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of the United Nations

Bagerhat Sadar 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

Bagerhat Sadar Upazilla

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Abbreviations

AR5	IPCC Fifth Assessment Report
AT	Air Temperature
BBS	Bangladesh Bureau of Statistics
BDT	Bangladeshi Taka
BFRI	Bangladesh Forest Research Institute
BIWTA	Bangladesh Inland Water Transport Authority
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
CPA	Chittagong Port Authority
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
DJF	December January February
DO	Dissolved Oxygen
DFO	District Fisheries Office
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
ECR'97	Environment Conservation Rules 1997
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
GDP	Gross Domestic Product
GED	General Economic Division
GIS	Geographic Information System
GoB	Government of Bangladesh
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
PL	Post Larvae
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
SW	South West
SWOT	Strength, Weakness, Opportunities and Threats
TDS	Total Dissolved Solids
TSE	Temperature Sensitive Environment
TSP	Triple Super Phosphate
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations Office for Disaster Risk Reduction
UP	Upazila Parishad
WARPO	Water Resources Planning Organization
WSS	White Spot Syndrome
WQ	Water Quality
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 particular emphasis on gender, need to be identified and analyzed at the national and local levels.

The current study evaluated climate change vulnerability of Bagerhat Sadar Upazila of Bagerhat District of the Khulna Division of Bangladesh, as it is one of the most severely affected by catastrophic climatic events, both historically and in recent times. The land elevation of this Upazila mostly varies between 2 to 20m, and 2.09% area is lying below Mean Sea Level (MSL) and about 37.17% of the area is lying between 0-2 m. These low-lying areas are subjected to tidal flooding, flood, sea level rise which inundates, erode shorelines, and contribute to coastal flooding.

The region experienced numerous catastrophic severe cyclone events, especially in the last two decades, including Sidr (2007), Rashmi (2008), Aila (2009), Roanu (2016), Mora (2017), Fani (2019), Amphan (2020) and others. It has been observed that a 10 m high wave (surge plus tide) along Bangladesh coast occurs every 20 years, while a wave with a 7 m height occurs every 5 years (Rahman, 2014). Cyclone Sidr (2007), Cyclone Aila (2009) and super Cyclone Amphan (2020) were accompanied with 3m to 5.5m level of storm surge and brought the saline water into the agricultural lands and also inundated housings of many coastal communities. Besides cyclones; coastal flooding, saline water intrusions, river bank erosion, sea level rise and drought have severely affected the people living in this region. Especially, tremendous rise in apparent temperature in the south-western region has caused fish farmers in Bagerhat Sadar Upazila to face numerous challenges, most importantly oxygen level drop in water and various viral, bacterial and fungal diseases. Although lightning susceptibility of the South-West zone is comparatively less than other zones of Bangladesh, but locals reported the spawning and breeding of fisheries to have been affected by this as well.

Future climate projections by CEGIS (2022) show that, maximum temperature will rise by 2.2°C and 0.9°C during winter and summer respectively in 2050s for SSP5-8.5 when compared to 1981-2010. Likewise, the minimum temperature will rise by 3.3°C and 2.2°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, MAM, and ON seasons by 84%, 38%, and 52% respectively and increase in JJAS by 30, while the total annual rainfall will be decreased by around 7% 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 water bodies in Bagerhat Sadar Upazila were found to have decreased from 1990 to 2020 by 5.9% on average. The reasons behind these changes are many, including illegal encroachments and increase in urbanization due to rise in human settlements that eventually resulted in the filling up of the permanent waterbodies. Sometimes the land use was also observed to have changed in areas such as fish habitats and breeding grounds, which have negative effects on fisheries and other aquatic animals.

The water quality tests undertaken found that nitrate content was higher than the standard in pond ecosystem. Excess nitrogen may cause an overgrowth of algae in a short period which may cause fish mortalities. 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 Barai Para and Shat Gambuj 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, Shat Gambuj, Rakhalgachhi and Barai Para unions were found to be high climate risk unions.

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% with increasing 1°C mean water temperature. However, this magnitude will decrease 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 Barai Para and Bemarta unions are highly sensitive to climate change induced hazard. Sensitivity assessment of culture fisheries show Bishnupur and Dema to be highly sensitive to climate change induced hazards. Adaptive capacity assessment reveals that Binsnupur, Dema and Shat Gambuj unions had high adaptive capacity for capture fisheries whereas Bishnupur Kara Para, Rakhalgachi and Shat Gambuj unions had high adaptive capacity for culture fisheries. Climate change induced hazard risk for culture fisheries impact chain analysis showed Dema, Shat Gambuj and Khanpur union were in high risk category for the base period, whereas Gota Para, Binsnupur and Barai Para union were in low risk in base year, however all the unions were found to be in high risk category for the year 2050. For culture fisheries, Dema, Shat Gambuj and Khanpur unions were in high risk and Barai Para, Gota Para and Bishnupur unions were in moderate risk in base period. However, all of these six unions will be in high risk zone in 2050s.

Most of the women in Bagerhat Sadar are involved in household related activities, with only 2.9% women (Upazila Field Office 2022) involved in fry collection, net making, pond preparation and culture fishing. However, those women involved in fish related activities were found to earn little from these compared to male counterparts. Exposure for gender-based livelihood analysis showed all the unions were highly exposed except the Bagerhat Paurashava, whereas sensitivity analysis showed Dema union is in highly sensitive zone for gender-based livelihood. Risk assessment shows all the unions except Bishnupur and Bagerhat Paurashava unions are at high risk for gender-based livelihood for both the base period and the 2050s time slice. In 2050s the Bishnupur union is found to be in high risk zone while it was in the moderate-risk zone in the base period.

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 uncertainty in future climate makes things worse, in addition to the inadequate capacity for impact assessment and 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 Bagerhat Sadar 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 Bagerhat Sadar 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 Survey and Key Informant Interviews (KIIs). The study conducted 3 FGDs with Community based Organisations led by Women (associated with fish culture and production), capture fisheries group and culture fisheries group/fish farm owner. Senior Upazila Fisheries Officer (SUFO), District Fisheries Officer, Chairman of BFRI, fish trader and Gher owner were interviewed for KIIs. Three community surveys at Barakpur, Sarkardanga and Kara Para 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 Bagerhat Sadar 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 is 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 Bhairab (Dartana) River, ponds and gher for laboratory tests to assess 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 has 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 were 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. Photos of the surveys are presented 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 Bagerhat Sadar 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

Bagerhat Sadar Upazila is located in Bagerhat district in Khulna Division between the 20°39' North latitude and 89°47' East longitudes. It shares boundary with Fakirhat, Chittalmari and Mollahat upazilas on the north, Kachua Upazila on the east, Rampal Upazila on the South and West and Morelganj Upazila on the East and South. The land elevation of Bagerhat Sadar Upazila mostly varies between 2 to 20 m. It has been found that, 2.09% of the area is lying below Mean Sea Level (MSL) and about 37.17% of the area lies between 0-2 m. These low-lying areas are subjected to tidal flooding, flood, sea level rise which inundates, erode shorelines, and contribute to coastal flooding. The Upazila covers an area of 316.97 sq. km (12.33 sq. mi). This Upazila is dominated mainly by rural settlement landuse, which covers almost 36.82% (11426.43 ha) of the Upazila. Freshwater aquaculture is the second most dominant land type (34.57%). Crop cover is around 3863.70 ha area and 12.45% of total land cover while 8.29% of total land use is brackish aquaculture.

2.2 Hydrological system

The main rivers of Bagerhat Upazila are Bhairab (Daratana), Panguchi, Madhumati, Pasur, Haringhata, Mongla, Baleshwar, Bhangra, Gosairkhali etc. The Atharbanki River, which flows through the Naihati Union of Rupsha Upazila of the Khulna District, is the source of the Bhairab River. The Gorai-Madhumati River is one of the longest rivers in Bangladesh and a tributary of the Ganges. Madhumati flows through Kushtia, Jessore, Rajbari, Faridpur, Khulna, Pirojpur and Barguna districts in Bangladesh. The Pasur River is a tidal river in southwestern Bangladesh and also a tributary of the Ganges. It continues the Rupsa River and meets the Shibsra River within the Sundarbans, and near to the sea the river becomes the Kunga River. The Baleshwari River is part of the western and eastern borders of the Barguna District and Bagerhat District. It shares an eastern boundary with the biggest mangrove forest in the world, which is located in the Ganges-Brahmaputra delta and is designated as the Sundarbans Reserve Forest in Bangladesh. The Baleshwar River flows south into the Haringhata River, which flows into the Bay of Bengal. The Panguchi River originates from the Kendua Bill of Mollhat Upazila and flows downstream under the name of Chitra River and meets with Bhairab River. Later the Panguchi River flows downstream and falls into the Bay of Bengal through the Sundarbans as the Baleshwar River, with an approximate length of 175.00 km. The **Figure 2.1** shows the Upazila hydrological systems and study areas among others.

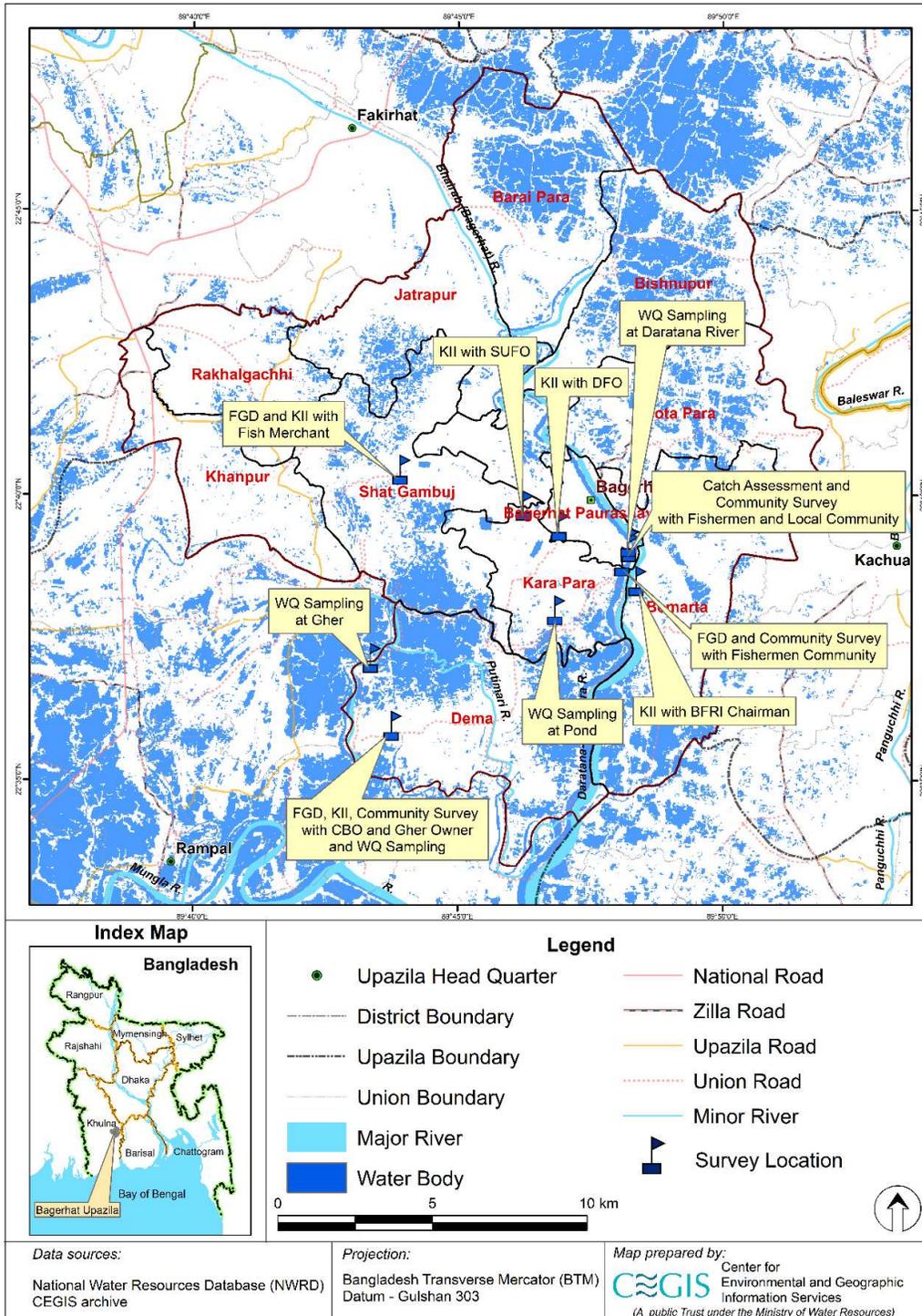


Figure 2.1: Hydrological system and locations of primary survey in Bagerhat Sadar Upazila

2.3 Aquatic ecosystem and its services

The major aquatic ecosystem consists of river, pond and Ghers. In addition to the major rivers, there are 5,760 ponds, 62 khals, 1 beel and 10,275 ghers (12,055ha), 25 fish farms and 221 crab farms in Bagerhat Sadar Upazila. The aquatic ecosystem provides numerous services in the project area including provisioning, regulating, supporting, and cultural services. It usually provides significant amount of drinking water, fish, fuelwood, and medicinal plants; regulates tidal 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

Bagerhat Sadar Upazila is rich in fisheries resources due to having multiple rivers and connecting Khals, and extensive area of shrimp/prawn farms and ponds. The Upazila has vast water area covering 751 hectare (ha) of river and Khal, 1,242 ha of pond, 12,055 ha of shrimp farm including golda and bagda, and 50 ha of crab fattening farms which contribute about 9,948 MT of fish and fisheries products annually (Upazila Fisheries Office, Bagerhat Sadar, 2021).

This Upazila has 3,221 registered fishers who are involved directly in fishing activities. Moreover, good numbers of people, both male and female, engage in the collection of shrimp and prawn post larvae (PL) in the nearer rivers and Khals. In addition to this, a good number of people are also involved in the shrimp processing and trading related activities.

2.5 Demographic characteristics

The Upazila has a population of 2,66,389 people; 50.2% male and 49.8% female. It has 10 unions, 1 Paurashava, 184 mouzas/mahallas and 185 villages. The population density is 1848 per sq.km and annual population growth rate is 1.30%. Total number of households in this Upazila is 82,970 and the average literacy is 65% (male 68% and female 62%). Main occupation include agriculture, agricultural labour, wage laborer, forestry, fishing, commerce, service and transport. People in this area are dependent on both capture and culture fishing. According to Bagerhat Sadar Upazila Fisheries office, about 3,221 fishermen livelihoods depend on capture fishing and about 12,717 on 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.

