indicators to CRVA Components	<ul style="list-style-type: none"> Assign weights to the various indicators Arithmetic aggregation indicators to CRVA components 	<ul style="list-style-type: none"> Assign weights derived from Impact Chain Finalization workshop Geo-spatial weighted arithmetic aggregation using GIS Estimate total score of each CRVA components i.e. for hazard, exposure and vulnerability 	<ul style="list-style-type: none"> Assign weights derived from FGDs, KIIs and based on National level impact chain of that region Geo-spatial weighted arithmetic aggregation using GIS Estimate total score of each CRVA components i.e. for hazard, exposure and vulnerability
7	Aggregating of CRVA Components	<ul style="list-style-type: none"> Assign weight and arithmetic aggregation of vulnerability components (i.e., adaptive capacity and sensitivity) Assign weight and arithmetic aggregation of CRVA components i.e., among hazards, exposure and vulnerability Estimate the total CRVA score and normalise the score again to single value (0 to 1) 	<ul style="list-style-type: none"> Assign weight among CRVA components derived from impact chain finalisation workshop Geo-spatial weighted arithmetic aggregation using GIS Estimate total score and normalise the CRVA score 	<ul style="list-style-type: none"> Assign weights derived from FGDs, KIIs and based on National level impact chain of that region Geo-spatial weighted arithmetic aggregation using GIS Estimate total score and normalise the CRVA score
8	Presenting the Outcomes of CRVA	<ul style="list-style-type: none"> Summarise and present the findings of CRVA in maps using GIS and graphs (spider, pie or bar chart) List down possible adaptation measures to reduce climate risk and vulnerability 	<ul style="list-style-type: none"> CRA maps for current and future for each selected region showing spatial variation up to District Level Separate maps for Capture and Culture Fisheries highlighting gender perspectives CRV map for fishery ecosystem 	<ul style="list-style-type: none"> CRV maps for current and future for each project site or Upazila showing spatial variation up to Union level Separate maps for Capture and Culture Fisheries highlighting gender perspectives CRV map for fishery ecosystem

Steps	Activities	Agenda	National Level	Local Level
			<ul style="list-style-type: none"> • List of potential recommendations for adaptation measures • Validating the outcome of CRVA with stakeholders • Update (if necessary) and publish the finalised CRV maps 	<ul style="list-style-type: none"> • List of potential recommendations for adaptation measures • Validating the outcome of CRVA with stakeholders • Update (if necessary) and publish the finalised CRV maps

Selected Indicators of Impact Chain

Hazard indicators used for Project Level Climate Change Risk and Vulnerability Assessment at Jagannathpur Upazila

	Factor	Indicator
H a z a r d	Salinity intrusion	Salinity Concentration
	Heat wave	Extreme temperature days(>36°C)
	Drought/ Less availability of Water	Successive non rainy days
	Flood/Tidal Flood	Inundation Depth and Tide Ingress
	Siltation	Channel Connectivity
	Storm Surge	Inundation Depth
	Thunderstorm	Frequency /Intensity/Injuries
	Flash Flood	Timing of Flash Flood
	Wave action	Wave Action/Wind Direction
	Fog	Number of Foggy Days
	Low Temperature	Number of Cold Days (<10°C)

Exposure indicators used for Project Level Climate Change Risk and Vulnerability Assessment at Jagannathpur adar Upazila

 Indicators excluded In CRVA

	Factor	Indicator	
C u l t u r e F i s h e r i e s	Culture Type	Fishing Culture Pattern and Abundance or Production per Species	
	Shrimp/ Prawn Culture	Production	
	Fishermen	Number/Percentage of Fishermen (between aged 14-60 years)	
	Marginal Fishermen	Number/Percentage of Poor Fishermen	
	Women	Percentage of Women involved in fishing	
	Hatchery	Presence (Density/Location/Number) of hatchery	
	Fish Farm		Presence (Density/Location/Number) of fish pond
			Presence (Density/Location/Number) of fish farm
	Post-harvest Infrastructure (transport, market etc.)	Presence (Density/Location/Number) of post-harvest infrastructure	
C a p t u r e F i s h e r	Number and composition of fish species (Hilsha, Brackish water species)	Number/abundance of species	
	Endangered and Threaten species	Number/abundance of endangered/threatened species	
	Fish migratory route	Change in migratory route	