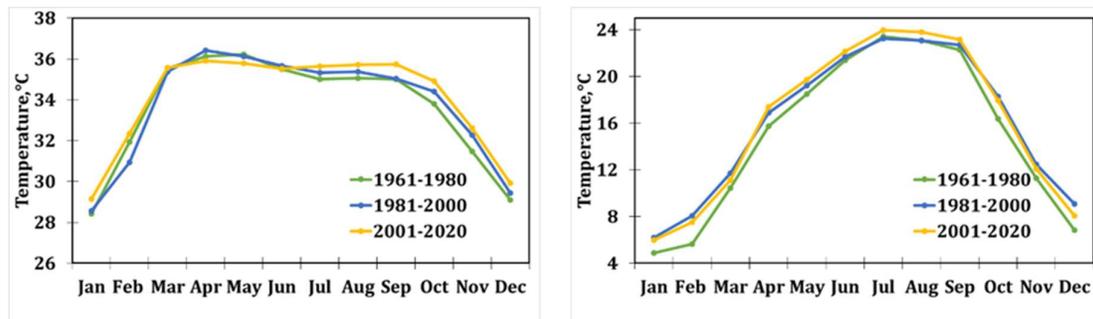
3.1 Climate change scenarios

3.1.1 Temperature

Temperature data analysis from 1961 to 2020 for Khulna 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 3°C and minimum temperature was 1.2°C while in winter season (December-February), minimum temperature increase was about 1°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 (0.0181°/decade) in 1961-1980, (0.033°C/decade) in 1981-2000, and then again at (0.139°C/decade) in more recent time slices. Whereas, annual maximum temperature has a decreasing trend in 1981-2000 but in next decade it had a significant increasing trend (0.3°/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 3.3°C and 2.2°C during winter and summer respectively in 2050s for SSP5-8.5. Mean average maximum temperature of DJF, MAM, and JJAS and ON season will be 29.1°C, 35°C, 33.8°C and 32.3°C for 2050s and mean average minimum temperature of DJF, MAM, JJAS and ON season will be 17.3°C, 25.5°C, 28.1°C and 24.4°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

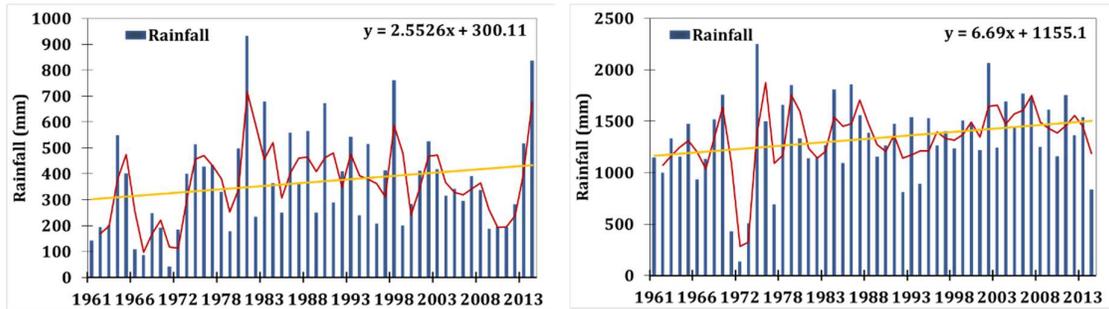
Figure 3.1: Average minimum (left) and average maximum (right) temperature of Khulna station

3.1.2 Rainfall variability

Rainfall data 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 are about 358.6 mm and 1342.1 mm respectively. Wet season rainfall is increasing with higher rate (6.69 mm/year) than that of dry season

(2.5mm/year) (Figure 3.2). The area experiences distinct seasonal variations the winter season (DJF), which is generally dry and contributes only 2 percent of the total annual rainfall; the pre monsoon hot season (MAM), which perceives 17 percent of convective thunderstorms or northwester (locally known as Kalbaishakhi); and the rainy season, which receives 81 percent of the total annual rainfall. Rainfall can range from 3 mm to 846 mm during the rainy season, with June often having the highest amount of rainfall.

The future rainfall projections in 2050, compared to the base year (1981-2010), show that rainfall will decrease during DJF, MAM, and ON seasons by 84%, 38%, and 52% respectively and increase in JJAS by 30%, where the total annual rainfall will decrease by around 7% under extreme climate change scenario (SSP5-8.5).

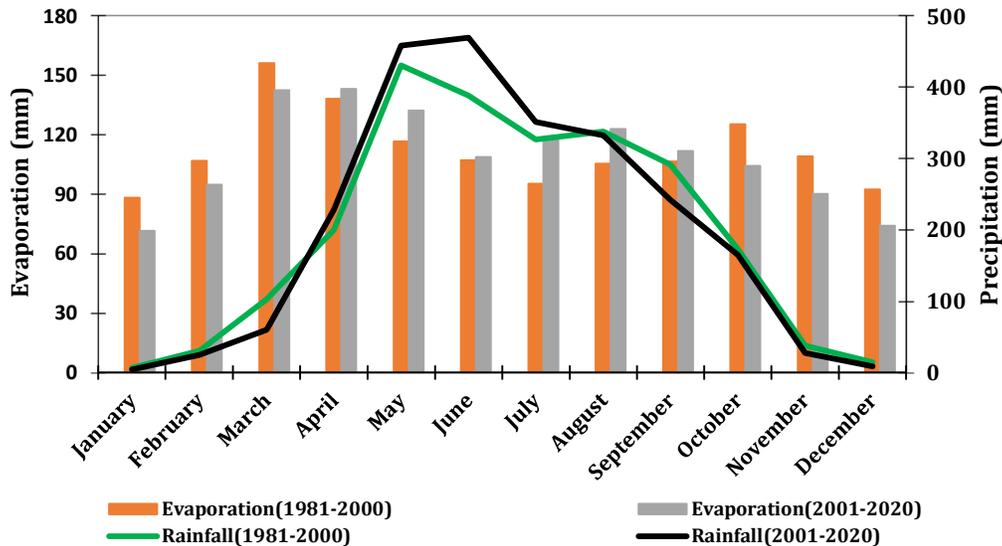


NWRD, BMD

Figure 3.2: Dry (Left) and wet (Right) season rainfall at Khulna 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 (Figure 3.3). 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.



NWRD, BMD

Figure 3.3: Monthly variation of rainfall and evaporation at Khulna station

3.2 Climate hazards and its impacts

The Bagerhat Sadar Upazila is particularly vulnerable to cyclones and storm surges, salinity intrusion, riverbank erosion, sea level rise, flood, extreme hot days, lightning 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 most reported hazards are increasing with high magnitude. For instance, extreme hot days was ranked more impactful than flood, cyclone, storm surge, salinity intrusion etc.

Table 3.1: Hazard ranking by local community

Hazard	Ranking	Trends/Frequency		Intensity
		Increasing (↑)		High=3
		Decreasing (↓)		Moderate=2
		Static (↔)		Low=1
Flood	2	↔		2
Drought	5	↔		1
Cyclone	3	↑		2
Storm Surge	4	↑		2
Extreme Hot Days	1	↑		3
Severe Cold Days	8	↑		2
Salinity Intrusion	6	↑		2
Thunderstorm	7	↑		2

CEGIS Field Survey, 2022

The present study identified five major climatic hazards for fisheries and aquaculture as found in Bagerhat Sadar Upazila (**Figure 3.4**). Among the hazards, heavy rainfall is identified as the most prominent hazard for aquaculture (especially shrimp farming). Moreover, the fishing activities are highly exposed to storm surge and cyclone. 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.

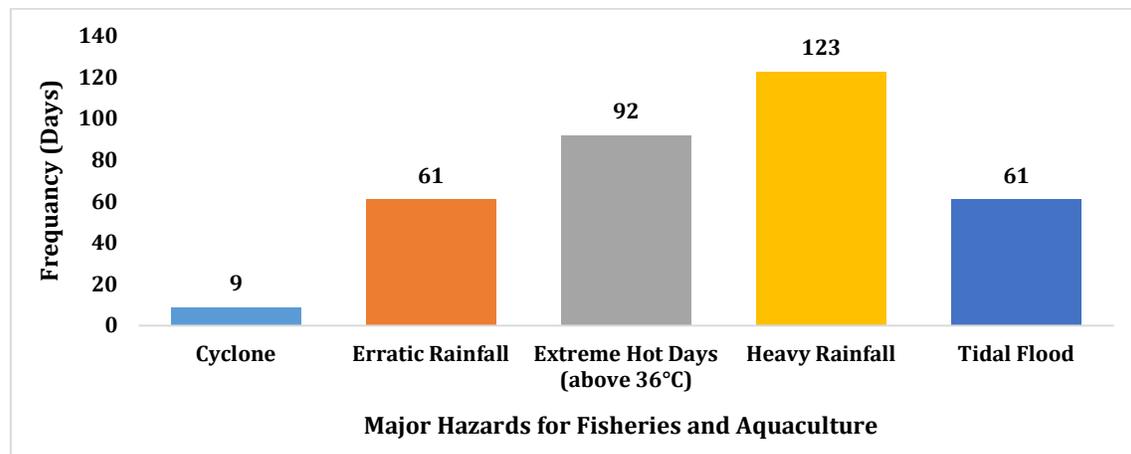


Figure 3.4: Frequency of climatic hazards on capture fisheries

CEGIS Field Survey, 2022

According to the hazard calendar developed by the fishing community, short duration high intensity but erratic rainfall has been increasing with less rain during monsoon, salinity intrusion is more severe during dry season than before. Flood usually occurs during Chaitra to Ashin but used to occur Baishakh to Srabon in the past. However, floods often occur due to embankment failure followed by high tidal surges causing great loss to people's livelihoods. Tidal wave height has increased compared to the past due to increased sea level and extreme hot and severe cold days. Each year, during high tides one or more embankments fail causing flood and intrusion of saline water.

Cyclone and storm surges

Being located in the south-western coastal region of Bangladesh, Bagerhat Sadar Upazila in Bagerhat districts has faced numerous catastrophic severe cyclone events, especially in the last two decades, including Sidr, Fani, Mora, Aila, Rashmi, Roanu, Amphan and others. In general, it has been observed that the frequency of a 10 m high wave (surge plus tide) along Bangladesh coast is about once in every 20 years, while a wave with a 7 m height occurs about once in 5 years. Cyclone Sidr (2007) and Cyclone Aila (2009) were accompanied with 3m to 5.5m level of storm surge and brought the saline water into the agricultural lands and also inundated housings of many coastal communities. Storm surge inundation modelling for base period and 2050s considering sea level rise illustrates unions adjacent to the rivers as such Dema, Gota Para and some part of Bemarta and Bisnupur union are mostly affected by SIDR equivalent cyclone under both SSP1-2.6 and SSP5-8.5. But in 2050s for SSP5-8.5 scenario inundation extent and impact will be higher in Dema and Gota Para Union.

It is observed that a severe cyclone strikes the country on average in every three years. 21 tropical cyclones (wind speed >117 km/hr) and severe cyclones (wind speed between 87 to 117 km/hr) struck the Bangladesh coast between 1960 and 2010 (MoEFCC, 2018). According to CEGIS analysis (1960-2020), the number of different cyclones types hitting Bangladesh has decreased over this period – from 24 in the 1960s to 13 in 2020s. Additionally, the formation of deep depressions and occurrence of super cyclones (> 222 km/hr) increased in the period 1990-2020 by 6% compared to the previous 30 years.

The cyclones have had huge negative impacts on fisheries-based livelihood. Cyclone Sidr resulted in damages and losses of \$1.7 billion, or 2.6 percent of GDP in 2007. About half the losses were in the housing sector, followed by agriculture and infrastructure. Infrastructures including ponds, dighis, and gheras as well as privately owned fishing gear like boats and nets are among the damages to the fishery subsector. 12,407 fish farms worth over 790 lakhs BDT and 8,890 ha shrimp cultivation land worth over 5,287 lakhs BDT were damaged in Bagerhat Sadar Upazila due to this severe cyclone.

On May 25, 2009, Aila struck Bangladesh's southwest coastal regions, affecting 15 districts, 76 Upazilas, and 491 Unions. The 13-hour onslaught of Aila which was followed by eight to 10 feet high tidal surges destroyed 18,788 shrimp enclosures worth over 150 crore BDT and over 8000 fish farms worth over Tk 70 crore taka in Bagerhat district. The super Cyclone Amphan in 2020 affected more than a million people in nine districts in Khulna and Barishal divisions of Bangladesh. Many freshwater ponds inside and 4633 fish farms in Bagerhat District were totally flooded with seawater due to this cyclone. According to DFO of Bagerhat, the total damages to fisheries sector was BDT 2.92 crore in Bagerhat district. The frequency and impacts of such extreme events are reported to be increased under climate change scenarios. The **Figure 3.5** below highlights the changes in occurrence of cyclone between the period 1960- 1989 and 1990 - 2020. The notable changes include increase of deep depression, decrease of super cyclonic storm, occurrence of super cyclonic storm (> 222 km/hr) etc.

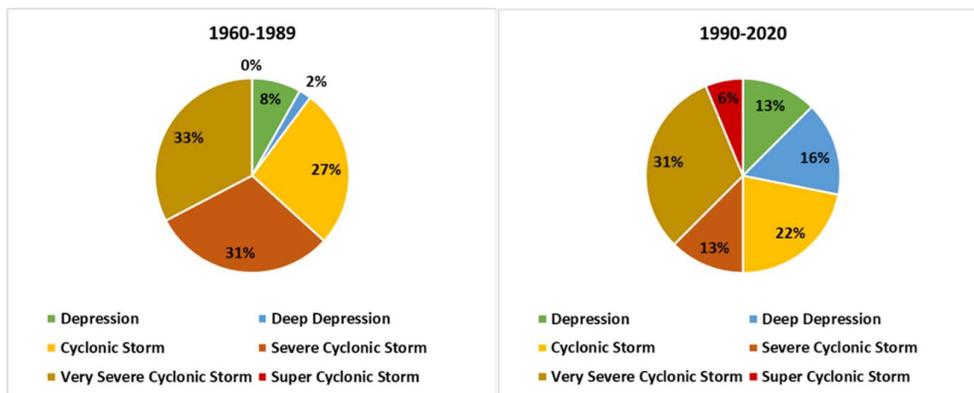


Figure 3.5: Distribution of high intensity cyclone along the Bangladesh coastline

Sea level rise and salinity

Trends analysis based on Sen’s slope of 30 years BWDB, CPA and BIWTA tidal water level reveals the upward trend in the south west Ganges tidal floodplain, which was 7-8 mm/year (DoE, 2016). On the other

hand, the trend was 6-10 mm/year in the Meghna Estuarine flood plain and 11-21 mm/year in the Chittagong coastal plain areas (DoE, 2016). This shows that Bagerhat which is situated in the south west Ganges tidal floodplain experiences higher sea level rise and salinity than the rest of the regions.