	Factor	Indicator
ies	Regional fish species	No of Species
	No. of Fishers	Number/Percentage of Fishermen (between aged 14-60 years)
	Number of marginal Fishers	Number/Percentage of Poor Fishermen
	Women Participation	Percentage of Women involved in fishing
	Post-harvest infrastructure (transport, market etc.)	Presence of post-harvest infrastructure
Ecosystem	Flora	Number/abundance/composition of species
	Fauna	Number/abundance of endangered/threatened species
	Habitat	Density of aquatic habitat area
	ECAs	Presence/Density of ECAs
	PAs	Presence/Density of PAs

Sensitivity indicators used for Project Level Climate Change Risk and Vulnerability Assessment at Jagannathpur Upazila

 Indicators excluded In CRVA

	Factor	Indicator	
Culture Fisheries	Unfavorable soil condition	Soil Nutrient Content	
	Unfavorable aquatic condition	Water quality (Ph, TDS, DO, BOD, COD, N2O, Temperature)	
	Fish Disease	Type of disease occurring	
	Fish Growth		Fish Growth Rate
			Fish Size
	Mortality Rate	Mortality Rate	
	Low resistance to Salinity	Fish Growth/Avoidance rate in higher salinity conc	
Low resistance to Temperature	Fish Growth/Avoidance rate in higher temperature		
Capture Fisheries	Unfavorable soil condition	Soil Nutrient Content	
	Unfavorable aquatic condition	Water quality (Ph, TDS, DO, BOD, COD, N2O, Temperature, Depth, Flow, Velocity...etc)	
	Fish Disease	Type of disease occurring	
	Fish Growth		Fish Growth Rate
			Fish Size
	Mortality Rate	Mortality Rate	
	Low resistance to Salinity	Fish Growth/Avoidance rate in higher salinity conc	
Low resistance to Temperature	Fish Growth/Avoidance rate in higher temperature		
Ecosystems	Habitat Condition	Soil condition (Soil Nutrient Content)	
		Water Quality ((Ph, TDS, DO, BOD, COD, N2O, Temperature, Depth, Flow, Velocity...etc)	

	Factor	Indicator
tem	Community Composition	No of Species/Abundance of species
	Reproductively	Reproduction rate
	Ecosystem Services	Ecosystem Services Harnessed/Disrupted
	Water resources conservation	Presence/Number of functional water resources management structures (regulator, sluices, culverts etc)
	Water infrastructure management	Presence of WMG in community
	Monitoring and evaluation	Number of monitoring program

Adaptive Capacity indicators used for Project Level Climate Change Risk and Vulnerability Assessment at Jagannathpur Upazila

 Indicators excluded In CRVA

	Factor	Indicator
Cultu re Fishe ries	Awareness Raising Program on CC	Number of Awareness Program on CC/literacy rate
	Training/Education on CC Impact and Adaptation	Number of Training/Education Received on Climate Change
	Advanced fishing gear/material use	Number/Density of Mechanized boats /Nets
	Use of RAS and Biofloc	Practice/Coverage of RAS and Biofloc
	Functional ETP	Number of Functional ETP Plants
	Quality fish Stocking	Number/Density of HYV Breeding Farm/Hatchery
	Proper leasing framework	Presence of lease framework
	Number of markets	Number of Fish Market
	Storage Facilities	Number/Density of Storage Facilities/Cold Storage
	Opportunities for Dry Fish Processing	Dry Fish Production
	Fish Feed Production	Production per capita Fishermen/Farm
	Road Connectivity to Markets/Landing sites	Density of Road
	Availability of freezer van	No of Van Available/transport index
	Climate Information Services (EWS)	Coverage of CIS/EWS
	E-Commerce	Involvement in E-Commerce by Fishermen
	Water Resources Management	Presence/Number of functional water resources management structures (regulator, sluices, culverts etc)
Availability of fish pass/fish friendly structure/fish pass	Number/Density of Fish Pass	
Capt ure Fishe ries	Awareness Raising Program on CC	Number of Awareness Program on CC
	Training/Education on CC Impact and Adaptation	Number of Training/Education Received on Climate Change
	Advanced fishing gear/material use	Number/Density of Mechanized boats /Nets
	Functional ETP	Number of Functional ETP Plants
	Proper leasing framework	Presence of lease framework
	Fishing Ban season	Number of adequate ban days
	Subsidies for fishermen	Avaialbility of subsidies (PES/BPP) program

	Factor	Indicator
	Number of markets	Number of Fish Market
	Storage Facilities	Number/Density of Storage Facilities/Cold Storage
	Opportunities for Dry Fish Processing	Dry Fish Production
	Road Connectivity to Markets/Landing sites	Density of Road
	Availability of freezer van	No of Van Available
	Climate Information Services /(EWS)	Coverage of CIS/EWS
	E-Commerce	Involvement in E-Commerce by Fishermen
	Water Resources Management	Presence/Number of functional water resources management structures (regulator, sluices, culverts etc)
	Availability of fish pass/fish friendly structure/fish pass	Number/Density of Fish Pass
Ecosystem	Low species richness	Abundance of Species
	Loss of ecosystem	Ecosystem Services Harnessed/Disrupted
	Resistance to Salinity	Aquatic species growth/avoidance rate in higher salinity conc
	Resistance to Temperature	Aquatic species growth/avoidance rate in higher temperature
	Provisions for Nature Conservation	Number/Area of reserved wetland/sanctuary/ECAs
	Monitoring and Enforcement	Number of monitoring/patrolling/enforcement program
	Water Resources Management	Presence/Number of functional water resources management structures (regulator, sluices, culverts etc)
	Availability of fish pass/fish friendly structure/fish pass	Number/Density of Fish Pass
	Weak ecosystem management practices	Number of Awareness Program on CC

Annex II: SWOT Analysis of Aquatic Ecosystem

SWOT scoring and outcomes for River ecosystem

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Provisioning	Water availability	3	2.25	3	2.5	The strength of water availability received Highest score due to availability of optimum water in the dry season and good water retention time and high percentage of diversified water use. Weakness scores medium condition because good connecting of surrounding hydrological system but connectivity obstructed due to high siltation and sandy river bed materials. There are good opportunities to increase water availability through dredging or re-excavation practices, high opportunities for law enforcement of IUU fishing and support alternative livelihoods so, the opportunities scored high. High encroachments, plan of upstream development due to rapid urbanization and presence of rubber dam and other obstacles are the main threats that scored high.
	Water quality	2.5	2	2	3	Water quality received a good score for strength as the Optimum Physio-Chemical Parameters (Temperature, DO, TDS, pH) from the field test are tolerable for water quality and water is largely used for different purposes. As the physio-chemical parameters are good than threshold range, so the weakness of water quality is scored medium. However, the presence of law enforcement of IUU fishing are good opportunities for water quality improvement and co-management is less active, so the opportunities received average scores. Sudden flash floods, excessive temperatures and drought due to climate change are the main threats to water quality. Moreover, chemicals and pesticides used in surrounding crop field, fish gher and waste dumping from the surrounding households causes the water quality more vulnerable, moreover industrial chemical discharge from fertilizer factory especially from Fenchuganj, Sylhet comes into kushiyara river during tide and deplete oxygen , so threats scored high here.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
	Soil quality	2.5	2.6	2	3	The strength of soil quality is scored high as the nutrients condition of the soil is optimum due to vegetation coverage. The weakness of the soil quality scored high due to presence of ordinary peat soil which is a very soft soil, average litter decomposition and soil is also polluted by anthropogenic activities and climate change. Opportunities for soil quality improve assigned medium scores because of optimum vegetation coverage. There are high threats to soil quality as chemicals and pesticides used in surrounding crop field and household discharge and waste dumping.
	Primary productivity	2	2	2	2	Availability of plankton, presence of usual aquatic vegetation at the edge of the river, good sediment retention, export, and floodplain fertility provide average strength scores for primary productivity. Weakness for primary productivity scored medium as moderate time needed to restore plankton and aquatic vegetation after disasters. Opportunities for primary productivity get medium scores because of moderate forest, vegetation coverage and EbA interventions. However, Threats scored medium due to adequate unsustainable harvest of the ecosystem resources.
	Fish diversity, community dynamics and production	2.3	2	2.5	2.3	This indicator received moderate score for strengths as water for integrated use for fishery, crop and nature is sufficient and soil quality is good for fisheries. Moreover, primary productivity is average. Weakness is scored medium due to good water retention capacity and average time needed to regenerate primary productivity, water quality fluctuates with climate change. Presence of green coverage is great, fishing ban period is monitored, the dolphin migration route is present, community involvement, EbA activities is moderately active, and People are well aware of the role of ecosystem for climate resilience, so the opportunities received good score. Frequent climate extreme event especially flash flood are the main threats to fish diversity, community dynamics and production. However, Disruption of environmental flow of the ecosystem due to infrastructure and upstream development is also disrupt fish diversity and production and received moderate score
Regulating	Ground water recharge	2.5	1.5	1	2.6	The strength for ground water recharge is high because of high percentage of sandy soil type and optimum vegetation coverage. Main weakness is floral degradation due to river erosion caused by flood which influence ground water recharge and scored medium here due to degradation of water holding capacity. As this is a natural ecosystem so there are few opportunities for ground water