Bangladesh Delta Plan 2100 (GED, 2018) indicated that SLR is likely to cause significant changes in river salinity in the coastal zone of Bangladesh during the dry season (October to May) by 2050, which will likely to lead significant shortages of drinking water in the coastal urban areas, scarcity of water for irrigational agriculture during dry season and significant changes in the coastal aquatic ecosystems. Simulation by CEGIS Bay of Bengal Model (2020) reveals that Bagerhat Sadar Upazila will be intruded by more than 4ppt surface water salinity by 2050s under extreme climate change scenario i.e. SSP5-8.5. As presented in the **Figure 3.6** below, 3 out of 10 unions of Bagerhat Sadar Upazila are experiencing surface water salinity near 4ppt and rest of the union are below 4ppt. By 2050 in all the union of Bagerhat Sadar Upazila, 4ppt isohaline line will shift on average by 17.5 km inward, which will break homeostasis and lead to significant stress, slow growth, low survival rate, and thus, incur high economic loss in shrimp farming industry. **Figure 3.6** illustrates salinity intrusion in Bagerhat Sadar Upazila for base period 2011 and future (2050) under SSP 5-8.5.

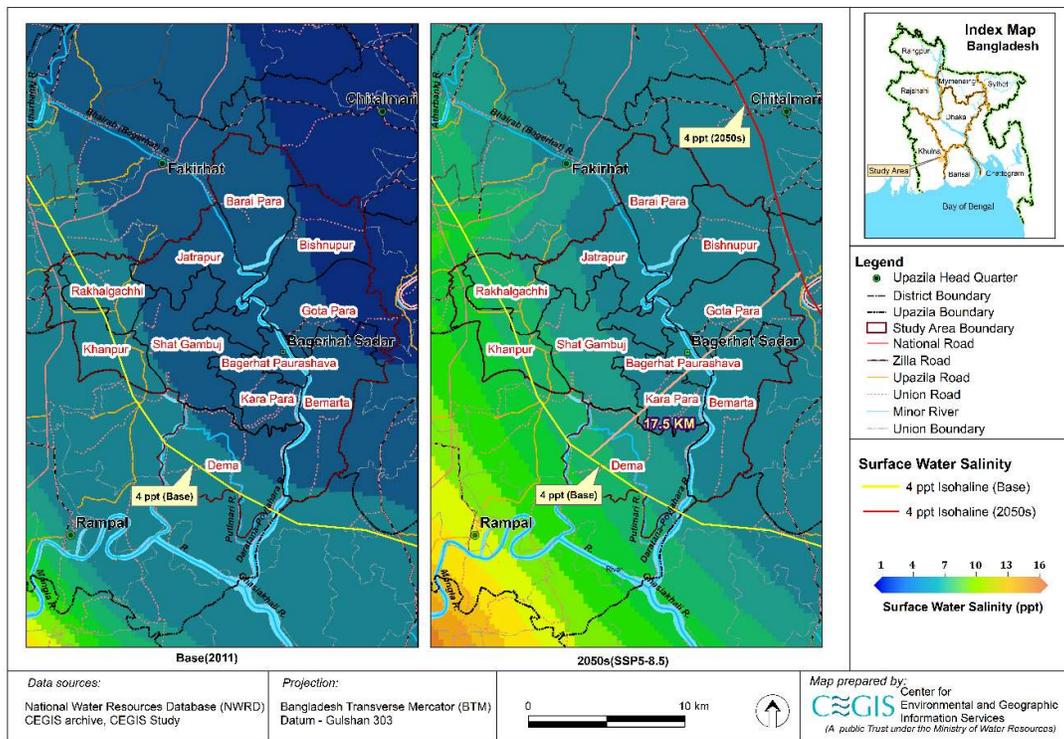


Figure 3.6: Salinity intrusion in Bagerhat Sadar Upazila

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 drop, 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, shrimp farmers in Bagerhat Sadar Upazila are facing numerous challenges, most importantly various viral, bacterial and fungal diseases (Islam et al. 2018)

Floods

Almost every year, many shrimp farms in Bagerhat Sadar Upazila get flooded. River bank erosion, mainly due to floods, is causing river siltation in Dharatana, Panguchi and Modhumuti River in Bagerhat Sadar

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. But as floods inundate more areas in the floodplain, there may be some beneficial effects for open water fisheries/flood plain fisheries, as fish get more grazing area, nutrients and sometimes, a longer time to grow.

Drought

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

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 lightning susceptibility of SW zone is comparatively less than another zone 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.

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: Hazard-wise impact matrix based on community perception

Sector	Impact	Flood	Drought	Cyclone	Storm Surge	Extreme Hot Temperature	Severe Cold Days	Salinity Intrusion	Lightning
Bio physical	Salinity Increase	Yellow	Red	Yellow	Red	Red		Red	
	Area Inundated	Green		Yellow	Yellow				
	Low water availability		Yellow			Yellow			
Ecosystem	Extensive Algae Bloom (FW)	Green			Yellow	Yellow			
	Decreased flora & Fauna		Yellow		Green			Yellow	
	Stress on aquatic species abundance and distribution		Yellow	Yellow	Yellow	Green	Green	Yellow	
	Infrastructure damage	Yellow		Red	Red				Yellow

CEGIS Field Survey, 2022

3.4 Multi-hazard mapping for Bagerhat Sadar Upazila

A multi-hazard scenario for Bagerhat Sadar Upazila was assessed using field findings, community perceptions and available secondary data layer and is presented in **Figure 3.7**. Salinity intrusion, Flood, Cyclone, Storm Surge, Drought, Extreme Hot Days, Lightning 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 salinity intrusion, storm surge and temperature data are projected for 2050s and other hazards are considered constant as base period during multi-hazard mapping using geo-spatial techniques. Dema and Rakhalgachhi union of Bagerhat Sadar Upazila are exposed to multiple climate hazards, with the highest severity in the base period. In 2050s Khanpur and Bemarta union will be in high risk zone along with the high risk union at the base period. Shat Gambuj, Barai Para and Gota Para union are found to be in moderate risk in base period and will be

continued to be the same in 2050s. Rest of the unions i.e. Kara Para, Jatrapur and Bishnupur are found to be in low risk of multi hazards for both time slices. **Figure: 3.7** below highlight the multihazards outlook for 2050 based on 2011.

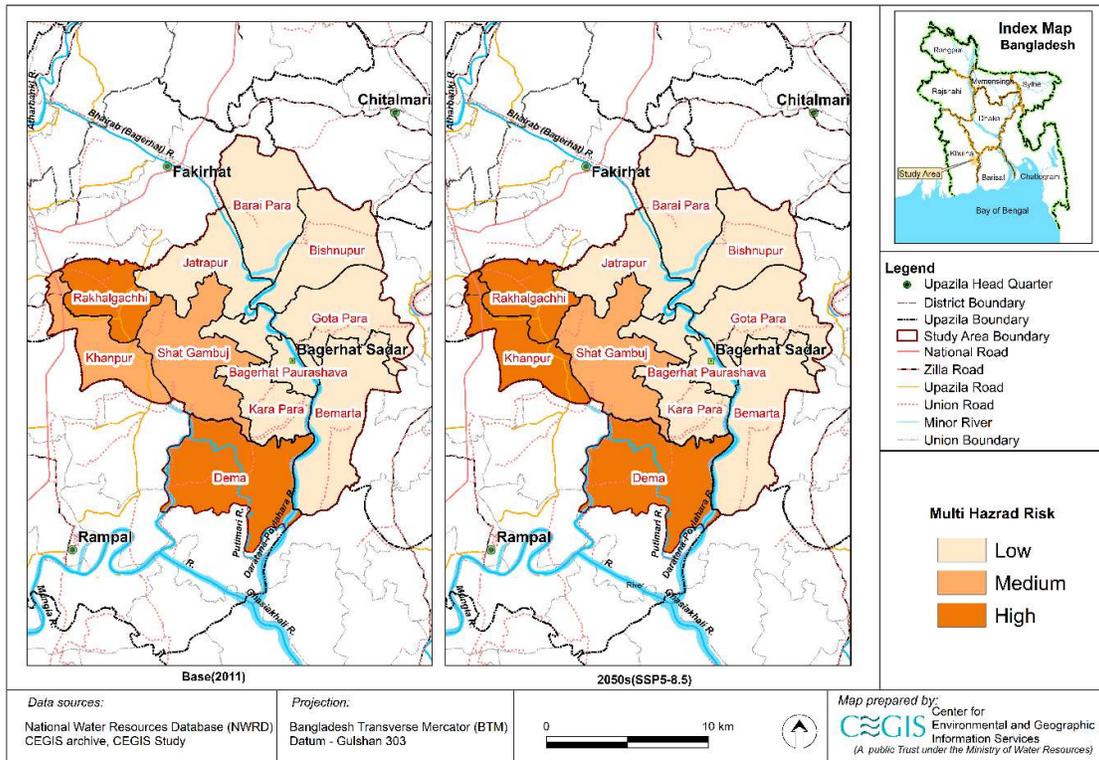


Figure 3.7: Multi hazard maps in Bagerhat Sadar Upazila

4 Climate Risk and Vulnerability

This chapter presents critical outcomes of the study, which is climate risk and vulnerability for the Bagerhat Sadar Upazila covering all of its unions. Risk and vulnerability were assessed following an 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. The following sections describe the key elements of risk and vulnerability separately for these four priority focus areas: exposure, sensitivity, adaptive capacity, vulnerability and risk. Risk and vulnerability assessment is done based on a 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 tropical cyclones and associated storm surges, and other climate change induced hazards cause severe devastation to the aquatic ecosystems in this region. Indicator based assessment for the developed impact chains was also used to assess the ecosystem exposure to climate change induced hazards in Bagerhat Sadar (Annex I). The exposure of hazards to aquatic ecosystem in Barai Para, Bemarta, Bisnupur, Gota Para, Jatrapur, Karapara, Khanpur, Rakhalgachhi and Shat Gambuj are identified as high and Dema union and Bagerhat Paurashava they were identified as medium and low respectively (**Table 4.2**).

4.1.2 Climate sensitivity of aquatic ecosystem

The rich and diversified aquatic ecosystem of the study area are found sensitive to climate change in various ways. Climate change and its extreme variability make the habitat condition unfavorable and severely disrupt the ecosystem services. The study analysed the ecosystem climate sensitivity (change in habitat area, disruption of services and aquatic environmental conditions) of both River and Pond/gher ecosystem in terms of disruption of ecosystem services and hampered habitat condition.

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. Bagerhat Sadar Upazila shows considerably higher extent of surface water loss. The permanent water body in Bagehat are found to be decreasing from 1990 to 2020. A total 5.4% area of permanent waterbody extent has been found decreased in Bagerhat from 1990 to 2020. The reason behind this may be illegal encroachments and increase in urbanization leading to rise in human settlements that eventually resulted in the filling up of the permanent waterbodies. This would have a negative impact on the fisheries sector because of the disturbance caused to the habitats and fish breeding grounds and other aquatic animals. The seasonal waterbodies increased during 1995 to 2005 then it started decreasing slightly. Increasing trends of seasonal waterbodies 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 revealed that increased saline or brackish water habitat and decreased freshwater habitat—and therefore, adaptation in fish farming practices need to be planned accordingly.

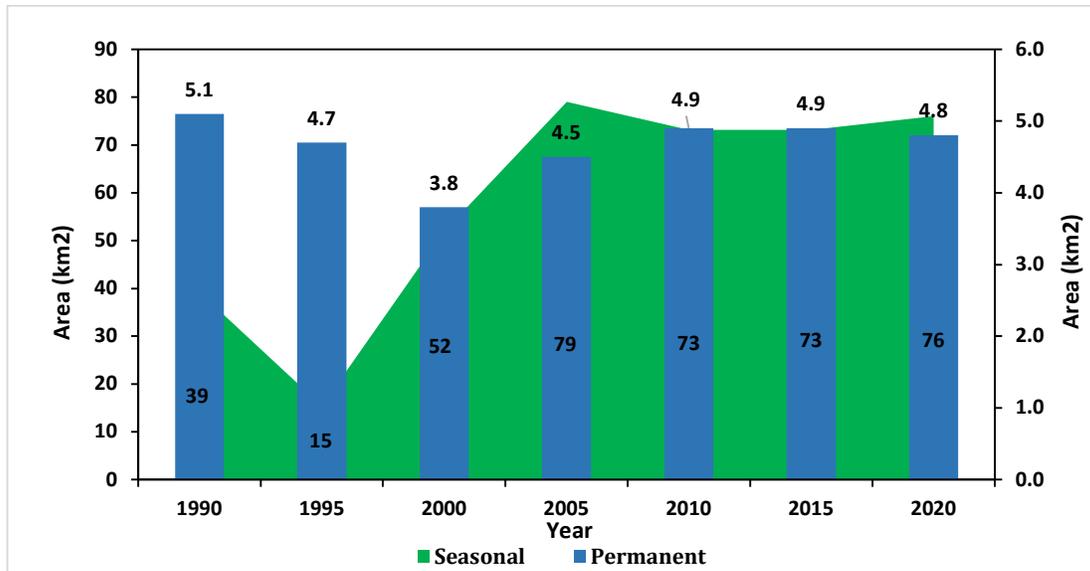


Figure 4.1: Waterbody changes in Bagerhat Sadar Upazila

Disruptions 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 a large amount of fish, fuelwood, and medicinal plants and plant parts along with grass from the river and pond ecosystems. Harvested rainwater in the pond after purification and boiling is generally used as main the drinking water source. Pond water is also used for domestic and household purposes. When the water remains sweet for six months in the monsoon period community people can use river water for consumptive and non-consumptive uses

Aquatic ecosystem is diversified with fresh, brackish and saline water species which facilitate carbon sequestration, heat absorption, nutrient cycling, sediment retention, groundwater replenishment, and most importantly act as storm surge barriers against extreme cyclone and storm surges. The study area receives an abundant amount of rainfall every year. A number of saline tolerant aquatic/ mangrove vegetation's observed on the torus and along the riverside toe of the Embankment Rivers because of tidal nature and saline intrusion. A higher proportion of the rainfall is infiltrated as ground water, which supports flow of water in the streams, irrigation in the agricultural fields, use of water by local people, Ponds accumulate organic matter in their sediments and therefore bury or sequester carbon. About 16.6 million Mt of carbon is buried annually in aquaculture ponds globally. The plants surrounded by rivers, 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 provisioning, regulating and supporting services as described above, local communities reported that aquatic ecosystem in Bagerhat Sadar also provides opportunities for cultural services such as revenue earning from eco-tourism. Being surrounded by different rivers, many tourist's attraction place developed beside the river in this Upazila which attracts tourists all year round to observe the scenic beauty, serenity, unique and diversified animals, tranquility and for their relaxation.

All the 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 the river has more weakness and threats due to rapid urbanization and environmental pollution—with a score of 0-15 representing low value, 16-30 representing medium value, and 31-45 representing high value. The results also show that both the river and pond ecosystem are in good condition and have balanced strength and opportunities, because their buffer areas are characterized by natural land-cover types and optimum water qualities.

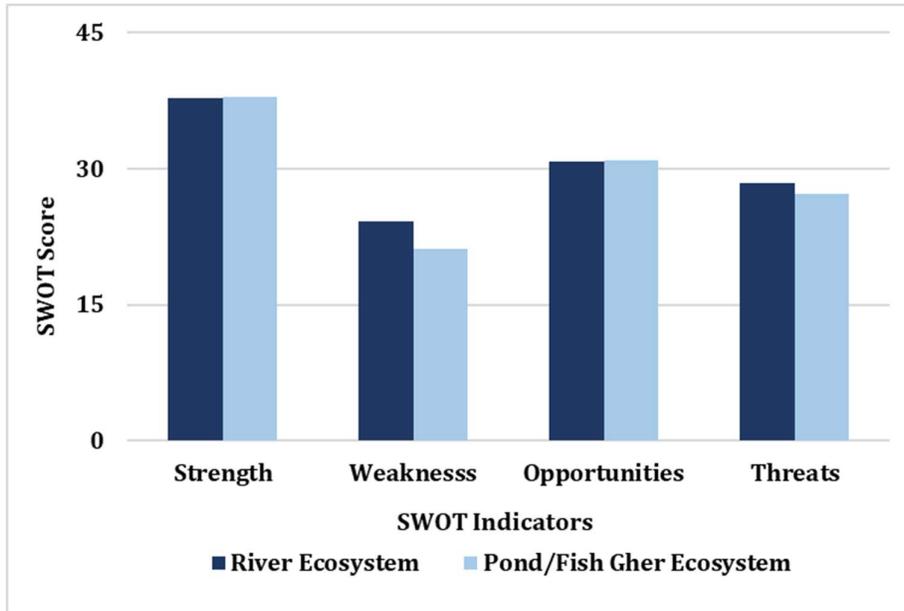
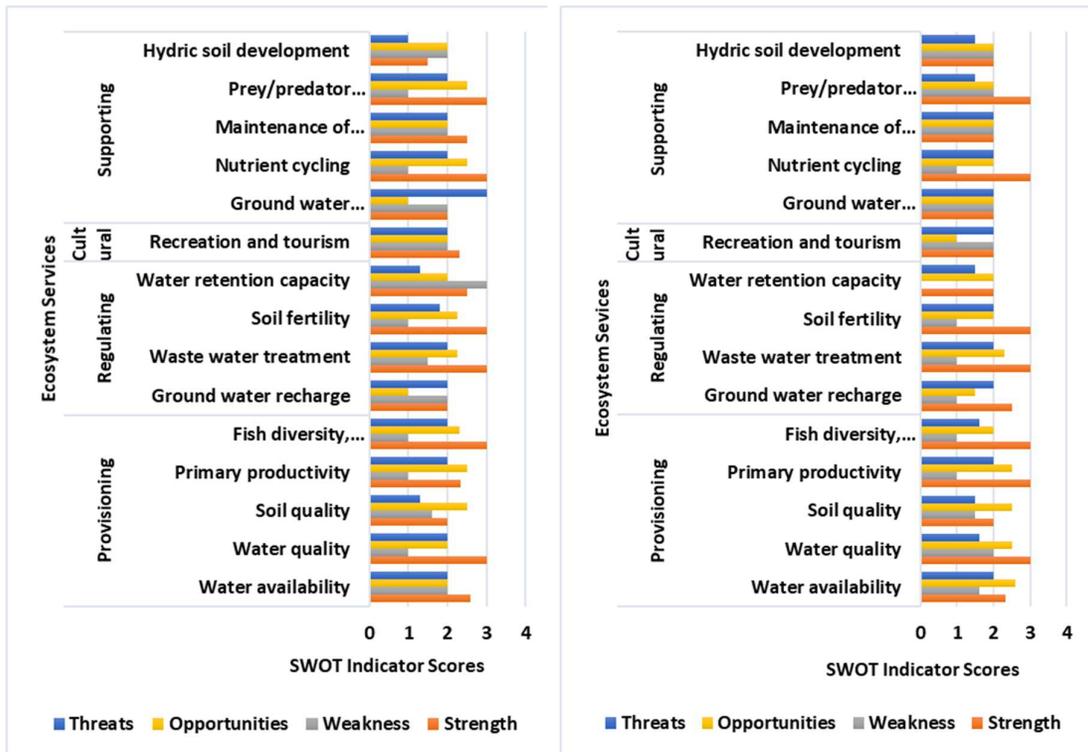


Figure 4.2: SWOT results of aquatic ecosystem services

To enhance the ecosystem services from rivers, haors, and ponds ecosystem, identified weaknesses and threats will need to be address to increase the related benefits sustainably. Therefore, ecosystem approaches for aquaculture (EAA) or fisheries (EAF) follow to sustainably manage the fishery ecosystem and its climate sensitivity Integration of fishery ecosystem during structural or non-structural intervention design for adaptation and the resilient building is needed to be mainstream widely to harness the desired level of the ecosystem services combating negative impacts exerted by climate and non-climatic factors.

The graph below (**Figure 4.3-a & b**) shows the aggregated score of the ecosystem services' strengths, weaknesses, opportunities, and threats indicators under four the categories for the river, pond, and Haor. All the indicators were ranked as per their scores obtained from field visits (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 Pond/gher

Figure 4.3: SWOT outcome for river and ponds/gher ecosystem

Aquatic habitat condition

Similar to ecosystem services disruption by climate change, in situ and laboratory tests of water quality also indicated ecosystem sensitivity to deteriorating due to climate change. pH, water temperature, DO, BOD, COD and Nitrate were found suitable and within the thresholds reference value but electrical conductivity (EC), and turbidity (TDS) were found exceeding the thresholds reference value of ECR'97 and different studies (marked in red color as shown in **Table 4.1**).

EC values of river, fish gher and pond samples were 11900µS/cm, 12810 µS/cm and 1060 µS/cm respectively (**Table 4.1**). The desirable range of EC is 100 to 2,000 µS cm-1 and acceptable range is 30-5,000 µS cm-1 for fish culture (Stone and Thomforde 2004). Therefore, the present values of EC are not suitable for fish culture. Standard level of TDS for fisheries is about 165 mg L⁻¹ and suitable range is 160 to 200 mg L⁻¹ for growth and production (Huq and Alam, 2005; Rahman et al., 2015). So, from the study it has been seen that TDS values of the present study are not suitable for aquaculture.

Communities during surveys reported occurrence of frequent algal blooms due to increased water temperature and fish mortalities specialty during summer. In addition, rising trend of salinity level, especially during the pre-monsoon and winter seasons was mentioned by respondents, and usually results into disappearance of some local aquatic species. Apart from climatic factors, farmers reported water quality deterioration for overuse of pond and decreased water levels due to drought reducing habitat and production of fish. Beds of the rivers and nearby canals have been silted up that reduced water carrying capacity of rivers. Excessive sediment loads are deposited in the rivers and their tributaries that cause floods during monsoon. These water quality condition will be exacerbated under climate change condition.

Table 4.1: Surface water quality at Bagerhat Sadar

Sample ID & Unit	Physical and aggregate properties of surface water resource								
	pH	Temp	DO	EC	TDS	BOD	COD	Nitrate (NO ₃ ⁻)	Salinity
	-	°C	mg/l	µS/cm	mg/l	mg/l	mg/l	ppm	ppt
River	8.3	31.2	6	11900	5900	2.32	151.72	2.9258	10.16
Fish Gher	8.7	30.3	5.9	12810	6400	2.6	122.82	2.2947	11.14
Pond	8.2	30.6	5.8	1060	520	2.9	54.18	11.378	0.7
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		10	
Study reference value	(6.5-9) ²	(25-32°C) ³	(6-7) ⁴	(30-5000 µs/cm) ⁵	(<160-200 mg/l) ⁶	(<5 mg/l) ⁷	(<200 mg/l) ⁸		

*Green colors indicate standard reference value of water quality parameters as per ECR'97 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, found that Barai Para, Shat Gambuj union and Bagerhat Paurashava are highly sensitive ecosystems whereas Bemarta, Jatrapur, Karapara and Rakhalgachhi union were found to be moderately sensitive ecosystem.

4.1.3 Adaptive capacity of aquatic ecosystems

Rapid restoration and regeneration of plankton and vegetation; abundance of flora and animals; soil health; decomposition of plant materials and co-management biodiversity; 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 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. On the other hand, Pond ecosystems also have some inherent

² <https://www.fisheriesjournal.com/archives/2020/vol8issue1/PartD/8-1-33-780.pdf>

³ Das, 1997. Das, B. 1997. Fisheries and Fisheries Resources Management. Bangla Academy, Dhaka, Bangladesh, 153-155p

⁴ 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

⁵ 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.

⁶ 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

⁷ Das, 1997. Das, B. 1997. Fisheries and Fisheries Resources Management. Bangla Academy, Dhaka, Bangladesh, 153-155p

⁸ 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.

ability to change, and cope with climate hazards. Apart from the systems 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 but due to salinity, they grow less and do not survive. 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. 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 (ZnSO₄). Lime CaO, Ca(OH)₂ and CaCO₃ to improve pond 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 Bagerhat Pauroshava have high adaptive capacity in compared to other areas in Bagerhat Sadar Upazila. Barai Para, Bemarta, Bisnupur, Gota Para, Jatra Para, Khanpur, Rakhalgachhi and Shat Gambuj union are found to be moderate in terms of adaptive capacity of aquatic ecosystem. 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 analyzing adaptive capacity and sensitivity of the system. From the assessment (**Table 4.2**) it was found that Barai Para union and Shat Gambuj union are 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, Bemarta, Jatrapur and Rakhalgachhi union are found moderately vulnerable and other unions ecosystem are found low vulnerable to climate change induced hazards.

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

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Barai Para	High	High	Medium	High
Bemarta	High	Medium	Medium	Medium
Bishnupur	High	Low	Medium	Low
Dema	Medium	Low	Low	Low
Gota Para	High	Low	Medium	Low
Jatrapur	High	Medium	Medium	Medium
Kara Para	High	Medium	Low	Low
Khanpur	High	Low	Medium	Low
Rakhalgachhi	High	Medium	Medium	Medium
Shat Gambuj	High	High	Medium	High
Bagerhat Paurashava	Low	High	High	Low

4.1.5 Risk of aquatic ecosystem

Climate change risk (**Figure 4.4**) on ecosystem in Bagehat Sadar Upazila has been calculated for both base period and 2050s following the CRVA framework (attached in Annex I). The unions Rakhalgachi and Dema are highly exposed and Shat Gambuj union is moderately exposed to multi-hazard risk in both present and future time periods. Khanpur becomes highly exposed to multi hazard in the future as opposed to the moderate hazard level of the present. This affects aquatic ecosystem negatively throughout the year in these unions. The seasonal waterbody in the Upazila has been found significantly increasing and the permanent ones slightly decreasing in last decades. The increase in waterbody extent may be due to shrimp farming, SLR and inundation due to flood and cyclone. These waterbodies are abundant with saline water which can be a threat to the fresh water aquatic ecosystem at the same time these waterbodies can potentially improve the brackish water ecosystem. Apart from the saline water, each year tropical cyclones destroy or heavily damage the ecosystem. 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 of aquatic ecosystem considering extreme climate change scenarios, Shat Gambuj, Rakhalgachhi and Barai Para unions are at high risk in both time slices. Jatrapur and Bemarta union are at medium risk in both periods. Rest of the unions are found under low risk in both time slices.

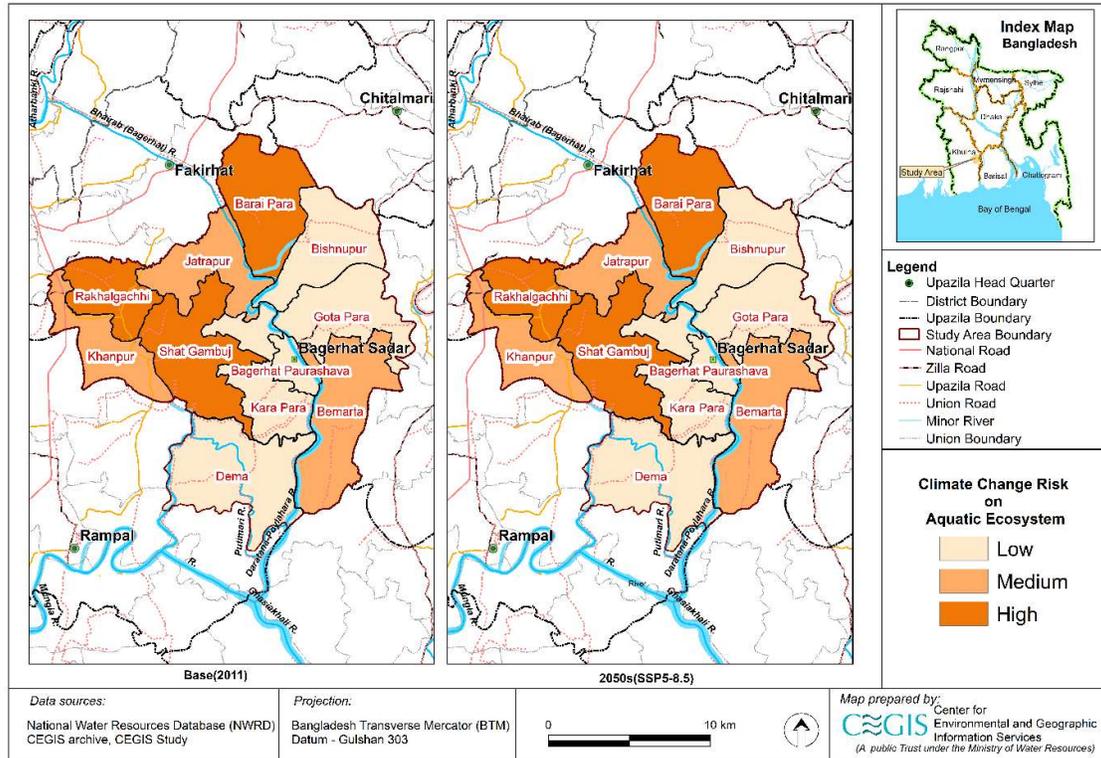


Figure 4.4: Climate risk of aquatic ecosystem in Bagerhat Sadar Upazila

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 of the exposure indicators of this ecosystem.

Fish habitat area

The riverine ecosystem is around 751 ha in Bagerhat Sadar Upazila. There is only one river passing through this upazila namely Doatana. The maximum area of the riverine ecosystem was found in the Bemarta Union, whereas the minimum area was in the Rakhalgachi Union (Table 4.3).