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
						recharge. Main threats are rapid unplanned urbanization, unsustainable use of forest and poor management of domestic waste which is scored high.
	Waste treatment water	2.5	2	2.6	2.6	The strength of waste water treatment received high score due presence of aquatic vegetation especially grasses and water hyacinth abundant in the riverbanks and availability of molluscs. Weakness scored medium condition because of high dense turbidity and average aquatic vegetation. Presence of co-management, awareness of the role of ecosystem for climate resilience and law enforcement are opportunities for this indicator but received good scores. Rapid urbanization, unsustainable use of forest and poor management of domestic waste are the main threats which is scored high.
	Soil fertility	2	2	2.6	2.5	Strength for soil fertility scored medium as existing moderate level of flora and fauna makes the soil fertile by decomposing organic materials which provide suitable habitat. So, the weakness also gets medium score. Opportunities for soil quality improve assigned good scores because of plantation of vegetation coverage, sustainable management and average increase awareness of the people. Presence of embankment, agro-chemicals use in the surrounding ghers, moderate water management structure, moderate deforestation are the main threats to soil fertility which scored high.
	Water retention capacity	3	3	3	2.3	Water retention and conveyance capacity is fluctuating with seasonal variation and strength for this indicators scored high though siltation is the main weakness and received highest score. There are high opportunities for dredging and new hydrological connection and it scored high. Presence of embankment, moderate water management structure and moderate deforestation disrupt water retention so the threats scored medium.
Cultural	Recreation and tourism	2.3	2.5	2.3	2.5	Availability of resources, scenic beauty provides good score for cultural services but the main weakness is recreation and tourism is not so planned and lack of sustainable management which received high score. There are good Opportunities for community based livelihood, education and research and inspirational values and received moderate scores. The main threats are environmental pollution and overexploitation of resources which received maximum score.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Supporting	Ground water replenishment	2.5	2	2	3	The strength for ground water replenishment is high because of sandy soil type and moderate vegetation coverage. vegetation degradation due to river erosion because of flash flood and storms is the main weakness and scored medium here due to average water holding capacity. As this is a natural ecosystem so there are opportunities for groundwater recharge which received medium score. Main threats are management of domestic waste and unplanned urbanization which is scored highest.
	Nutrient cycling	2	2	2.5	3	Nutrient cycling gets moderate score as presence of standard existing biodiversity which makes the soil fertile by decomposing organic materials and enrich nutrients to the soil. So, the weakness also gets medium score. Opportunities for nutrient cycling received high score because of increasing forest and vegetation coverage and sustainable management. Disasters, rapid urbanization, encroachments are the main threats for nutrients cycling which received high scores.
	Maintenance of floodplain fertility	3	2	2.3	2.5	The strength of this indicator received maximum score because floodplains are highly fertile as sediment is rich in organic matter and nutrients. Floodplains are home to some of the most biologically rich habitats on Earth. They provide opportunities of spawning grounds for fish and critical areas of rest and foraging for migrating waterfowl and birds. So, opportunities received a good score. Weakness and Threats received average score as flash flood, river erosion and siltation which can undermine the stability of nearby infrastructure or disperse or degrade quality soils necessary for nutrient cycling and vegetative viability.
	Prey/predator relationships	2	2	2	3	Strength and opportunities for this indicator are medium for multitrophic interaction and medium species & genetic diversity as many fresh species is supporting the ecosystem. Weakness for this indicator received moderate score due to rapid urbanization and environmental pollution which disrupt the species habitat. Frequent climate extreme events and deforestation due to urbanization are the main threats for Prey/predator relationships which received high score
	Hydric soil development	2.5	2	2.3	2.5	The strength of this indicator is high because of optimum vegetation coverage and sandy soil type. Vegetation degradation is the main weakness and scored medium here due to low water holding capacity. Opportunities received good score due to the natural ecosystem support. Presence of embankment and infrastructure are the main threats to hydric soil development which gets high scores.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Total	Total Service=15	36.6	31.85	34.1	39.3	

SWOT scoring and outcomes for Haor ecosystem

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Provisioning	Water availability	2	2.3	2	2	The strength of water availability received average due to adverse condition of availability of optimum water in the dry season but suitable condition in the wet season, Water retention time is good in the wet season, and water use for consumptive and non-consumptive purposes. Weakness scores medium condition because adequate connecting of surrounding hydrological system, connectivity obstructed due to high siltation and sandy river bed materials which scored medium. There are adequate opportunities to increase water availability through dredging or re-excavation practices, high opportunities for law enforcement of IUU fishing and support alternative livelihoods so, the opportunities scored medium. Plan of upstream development due to rapid urbanization and encroachments are the main threats that scored medium.
	Water quality	2.5	2	3	3	Water quality received a strong score for strength as the Optimum Physio-Chemical Parameters (DO, TDS, pH) from the field test are favorable for water quality except for temperature and water can be used for multipurpose. As the physio-chemical parameters are tolerable than the threshold range, the weakness of water quality is scored low. However, EbA interventions for dust management and the presence of law enforcement are good opportunities for water quality improvement so, the opportunities received high scores. Seasonal flash flood, extreme heat and drought due to climate change are the main threats to water quality. Moreover, chemicals and pesticides used in surrounding crop field, fish gher and waste dumping from the surrounding infrastructures cause the water quality more vulnerable so threats scored high here.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
	Soil quality	2.5	2	2.5	2.5	The strength of soil quality is scored high as the optimum soil nutrients is in good condition due to floodplain fertility and presence of coarse bed materials. The weakness of the soil quality scored medium due to average litter decomposition and vegetation coverage. Soil also polluted by anthropogenic activities. Opportunities for soil quality improve assigned high scores because of plantation of vegetation coverage around the haor embankment and excessive land use practice. There are high threats to soil quality as chemicals and pesticides used in surrounding crop fields and fish gher and household discharge and waste dumping which scored high here.
	Primary productivity	2.3	2	2.5	2	Availability of plankton and aquatic vegetation in wet season, good sediment retention, export and floodplain fertility provide good strength scores for primary productivity. Weakness for primary productivity scored medium as average time needed to restore plankton and aquatic vegetation after disasters because of ecosystems inherent capacities such as availability of seedlings and gene flow. Opportunities for primary productivity get high scores because of high land use practice but distressing forest, vegetation coverage and increasing EbA interventions. However, Threats scored medium due to lack unsustainable harvest of the ecosystem resources.
	Fish diversity, community dynamics and production	2	1.6	1.75	2.3	This indicator received average score for strengths as water for integrated use for fishery, crop and nature is sufficient in wet season but deficient in dry season, water and soil quality is optimum for fisheries and primary production is high during the monsoon period. Weakness is scored low due as water retention capacity fluctuating with season and time needed to regenerate primary productivity once the wetland is converted into agriculture land. The presence of green coverage is not sufficient due to felling trees for crop harvest, the fishing ban period is not properly maintained, community involvement, EbA activities are moderately active, so the opportunities received an average score. People have not adequate access to climate and hydrology information, frequent climate extreme event are the main threats to fish diversity, community dynamics and production and received moderate score.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Regulating	Ground recharge water	2.5	2	2	2	The strength for ground water recharge is high because of sandy soil type and optimum vegetation coverage surrounding the haor. Soil type and high floral degradation makes the weakness score medium here due to decent water holding capacity. As this is a natural ecosystem so there are few opportunities for ground water recharge. Main threats are rapid urbanization and poor management of domestic waste which scored medium here.