Table 4.3: Area of riverine habitat in different unions of Bagerhat Sadar Upazila

Unions	Riverine habitat area (ha)
Bagerhat Paurashava	46
Barai para	60
Bemarta	45
Bishnupur	207
Dema	61
Gota para	165
Jatrapur	44

Kara para	40
Khanpur	65
Rakhalgachhi	13
Shat Gambuj	3
Total Area	749

Satellite image 2019 and CEGIS Field Survey (KII with Upazila Fisheries Office), 2022

Fish diversity

The riverine ecosystem under the Bagerhat Sadar Upazila is characterized by the Low Salinity Zone (LSZ), having less than 10ppt mean salinity, which can support stenohaline fish species (short range salinity tolerance). 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 Bagerhat Sadar Upazila (shown in **Figure 4.5-A**). The present study found that the instantaneous catch is very high dominated by Chela and Chame Chingri (**Figure 4.5-A**). The colors in the following figure denote the composition of fish species. Very high dominance indicates composition of 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 indicate less than 30% of species in the composition.

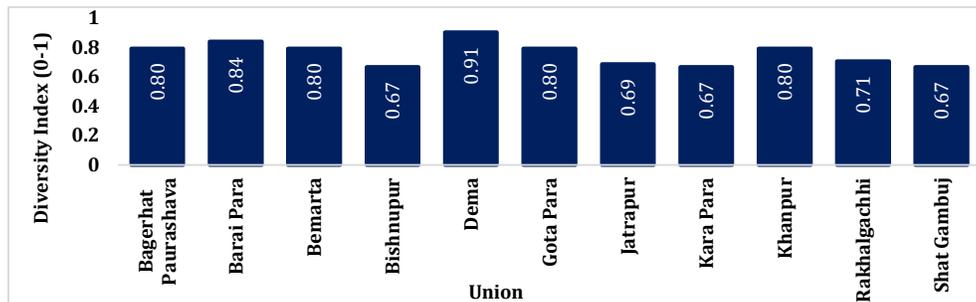
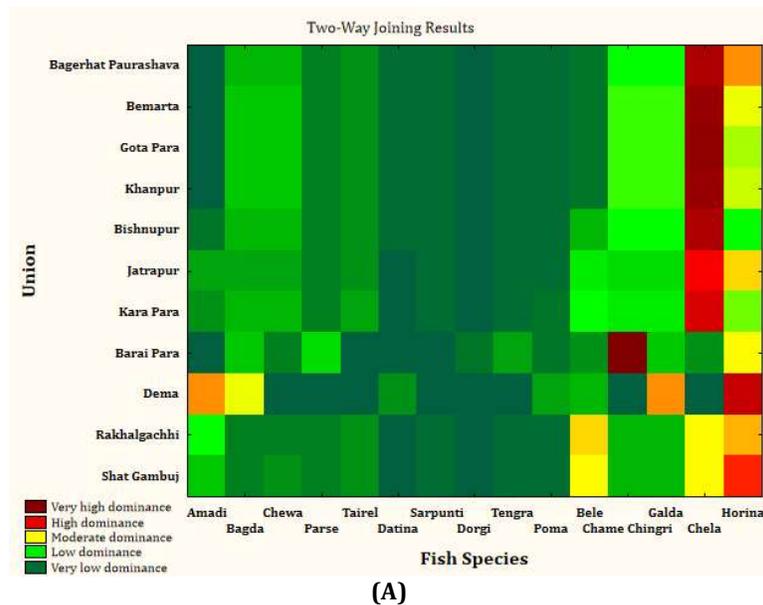


Figure 4.5: Species composition (A) and Biodiversity index (B) of the instantaneous catch of different unions of the Bagerhat Sadar Upazila

CEGIS Catch Assessment Survey, 2022

This study also analyzed 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 from 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. The analysis by this study show that all species are more or less evenly distributed within the riverine ecosystem of Bagerhat Sadar Upazila.

Livelihoods

According to Upazila records, the total number of registered fishermen in the region is 2,144. The study found that most of capture fishermen catches fish from open water bodies (i.e. sea, river, canal etc.) and on average fisher households earned between BDT. 10,000-13,0000 monthly. The field findings also reveal that most women were involve in household related activities with only 2.9% women involved in fry collection and culture fishing. However, women's income from capture fish is very low as they mostly catch fish for family consumption and usually sell only after surplus. Fishermen have reported that less fish is being caught than in last years. The reasons behind catches and disruption of income from fish is attributed to decreasing of navigability of water, lack of rainfall, raising salinity and temperature, water contamination etc.

Indicators for abundance of species in open waterbodies, migratory route, and number of endangered species etc. were considered for exposure assessment. Exposure assessment results (**Table 4.7**) found that Barai Para, Bemarta, Gota Para, Kara Para, Rakhalgachhi union are highly exposed to climate change induced hazards, may be due to high presence of river ecosystem within these. Dema, Jatrapur, Khanpur and Shat Gambuj union are moderately exposed. Rest of the unions have comparatively lower exposure for capture fisheries.

4.2.2 Sensitivity

Habitat under threshold

According to the SWOT analysis on the provisioning services of the riverine ecosystem, a strong water availability condition was observed in the study area. This was achieved by ensuring the availability of optimum water in dry season and water retention time by the surrounding hydrological system and low sandy bed materials. It was observed that days of high temperature, high evaporation rate and no rainfall create a stress environment because of oxygen depletion, lowering water depth of connecting khals due to increased water loss and siltation. The present study calculated the sensitivity scores ranging from 0 (low sensitive-deep green) 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 sensitive 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.

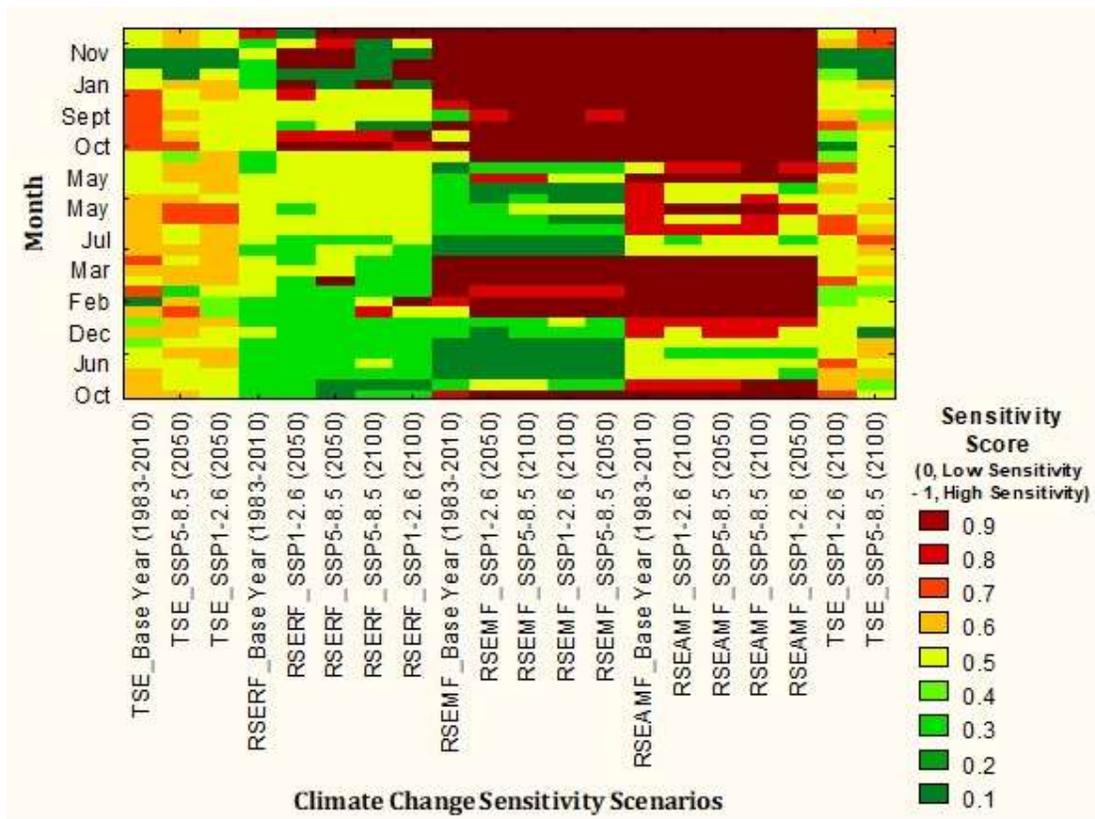


Figure 4.6: Habitat sensitivity to climate change scenarios

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

Fish breeding/Spawning

Most species use the river as breeding and spawning ground. The breeding and spawning ground of Bagda and Galda is estuary. Breeding season of Chela and Sarpunti is from late June to early September and spawning season is from July to August. Breeding and spawning season of both Galda and Bagda is in the month of January and, another during February-April. Aire start breeds in the month of June and continue up to September and, spawns in from July to August. Bele has two breeding and spawning seasons (**Table 4.4**).

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

Species	Locality	Breeding season	Spawning Season
Sarputi	River	Late June to early September	July and 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	Pond	June-September	July and August
Bagda	Estuary (Sundarbans)	January	February- April
Galda	Estuary (Sundarbans)	January	February- April
Aire	River	June-September	July and August
Datina	River	December-April	Jan-March

Literature review and CEGIS Field Survey, 2022

It is found from various studies that maximum fluctuations from the optimum ranges might result in lowering chances for fertilization success, and thus in reducing breeding and spawning success. The present study predicted that the magnitude of breeding/spawning success in case of Galda, Sarpunti, Bata and other available inland fishes might be significantly increased in 2036-2065 average year, but decreased in 2070-2100 average year under both SSP1-2.6 and SSP5-8.5 scenarios (**Figure 4.7**). There would be no significant change in breeding magnitude in case of Bagda, Boal and Hilsa Shad.

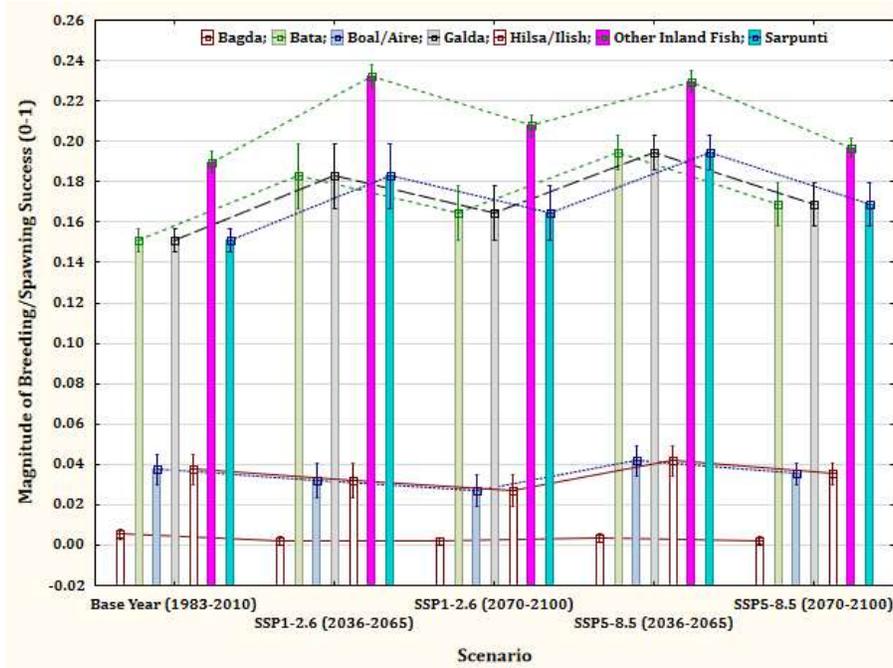


Figure 4.7: Magnitude of Breeding/Spawning success of the available fish species

Fish migration

The rivers in the unions of the Bagerhat Sadar Upazila provide necessary ecological demand for feeding, breeding/spawning and nursing of fries and juvenile fishes of different migratory fish species. The river residence fishes migrate longitudinally to the upstream or laterally to the Khals for spawning, feeding or escaping from predators. According to the local fishermen and Upazila Fisheries Officials, major longitudinal migratory fishes in the rivers are Pangas (*Pangasius pangasius*), Vetki (*Lates calcarifer*), Ramchos (*Polynemus paradiseus*), Poma (*Otolithoides pama*), Tular Dandi (*Sillaginopsis panijus*) and Tirel (*Eleutheronema tetradactylum*). The lateral migration occurs mostly for small fishes like Tengra (*Mystus bleekeri*), Guli (*Mystus gulio*), Parse (*Liza Persia*), and small shrimp/prawn are mostly limited between river and Khal.

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**). The values ranging from 0 to 1 are divided into five (05) fractile 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). The catch assessment survey found that Bagda has the very high migration extent among other observed fish species (**Figure 4.8**). It has predicted that the migration rate for Hilsa, Aire, Bata, Sarpunti and Galda would be increased in SSP5-8.5 (2036-2065) scenario. On the other hand, migration rate of Bagda would not be changed with the future climate change scenarios.

Fish migration may be affected by various climatic factors such as, salinity ingression, erratic rainfall, changes of flooding seasonality, temperature fluctuation, etc. Salinity ingression may pose threats to freshwater fish assemblages and their habitats. The migration length may be decreased in the riverine ecosystem due to salinity ingression 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.

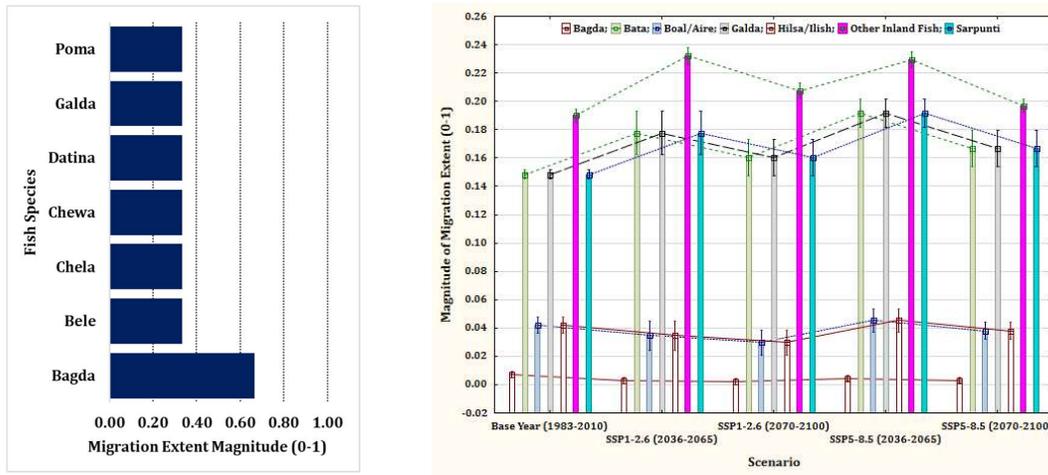


Figure 4.8: Migration extent of different migratory fish species

CEGIS Field Survey, 2022

Growth coefficient and natural mortality

Amadi has a higher growth coefficient (>3), whereas the majority of fish species have a lower growth coefficient (0.5) (Figure 4.10). 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 Chewa have the highest mortality rates, losing more than three generation cohorts per year, while other fish species were reported to lose two generation cohorts annually (Figure 4.9).