	Waste treatment water	2.5	2	2.25	2	The strength of waste water treatment received high score due average condition of aquatic vegetation and abundance of molluscs. Weakness scored average because of low abundance of aquatic vegetation and dense turbidity. Presence of co-management, EbA interventions, increase awareness of the role of ecosystem for climate resilience and law enforcement are good opportunities for this indicator and received good scores. Rapid urbanization and poor management of domestic waste are the main threats which scored medium.
	Soil fertility	2.5	1.5	2	2.3	Strength for soil fertility scored high as existing average biodiversity makes the soil fertile by decomposing organic materials which provide suitable habitat. So, the weakness also gets low score. Opportunities for soil quality improve assigned good scores because of plantation of trees and vegetation around the haor area, increasing awareness of the people and integrated ecosystem based management approach. Presence of embankment and agro-chemicals use in the surrounding ghers, moderate water management structure, deforestation are the main threats to soil fertility which scored medium.
	Water retention capacity	2	3	2	2.5	Water retention and conveyance capacity is good in wet season but seasonally fluctuate and strength for this indicators scored medium. Siltation is the main weakness and received maximum score. There are average opportunities for dredging and new hydrological connection so it scored medium. Presence of embankment and high deforestation disrupt water retention so the threats scored high.
Cultural	Recreation and tourism	2.3	2.5	2.6	2	High resource availability, scenic beauty provides satisfying score for cultural services but the main weakness is recreation and tourism are not so planned and lack of sustainable management which received high score. There are high Opportunities for community based livelihood, education and research, inspirational values and received top score. The main threats are environmental pollution and overexploitation of resources which received medium score.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Supporting	Ground water replenishment	2.5	2	2.2	2.5	The strength for ground water replenishment is high because of sandy soil type and average vegetation coverage. Vegetation destruction is the main weakness and scored medium here due to low water holding capacity. There are few opportunities like dredging, digging for groundwater recharge which received moderate score. Main threats are deforestation and unplanned urbanization which is scored highest.
	Nutrient cycling	2	2.5	2.2	2.5	Nutrient cycling gets medium score due to presence of average biodiversity which makes the soil fertile by decomposing organic materials and enrich nutrients to the soil. The weakness gets high score due to destruction of vegetation. Opportunities for nutrient cycling received moderate score because of increasing forest and vegetation coverage by plantation and natural regeneration and sustainable management of haor ecosystem. Disasters, rapid urbanization, encroachments are the main threats for nutrients cycling which received moderate scores.
	Maintenance of floodplain fertility	2.5	2	2.5	2	The strength of this indicator received maximum score because floodplains are highly fertile as sediment is rich in organic matter and nutrients. Floodplains are home to some of the most biologically rich habitats on Earth. They provide opportunities of spawning grounds for fish and critical areas of rest and foraging for migrating waterfowl and birds. So, opportunities also received a peak score. Weakness and Threats received average score as stream bank erosion, and siltation which can undermine the stability of nearby infrastructure or disperse or degrade quality soils necessary for nutrient cycling and vegetative viability
	Prey/predator relationships	2.5	1	2.5	2	Strength and opportunities for this indicator are high for multitrophic interaction among birds, fishes, vegetation, aquatic organisms and high species & genetic diversity of fresh water species supporting the ecosystem. So, weakness for this indicator received negligible score. Frequent climate extreme events and deforestation due to urbanization are the main threats for Prey/predator relationships which received a medium score
	Hydric soil development	2.5	2.2	2.5	1.8	The strength of this indicator is high because of sandy soil type and average vegetation coverage. Degraded vegetation are the main weakness and scored medium here due to low water holding capacity. Opportunities received good score due to the natural ecosystem support and dredging opportunities. Presence