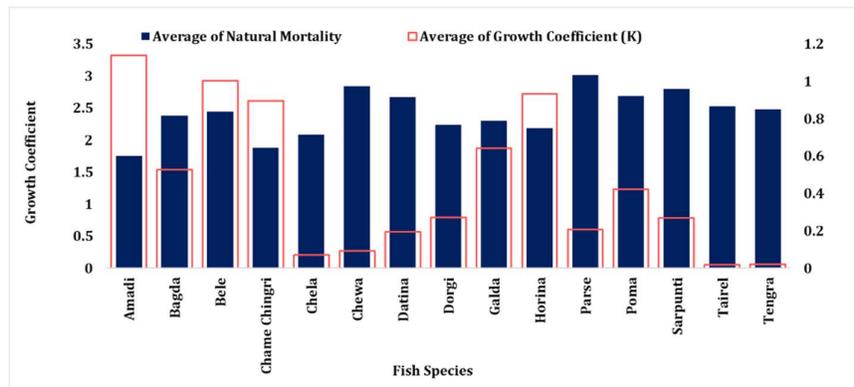


Figure 4.9: Growth coefficient and natural mortality of the available fish species in the instantaneous catch

CEGIS Catch Assessment Survey, 2022; Fish Base Life-History Data

The Study found that under the SSP1-2.6 scenario, growth performance magnitude may slightly increase for Bata, Boal, Galda and other readily accessible inland fishes (**Figure 4.10**). Future possibilities for Bagda 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 (**Table 4.5**). 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.

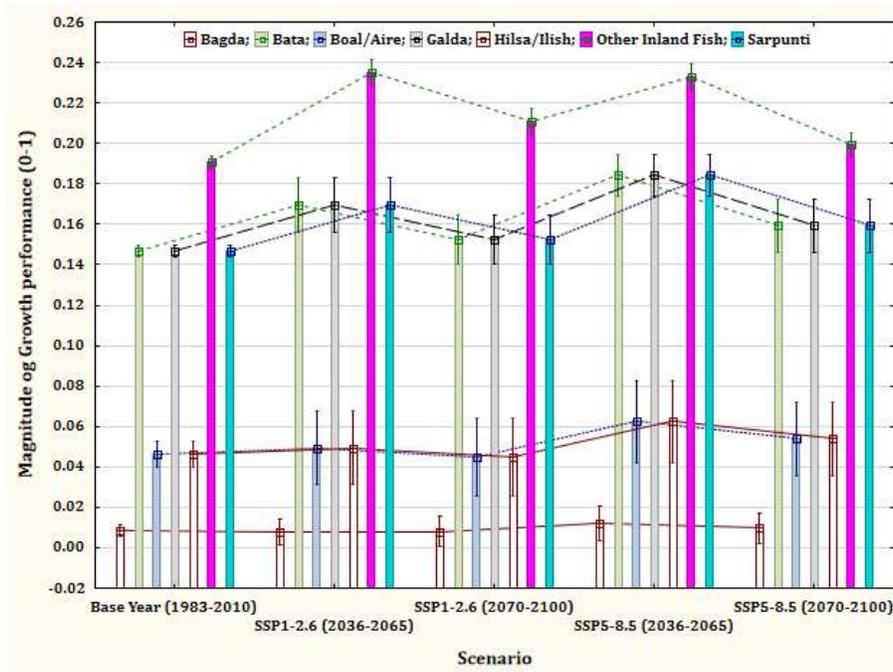


Figure 4.10: Magnitude of growth performance of the available fish species

Impact Chain Analysis, CEGIS (2022)

Fish production

With the changes mentioned above in habitat condition, fish diversity, fish migration and fish biology in respect of different climate change scenarios, riverine fish production in different unions of the Bagerhat Sadar Upazila would be about 291 MT, 294 MT, 303 MT and 303 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)
Bagerhat Paurashava	23	23	23	24	24
Barai Para	17	18	18	18	18
Bemarta	80	80	81	84	84
Bishnupur	24	24	24	25	25
Dema	64	64	65	67	67
Gota Para	17	17	17	18	18
Jatrapur	15	16	16	16	16
Kara Para	25	25	26	26	26
Khanpur	5	5	5	5	5
Rakhalgachhi	1	1	1	1	1
Shat Gambuj	18	18	18	19	19
Total =	289	291	294	303	303

Impact Chain Analysis, CEGIS (2022)

Livelihoods

Due to climate change, the sensitivity of fisheries based livelihoods is determined by their dependency on fishing resources in terms of the unavailability of alternative livelihoods, lack of financial capital, lack of institutional support for the diversification of income sources, and lack of human capital to engage in AIGAs. Seasonal variability, post-harvesting loss, and low income of fishermen made them highly sensitive to climatic shocks. Bagerhat Sadar field finding indicates that fish farmers also relied upon alternative sources to balance their financial demands, including shop keeping, small business, labor, part-time jobs, auto-rickshaw driving, carpenter, etc. Additionally, they receive alternative income training from various government and private institutions. Besides, many take loans from various NGOs and banks to improve on their livelihoods.

As a part of the risk assessment, sensitivity of fisheries sector in Bagerhat Sadar upazila was also assessed (**Table: 4.7**). According to the assessment, Barai Para and Bemarta unions are highly sensitive to climate change induced hazard. The rest of unions were found to have a low sensitivity to climate induced hazards. Generally, cyclone intensity increases from April to May and September to November. Because of these extreme climatic events, fishing seasons reduce 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 cyclones and flooding. This climate sensitivity poses 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 been limited capacity to adapt with the mentioned climatic events as most of the fishers are poor and having narrow scope of coping with the hazardous situation. However, 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 Bagerhat Sadar Upazila is shown in **Figure 4.11**.

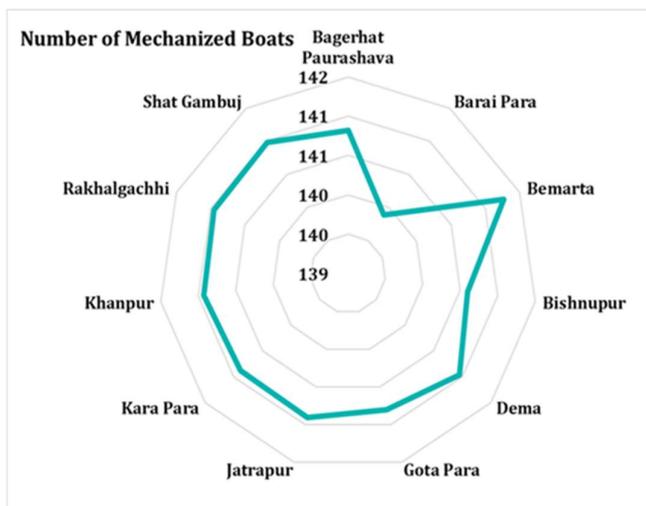


Figure 4.11: Availability of mechanized boats

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 the 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 4.6**.

Table 4.6: 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.)
Behundi Jal	11	27	13	0.48	13	24	24	1
Vesal Jal	66	22	12	0.54	77	19	20	1.05

CEGIS Field Survey, 2022

Similar to exposure and sensitivity assessment, adaptive capacity was assessed for Bagerhat Upazila through indicator-based impact chain analysis. This assessment (**Table 4.7**) reveals that Bishnupur, Dema and Sat Gambuj union have high adaptive capacity for capture fisheries. Rest of the unions are in low adaptive capacity zone for Capture fisheries in this region.

4.2.4 Vulnerability

The study assessed vulnerability of Capture fisheries of Bagerhat Upazila 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 4.7**) Barai Para and Bemarta union were high vulnerable. These unions had high sensitivity and low to moderate adaptive capacity. Bishnupur and Dema union were in moderate vulnerability zone while rest of the unions were in low vulnerable zone.

Table 4.7: Summary of climate vulnerability assessment for capture fisheries in Bagerhat Sadar Upazila

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Barai Para	High	High	Low	High
Bemarta	High	High	Low	High
Bishnupur	Low	Low	High	Medium
Dema	Medium	Low	High	Medium
Gota Para	High	Low	Low	Low
Jatrapur	Medium	Low	Low	Low
Kara Para	High	Low	Low	Low
Khanpur	Medium	Low	Low	Low
Rakhalgachhi	High	Low	Low	Low
Shat Gambuj	Medium	Low	High	Low
Bagerhat Paurashava	Low	Low	Low	Low

4.2.5 Risk

The study also assessed the risk associated to capture fisheries for base and 2050s time period. The unions Rakhalgachi and Dema are highly exposed and Shat Gambuj union is moderately exposed to multi-hazard risk in both present and future time periods. Khanpur becomes highly exposed to multi hazard in the future as opposed to the moderate hazard level of the present. This affects capture fisheries activities negatively throughout the year in these unions. Rivers Bhairab and Daratana run through unions Dema, Kara Para, Bemarta, Gota Para, Bishnupur, Jatrapur, Barai Para and Bagerhat Pourashava which create capture fisheries opportunity in these unions but also leave them exposed to flood, erosion, sea level rise etc. Due to lack of proper early warning system, fishermen often get caught up in heavy rainfall and storm 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. Additionally, the unions adjacent to the rivers and the sea face salinity ingression which hampers the freshwater fisheries activities in Dema, Khanpur and Rakhalgachi unions at present and will continue to affect more unions when salinity intrudes further inwards. 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 the risk analysis of capture fisheries, Bemarta, Barai Para and Rakhalgachhi union were found in high risk in the base period and will be continued to be the same in 2050s. Besides this, Dema, Shat Gambuj, Gota Para and Kara Para union were in moderate risk in base period and will be continued to be the same in 2050s. Jatrapur, Bisnupur union were 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. **Figure 4.12** below shows the risk of capture fisheries in Bagerhat Sadar Upazila.

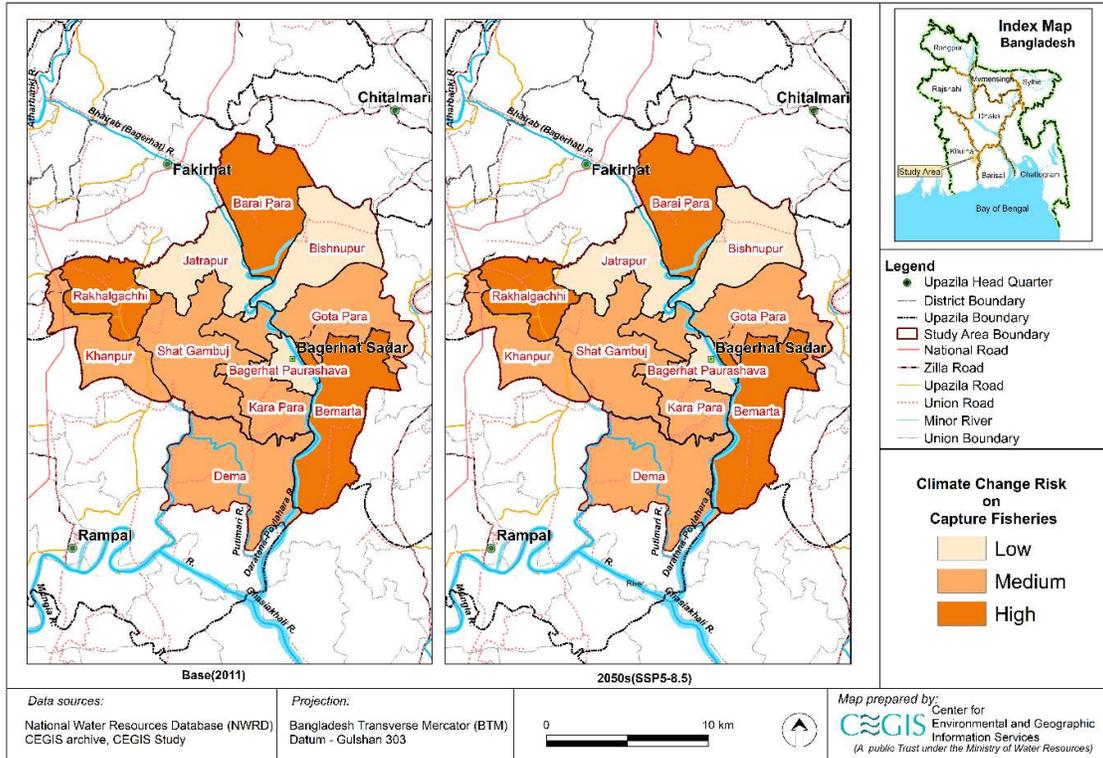


Figure 4.12: Climate risk of capture fisheries in Bagerhat Sadar Upazila

4.3 Culture fisheries

4.3.1 Exposure

About 14,322 ha is under aquaculture in the Bagerhat Upazilla. Aquaculture in the study area includes Shrimp/Prawn/Fish farm and Fish Pond. The habitat assessment of these aquaculture habitats and cultivable fish species are briefly described in respect of the exposure indicators in the following sections.

Habitat

In Bagerhat Sadar Upazila, there were about 14,322 ha of the shrimp/prawn/fish farm. Among the Shrimp/Prawn/Fish farm, some are the Bagda Gher where Bagda (*Peneus monodon*) along with other shrimp and fish are cultured all the year-round, and the Golda Gher where rice and white fish (major carp, tilapia, etc.) are cultured in mix way in the wet season. There is a few numbers of fish ponds covering an area of 28 ha comprising of semi-intensive, which are vary in size and the larger ponds retain water round the year at a level for which they are able to practice at least two cycles of fish culture by adopting semi-intensive culture method. Major carp, exotic carp and other fast-growing fish species are cultured in the ponds following poly-culture technology. **Figure 4.13** presents union wise fish habitat under Bagerhat Sadar Upazila.