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
						of embankment and infrastructure are the main threats to hydric soil development which gets medium scores.
Total	Total Service=15	35.1	30.6	34.5	33.4	

SWOT scoring and outcomes for Fish Pond ecosystem

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Provisioning	Water availability	2.3	2	3	1	The strength of water availability received a medium score as deficient of optimum water in the dry season, average water retention time but water can be used for domestic purposes. Weakness scored medium as the fish pond is less connected with the surrounding hydrological system to support water availability in the dry season, pond bed materials are mostly silt soil which can hold a certain amount of water, siltation is another big weakness that covers the pond bed during the flood. There are high opportunities to increase water availability through rainwater harvesting, re-excavation practices, and community-based management. There are low threats on the Plan of upstream development and unsustainable use of ponds that received low scores.
	Water quality	2.5	2	3	2	The strength for water quality received a high score as the Optimum Physio-Chemical Parameters (DO, TDS, pH) from the field test are good for water quality and water can be used for multi-purposes. Weakness for water quality is scored high as the physio-chemical parameters are average but algal blooms occur due to climate change impact. However, EbA interventions, increase vegetation coverage and community-based management are good opportunities for water quality improvement so the opportunities received strong scores. Floods, Heat, and drought due to climate change are the main threats to water quality deterioration but have a significant impact. Moreover, chemicals and pesticides used in