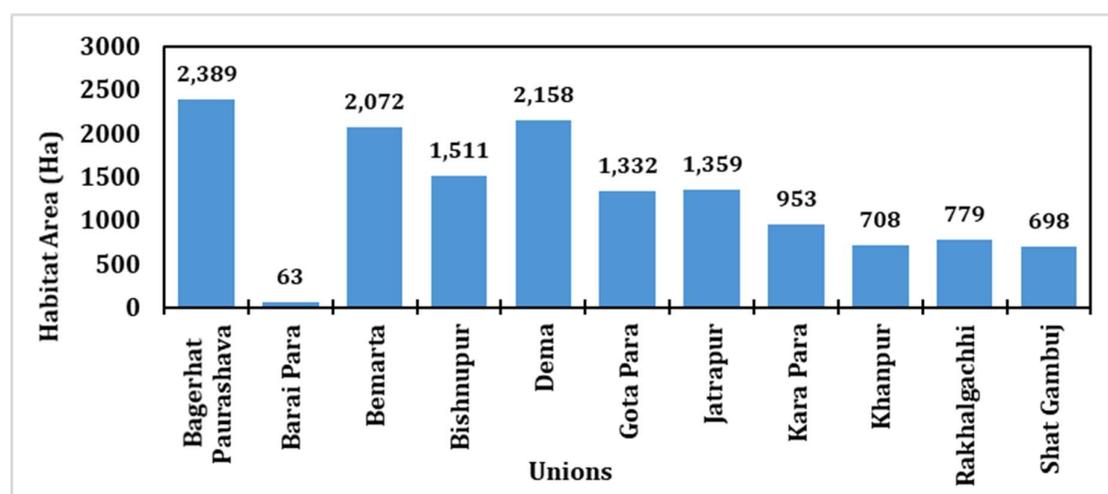


Figure 4.13: Spatial distribution of the fish pond and shrimp/prawn/fish farm in different unions of the Bagerhat Upazila

Satellite image 2019 and CEGIS Field Survey (KII with Upazila Fisheries Office), 2022

Cultured fish species

Rui, Bagda and sarpunti were found to be highly cultivable fish species in the Upazila (**Table 4.8**). The farm owners mainly cultivated finfishes in order to cope with the production loss from Bagda because of its high mortality rate due to temperature-driven viral infection.

Table 4.8: Composition of the cultured fish species in the shrimp/prawn/fish farms

Species name	Species composition (%)
Bagda	12.1
Catla	2.3
Chital	0.7
Galda	4.2
Grass Carp	1.0
Magur	0.5
Mirror Carp	3.9

Species name	Species composition (%)
Mrigal	5.5
Pangas	3.7
Rui	35.5
Sarpunti	10.5
Silver carp	1.2
Tengra	7.8
Tilapia	10.8
Vetki	0.3
Sub Total	100

CEGIS Field Survey, 2022

Livelihoods

Recently, the trend of shrimp farming has been gradually increasing in this region instead of rice farming. Because, shrimp farming is a much more demanding business than rice farming as it has more economic returns than rice in Bagerhat Sadar Upazila (Filed findings 2022). The average monthly income of Shrimp Farmer is about BDT. 14,000-20,000 (monthly). Women who are involved in fish culture, earns very low because most of them help their husbands and do not own ponds. Those actively involved in capture fisheries and own fish farms earn an average of BDT. 12000-15000 monthly. With favorable weather, this income can increase but it depends on how many ponds owned by shrimp farmers or Gher. Earlier it was seen that there was not much surplus after paying household needs from only paddy farming but now farmers are getting more profit from shrimp farming. Additionally, road communication became somehow developed and this is also increasing possibilities of higher income generation for shrimp farmers.

Every year, due to adverse impact of weather, fish farmers are not able to make the expected profit, thus adversely affecting their livelihood. Particularly, the small and medium fish farmers who cultivate small areas or take lease are the mostly affected and live below the poverty line. Earlier, small farmers used to grow paddy in a small area to meet their family needs. With the damages inflicted on to their shrimp gher following extreme weather conditions, they have no other means of livelihood making it very difficult for them to make a living. It was also observed that the fish laborers, small and marginal fishermen in the area are poor.

The study further made an assessment to understand the culture fisheries exposure to climate induced hazards in Bagerhat Sadar Upazila and eleven exposure indicators were selected (Annex I) and mapped following the impact chain analysis. **Table 4.14** below shows the exposure status of Bagerhat Sadar Upazila and from the assessment, it revealed that Barai Para and Shat Gambuj unions are in a highly exposed zone whereas Bemarta, Gota Para, Khanpur and Rakhalgachhi unions were found to be moderately exposed 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 to higher than 33 °C and results in slow growth and reduce fish feeding efficiency (A. Adey et. Al., 2015, M. Shahjahan, 2021). Temperature higher than 36°C is lethal 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). This study found out that shrimp/prawn/fish farms are facing significant stress environment with respect to TDS and DO in most of the unions, whereas in terms of water temperature it is very slightly beyond optimal range for 4 unions (**Table 4.9**). It has also been predicted that extreme temperatures coupled with erratic rainfall patterns have direct impact on fish physiology, growth, feeding behavior and mortality in the aquaculture habitat. Moreover, excessive rainfall will breach the dyke of fish pond and increase the natural mortality due to the reduction of pH.

Table 4.9: Stress magnitude of the shrimp/prawn/fish farm ecosystem in Bagerhat Upazila

Unions	PH	TDS (gm/l)	Water Temperature (°C)	DO (mg/l)	BOD (mg/l)
Bagerhat Paurashava	8.53	384	30	5.74	1.00
Barai Para	8.18	1243	30.9	6.58	3.14
Bemarta	8.19	1270	30.9	6.47	3.52
Bishnupur	8.18	621	30.9	8.11	2.71
Dema	7.47	244	30	7.18	1.20
Gota Para	7.42	704	30	5.18	7.60
Jatrapur	7.79	288	30	4.95	0.81
Kara Para	8.16	1368	30	6.59	3.09
Khanpur	8.20	692	30	5.40	3.04
Rakhalgachhi	8.25	1233	30	7.20	1.00
Shat Gambuj	8.07	1174	30.9	6.53	3.30
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 found that the average water depth of the fish pond and shrimp/prawn farm is above the minimum required water depth (1m) in all the unions of the Bagerhat Sadar Upazila (Figure 4.14). Water depth (>1.5m) was found to be optimum level for aquaculture production in all unions. The farms having higher coverage of submerged vegetation (>25%) are expected to produce high abundance of methanotrophs, which can act as a biological sink for the greenhouse gas methane.

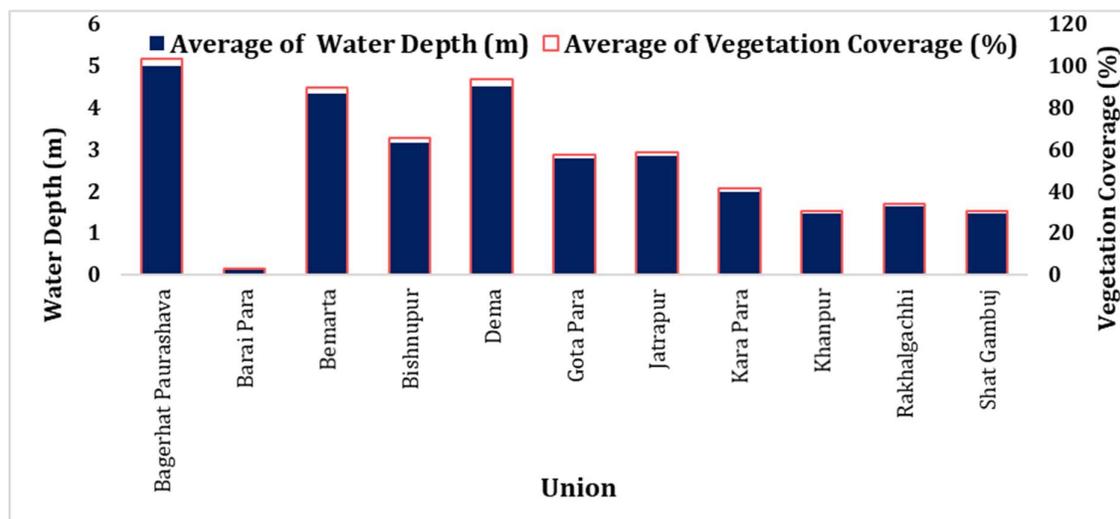


Figure 4.14: Average water depth and vegetation coverage in the fish ponds and shrimp/prawn/fish farms in different unions of the Bagerhat Sadar Upazila

CEGIS Field Survey, 2022

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 out that

the highest growth rate in aquaculture is among the Grass Carp (about 0.15cm per day). However, the highest mortality has also been found in case of Bagda (**Figure 4.15**). From the survey, this mortality is mainly as a result of viral infection accelerated by increasing temperatures.



Figure 4.15: Exposure of shrimp and fin fishes to major climate induced hazards

CEGIS Field Survey, 2022

Production loss due to climate-induced diseases

The farms in different Unions of Bagerhat Sadar Upazila was estimated to lose a considerable amount fish production due to climate-induced diseases and other extreme events as shown in **Figure 4.16**. During field survey, three climate induced diseases have been identified, among them antenna cut and White Spot Syndrome (WSS) caused by extended days of extreme high temperature and, Epizootic Ulcerative Syndrome (EUS) as a result of extended days of severe cold temperature.

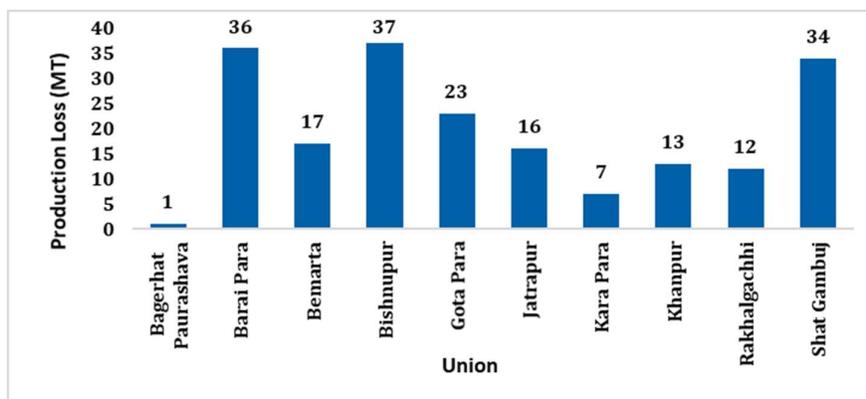


Figure 4.16: Production loss due to climate-induced disease

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 different unions of the Bagerhat Sadar Upazila would be about 6,017 MT, 4,677MT, 5,723MT and 6,148 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 4.10**.

Table 4.10: 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)
Bagerhat Paurashava	24	27	21	26	27
Barai Para	797	891	692	847	910
Bemarta	581	649	505	618	664

Union	Fish Production (MT)				
	Base Year	SSP1-2.6 (2050)	SSP1-2.6 (2100)	SSP5-8.5 (2050)	SSP5-8.5 (2100)
Bishnupur	830	928	721	882	948
Dema	512	572	445	544	585
Gota Para	523	585	454	556	597
Jatrapur	366	409	318	389	418
Kara Para	267	298	232	284	305
Khanpur	300	335	261	319	343
Rakhalgachhi	269	301	234	286	307
Shat Gambuj	914	1022	794	972	1044
Total =	5,383	6,017	4,677	5,723	6,148

Impact Chain Analysis, CEGIS (2022)

Livelihoods

Yearly, the aquaculture sector is negatively affected by adverse weather conditions, climate change, and increasing natural calamities. Fry collectors encounter cyclone every year, which impacts of their resilience. Additionally, cyclones, storm surges wash out the fish Gher causing significant losses to the fish farmers. Additionally, the rise in temperature cause shrimp death during summer months, making considerable negative effects on shrimp farms. The natural mortality rate has been increasing with increasing total hot days and other climatic hazards. In this way, loss of production increases the vulnerability of small and poor farmers and become more sensitive to be resilient with the climatic shocks. Economic or financial capital has vital role for resilience in livelihoods. Monsoons generally limit the flow of the rural economy and access to informal jobs due to water logging, inaccessibility, and other adversities. It is found that most of the people in this region are involved in fish farming/shrimp cultivation. Every year due to adverse impact of weather, fish farmers are not able to make the expected profit, thus adversely affecting their livelihood. Particularly, the small and medium fish farmers who cultivate small areas or taking lease are the mostly affected and live below the poverty line.

Additionally, they are receiving training related to alternative income from various government and private institutions—and many of them take loans from various NGOs and banks to strengthen their livelihoods.

Other than above assessments, an indicator-based sensitivity analysis (**Table 4.14**) was also made to identify sensitive unions of Bagerhat Sadar Upazila. Total thirteen indicators (Annex 1) were used to represent the sensitivity of culture fisheries in Bagerhat Sadar. According to the sensitivity analysis, Bisnupur and Dema unions are found to be highly sensitive and Khanpur and Dema unions are found to be moderate sensitive for culture fisheries.

4.3.3 Adaptive capacity

There are two types of adaptive measures found to be adopted by the farm owner in order to adapt with the extreme climatic events in the unions of the Bagerhat Sadar Upazila. One includes farm management and another is the disease control as discussed below.

Aquaculture production system

The study found that farm owners in all the unions take about 61 days (from November to December) to prepare the land for aquaculture. They use about 247kg of fertilizer and 123kg of lime per hectare for their farm management (**Table 4.11**). Stocking rate of these farms mainly depends on the farm area and water depth. Vegetation coverage also have an influence on the farm management. For example, most of them do not use supplementary food. They practice mainly extensive aquaculture.

Table 4.11: Aquaculture production system in different unions of Bagerhat Sadar Upazila

Union	Land Preparation (Days/Year)	Fertilization (kg/ha)	Lime (kg/ha)
Barai Para	61	237	115
Bemarta		245	128
Bishnupur		260	116
Dema		247	111
Gota Para		249	125
Jatrapur		238	129

Union	Land Preparation (Days/Year)	Fertilization (kg/ha)	Lime (kg/ha)
Kara Para		241	134
Khanpur		260	123
Rakhalgachhi		266	141
Shat Gambuj		239	110
Bagerhat Paurashava		240	123
Average		247	123

Source: 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 pumping water and use of coconut leaves over water to make shade. During the drought period, fish framers mainly use groundwater (Table 4.12). Some of the farmers use fine net to surround their farms during rainy season and/tidal floods to protect their fishes from overtopping. Rather than this, they do not practice any measures to protect farms against heavy rainfall, cyclone, erratic rainfall and wet days. In the study, a survey was conducted on 60 participants where 67% took no adaptive measures against heavy rainfall, cyclone, erratic rainfall and wet days.

Table 4.12: Adaptive measures for farm management

Hazard	Adaptive Measures	Response (%)
Extreme Hot Days	<ul style="list-style-type: none"> ● Pumping water ● Use of coconut leaves over water to make shade 	16
Longer Days of Water Unavailability	<ul style="list-style-type: none"> ● Using Groundwater ● Farmers irrigate water to the Gher and maintain water level at least 1.0 meter in the dry season. 	3
Tidal Flood	<ul style="list-style-type: none"> ● Fish farmers fenced by Nylon net or bamboo made mat (Bana) around the Gher to prevent Golda and white fish from escaping ● The farmers heighten the Gher dyke to prevent fish from escaping ● The farmers harvest fish at earl stage before flooding to some extent. 	14
Heavy Rainfall	Fish farmers usually do not take any measure in case of these hazards.	67
Cyclone		
Erratic Rainfall		
Wet Days		

CEGIS Field Survey, 2022

Climate-induced disease control measures

The aquaculture farm owners frequently use aqua-medicine and liming for antenna cut and White Spot Syndrome and aqua-medicine, liming and salt for controlling WSS and EUS (Table 4.13).