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
						surrounding crop fields and fish ponds can deteriorate water quality so, threats received a medium score.
	Soil quality	3	1.3	3	2	The strength of soil quality is scored high as the optimum soil nutrients are in suitable condition due dominance of herbs, shrubs, and trees. The weakness of the soil quality is scored low due to high litter decomposition and vegetation coverage and presence of peat soil, so the soil is less polluted. Opportunities for soil quality improve assigned high score due to increasing suitable crops and vegetation coverage. There are medium threats on soil quality as chemicals and pesticides used in surrounding crop field and fish pond.
	Primary productivity	3	1	3	1	The presence of superior aquatic vegetation and plankton provides high strength scores for primary productivity. Weakness for primary productivity scored low as comparatively little time is needed to restore plankton and aquatic vegetation after disasters because of soil fertility and favorable condition. Opportunities for primary productivity get a high score for increasing awareness to plant a suitable trees and crops, vegetation coverage, and EbA interventions. However, low threats to productivity due to unsustainable harvest of the ecosystem resources received poor score.
	Fish diversity, community dynamics and production	2.6	1.6	2.75	2.5	This indicator received the highest score for strengths as water for integrated use for the fishery, crop and nature is sufficient but varies seasonally and water quality and soil quality are suitable for fisheries. Moreover, primary productivity is high. Weakness is scored low due to average water retention capacity, shifting water quality during the flood, and high temperature but less time is needed to regenerate primary productivity. The presence of green coverage is high, community-based activities are active, and awareness of the role of the ecosystem for climate resilience increases which are good opportunities and received maximum scores. Frequent climate extreme events are the main threats to fish diversity, community dynamics, and production, and access to climate and hydrology information are limited, so threats received a high score.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Regulating	Ground recharge water	2.5	1.5	2	1.3	The strength for groundwater recharge is high because of the sandy and silty soil type and high vegetation coverage. Sandy and silty soil type influences groundwater recharge and weakness scored low here due to high water holding capacity, floral degradation is negligible. There are good opportunities for groundwater recharge by altering soil conditions, re-excavation and planting suitable crops which scored medium. Dependence on vegetation is medium, use of water is tolerable. and urbanization is slightly unplanned, so the threats scored low.
	Waste treatment water	3	1.5	2.6	1.3	The strength of waste water treatment received high score due improved condition of aquatic vegetation and presence of molluscs. Weakness scored low condition because of high aquatic vegetation and low dense turbidity. EbA interventions, community based management and awareness raising are good opportunities for this indicator and received strong scores. Optimum harvesting of vegetation, adequate management of domestic waste and unplanned urbanization considered as the threats which scored low for this indicator.
	Soil fertility	3	1	2.6	2	Strength for soil fertility scores high due to the abundance of flora and fauna. So, the weakness gets the lowest score for the high abundance of flora and fauna. Opportunities for soil quality improve assigned strong scores by increasing suitable tree and vegetation coverage, sustainable management, and increased awareness of the role of the ecosystem in climate resilience. Improper re-excavation, agro-chemicals use, and unsustainable harvest of fuel wood are the main threats to soil fertility which scored medium.
	Water retention capacity	2	3	2.5	1	Water retention and conveyance capacity are good but vary seasonally and strength for these indicators scored medium. Siltation during the flood is the main weakness and received a medium score. There are good opportunities for re-excavation of the pond and connecting with the new hydrological system so it scored medium. Threats scored low due to low unsustainable fuelwood extraction and moderate water management structure.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Cultural	Recreation and tourism	1.6	2.5	2.6	1.5	Existing biodiversity, scenic beauty, and resource availability provide a low score for cultural services and the main weakness is unsustainable management of the ecosystem which scored average. Opportunities received a high score for social relations and inspirational values. The main threats are environmental pollution and over-exploitation of resources and received a weak score for threats.
Supporting	Groundwater replenishment	2.5	1.5	3	2	The strength for groundwater replenishment is high because of high vegetation coverage. Sandy and silty clay soil type is the main weakness and scored low here due to good water holding capacity. There are high opportunities for groundwater recharge by increasing vegetation and modifying soil texture which received the highest score. Main threats are the management of domestic waste and unplanned urbanization which scored moderately.
	Nutrient cycling	3	1	3	1.5	Nutrient cycling gets a high score due to its richness of biodiversity which makes the soil fertile by decomposing organic materials. So, the weakness gets the lowest score due to improving nutrient cycling. Opportunities for nutrient cycling received high scores because of increasing suitable tree and vegetation coverage. Frequent climate extreme events are the main threats to nutrient cycling which scored low.
	Maintenance of floodplain fertility	3	2	2.5	2	The strength for this indicator received high score because floodplains are sometimes highly fertile as sediment is rich in organic matter and nutrients. Floodplains are home to some of the most biologically rich habitats on Earth. They provide opportunities of spawning grounds for fish and critical areas of rest and foraging for migrating waterfowl and birds. So, opportunities received high score. Weakness and Threats received average score as stream bank erosion, which can undermine the stability of nearby pond infrastructure or disperse or degrade quality soils necessary for nutrient cycling and vegetative viability

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
	Prey/predator relationships	3	1	3	1.5	The strength and opportunities for these indicators are high for multitrophic interaction, species, and genetic diversity. Weakness for this indicator received a low score due to the abundance of flora and fauna. Frequent climate extreme events are the main threats to Prey/predator relationships which received a poor score.
	Hydric soil development	2.5	2	2.5	1.5	The strength of this indicator is high because of the good vegetation coverage. Weakness scored medium here due to the presence of sandy and silt soil type and scored medium here due to medium water holding capacity. Opportunities received high scores due to community-based management and EbA interventions. Rapid urbanization is the main threat to hydric soil development which scored low.
Total	Total Service=15	39.5	24.9	41.05	24.1	

Annex III: Photo Album of FGDs, KIIs, Community Survey and In-situ Test

FGD at Jagannathpur Upazia



FGD with CBO group-1



FGD with CBO group-2



FGD with Capture fisheries Group-1



FGD with Capture fisheries Group-2

Community Survey, KII and Water Quality Sample Collection