Most of the Gher owners' activities are limited to fish farming though they would wish to be involved in the other income generating activities. However, they are limited by their inadequate knowledge on technology and training on AIGs. In this regard, it is very much essential for them to have capacity building training on AIGs and modern aquaculture technology—which would eventually contribute to their resilience through choosing new opportunities and other livelihoods options.

Livelihood outcomes on fish farming still now recognized in this area and people positively want to increase their income through fish farming. For sustainable livelihood of pond fish farmer, it essentially required to provide government support by providing loan without interest, Extension facility and technical support.

Table 4.13: Adaptive measures for disease control

Climatic Cause	Disease	Disease Control Measures	Response (%)
Extended days of extreme high temperature	Antenna Cut	Using Aqua-medicine and Liming	14

Climatic Cause	Disease	Disease Control Measures	Response (%)
	WSS		43
Extended days of severe cold temperature	EUS	Using Aqua-medicine, Liming and Salt	7
		Taken no measures	36

CEGIS Field Survey, 2022

Union-wise adaptive capacity was also assessed (Table 4.14) through different indicator-based impact Chains. These indicators mainly demonstrate the coping mechanism of the culture fisheries in hostile conditions induced by climate change. However, the culture fisheries scenario assessment in this study followed 17 adaptive capacity indicators. Although, due to study limitations, the study team could cover only three unions during the field visit. The study team assessed union-wise conditions by consulting SUFOs, key informants, secondary data sources, and expert judgment. A set of indicator lists are attached (Annex I). From the adaptive capacity assessment of the culture fisheries in Bagerhat Sadar Upazila it was found that Bemarta, Dema, Gota Para and Bagerhat Paurashava unions are highly adaptive for culture fisheries whereas Barai Para, Jatrapur, and Khanpur unions are moderately adaptive for culture fisheries.

4.3.4 Vulnerability

The vulnerability of culture fisheries (Table 4.14) of Bagerhat Sadar Upazila was also assessed through validated impact chain analysis. Generally high vulnerability occurs when for particular union sensitivity is high but adaptive capacity is low. From the assessment Bishnupur and Dema union were highly vulnerability. These unions had high sensitivity and low to moderate adaptive capacity. Barai Para, Gota Para, Kara Para, Khanpur and Shat Gambuj union were in moderate vulnerability zone while rest of the unions were in low vulnerable zone.

Table 4.14: Summary of climate vulnerability assessment for culture fisheries in Bagerhat Sadar Upazila

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Barai Para	High	Low	Medium	Low
Bemarta	Medium	Low	High	Low
Bishnupur	Low	High	Low	Low
Dema	Low	High	High	High
Gota Para	Medium	Low	High	Medium
Jatrapur	Low	Low	Medium	Low
Kara Para	Low	Low	Low	Medium
Khanpur	Medium	Medium	Medium	Low
Rakhalgachhi	Medium	Low	Low	Low
Shat Gambuj	High	Medium	Low	Low
Bagerhat Paurashava	Low	Low	High	Low

4.3.5 Risk

Climate change induced hazard/risk for culture fisheries was assessed through impact chain analysis for base and 2050s time period. Bagerhat Pourashava, Bemarta, Bishnupur and Dema unions contain the highest number of aquaculture farms in Bagerhat Upazila. However, these unions are also low-lying and face inundation during cyclone and flood events due to lack of proper cyclone and flood protection infrastructure. Fish farmers often elevate the banks of their ponds to prevent saline water intrusion during flood. Due to climate change, in recent years Barai Para, Bishnupur, Gota Para and Shat Gambuj unions have faced high amount of production loss. Lack of proper storage and transportation facility result in considerable production loss. The rising 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 process found Dema, Shat Gambuj and Khanpur unions to be in high risk for the base period. In 2050s Gota Para, Bishnupur and Barai Para union will be in high-risk zone along

with the high-risk union at the base period. Rakhalgachhi and Bemarta union were in moderate risk at the base period and will continue to be the same in 2050s. Initially Karapara and Jatrapur union were in low risk zone in the base period but due to increased impact of climate change they will be in moderate risk zone in 2050s. **Figure 4.17** shows the risk of culture fisheries in Bagerhat.

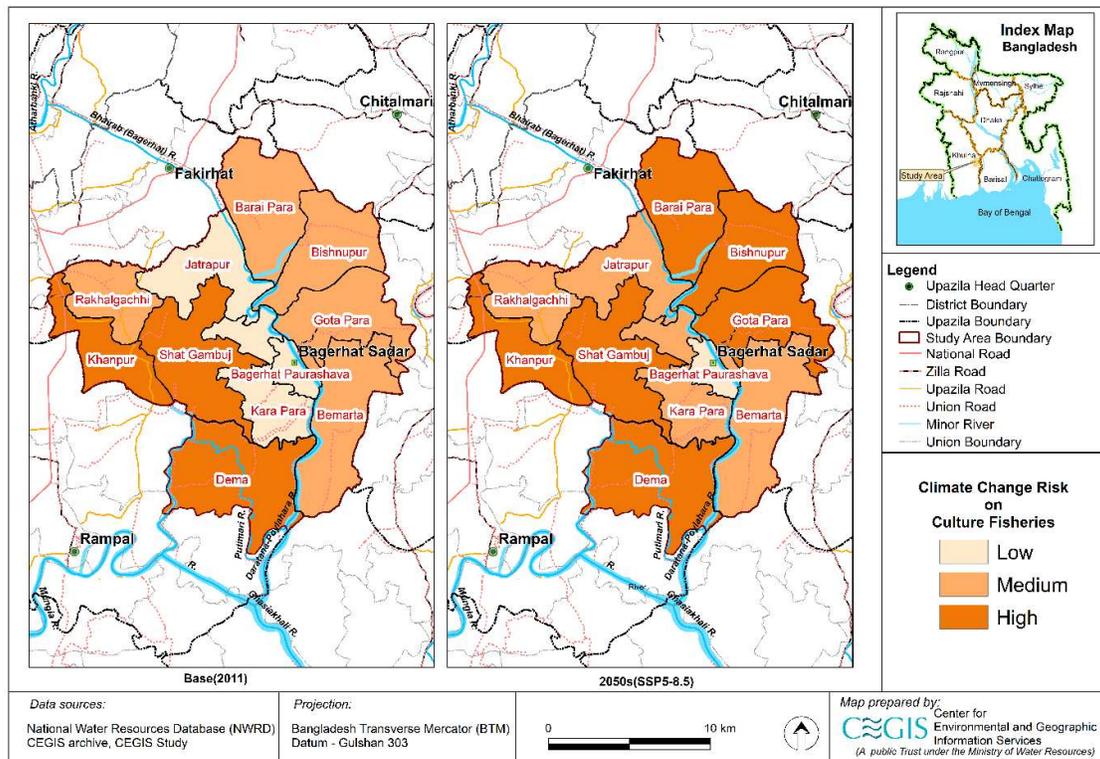


Figure 4.17: Climate risk for culture fisheries in Bagerhat Sadar Upazila

4.4 Gender

The 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.

Being a coastal area high vulnerability in terms of food insecurity, income, water, health, and poverty are prominent in this region (BBS et al. 2009; GoB 2006). The area faces various natural risks and hazards resulting in social, economic and physical impacts. The fisheries and aquaculture sector is one of the major sources of livelihood in this area. This sector becomes vulnerable due to Cyclone, Storm Surge, Extreme Heat, Flooding and Salinity Intrusion. Women in this area are actively involved in fisheries and aquaculture and they are mostly involved in catching fish, net making, pond preparation, harvesting and marketing. Their contribution in this sector hugely makes an impact to their family earning though their ownership pattern is not visible.

Mostly women work with their male counterparts—with the working hours for women even higher than for men. However, their contribution in decision making process and access to market, income and wages is far more less which makes them more susceptible to the impacts associated with climatic hazards.

Under this section, findings from the gender-based vulnerability are presented, considering the impacts of climate change on women, children, aged and disable people in terms of the exposure, sensitivity and adaptive capacity. During the assessment, both quantitative and qualitative data was collected from the

field and analyzed to identify the risks, mitigation action and future adaptation measures for developing a gender-responsive future plan on fisheries and aquaculture.

4.4.1 Exposure

The impact of climate change has increased the number of various hazards that adversely affect fisheries and aquaculture. In fisheries and aquaculture sector, exposure determines the risks to be exposed of fisheries resources (i.e. ponds, Gher, Fishing Gear, boats) and vulnerable communities who are become affected due to the climate change. The study area covers 10 unions where majority people are involved in fish farming.

Capture fisheries

In terms of women's involvement in fishing, it was found that very few women are involved in active fishing. However, though they are not directly involved in fishing, they are participating in net weaving and other fishing related activities. Women are involved in this work especially in the villages along the Bhairav River.

Aquaculture

Women contributes to aquaculture, particularly shrimp farming and also participate in fishing along with household work. It was found that Durgapasha union has the highest number of women involved in aquaculture among the unions of Bagerhat Sadar Upazila (**Table 4.15**). The study revealed that women ownership of aquaculture farms is not as visible as for male farmers. However, it was also realized that men are getting involved in other work, in addition to aquaculture, and women are assuming the responsibility of pond maintenance and fish farming too. It was also discovered that a number of women in the Shat Gambuj union are also engaged in online fish marketing. Besides, most women who are involved in fish farming have knowledge about online fish marketing—with some of them much aware on how to buy and sell fish online.

Table 4.15: 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 (%)
Shimulbak	81.1	18.9	40.9
Paschim Pagla	81.6	18.4	39.4
Joykalas	90.9	9.1	41.7
Purba Pagla	91.0	9.0	41.6
Patharia	87.5	12.5	41.6
Durgapasha	73.6	26.4	39.1
Paschim Birgaon	82.0	18.0	37.9
Purba Birgaon	90.4	9.6	37.9

In some unions of Bagerhat Upazila, water is not suitable for drinking due to high salinity. Women therefore struggle a lot to access and/or collect drinking water for their families. Most of the time they have to go far places to collect water and carry it on foot. With the regular increase of flood, cyclone and storm surge, access roads, fresh water ponds became vulnerable in which women have to endure sufferings because of the exposure of roads, fresh water ponds due to the climatic hazards. Thus, in gender perspectives (based on the people's perspective from different unions) fish ponds/*Gher*, access roads, fresh water ponds, growth centre and IGA are being exposed by the hazards which have been occurring in this Upazila.

4.4.2 Sensitivity

In general, women, aged and physically challenged people have the limited access to healthcare, education or other skill-building exercises—which makes them more vulnerable and sufferings during and post disasters period. Besides, the immediate impacts of a disaster, it is often found that women's sensitivity made remarkable change in which gender-based risks increased. Poverty, mobility, health and physical condition become more sensitive due to the regular occurrence of cyclone, storm surge, salinity intrusion,

extreme heat and flood. Women’s mobility is being constrained to the home. When the disaster strikes, everyone did not have the same ability to move.

Figure 4.18 below shows the monthly average income of women fish farmers who owned fish ponds/Gher in Bagerhat Sadar. Due to social challenges, women who have own fish farms on average earn between BDT. 12000-15000 monthly. It’s also observed (**figure 4.18**) that women income in almost all unions is more or less the same i.e. not more than 15000 tk. Moreover, natural disaster disrupts farming every year, causing extensive damage to fish and ponds leading to a reduction in income. As a result, their families do not run properly with this low income as it becomes very tough for them to bear the routine family expenses.

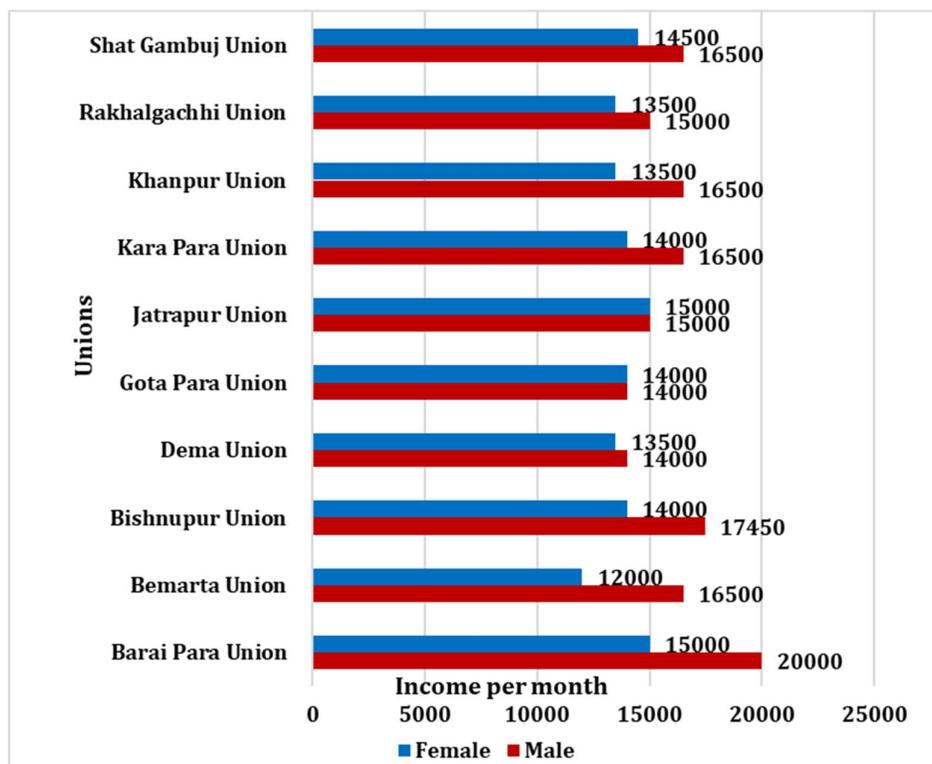


Figure 4.18: Monthly average income of women fish farmers by union

There are very few work opportunities for women in the region and even in emergency situations there is no work opportunity at all. Additionally, women labor wages are much lower than for men. Whereas a male laborer is paid Tk 350 to Tk 450 for a working day, women are on average paid between Tk 250 to maximum Tk 300. In fish farming, women are involved in all kinds of work such as pond preparation, feeding and fertilizing, where they often spend more time than men. Despite all this, their low income, less working opportunities and poverty makes them more vulnerable to the changing climatic conditions. In this way, women, disable and aged people who have less access to resources decision making suffer a lot and become more sensitive following climate related disasters. **Table 4.16** shows different climate risk indicators and its impacts on gender that will make more sensitive.

Table 4.16: Impacts of climate risks/hazards on gender

Indicators	Impacts
Housing and Homesteads	Disasters damage housing structures and women have to struggle more for it recovery. Women have to take on most of the household responsibilities during disaster period. High salinity disrupts homestead vegetable production. Besides, fruit trees and medicinal plants cannot be grown in homestead.
Impact on pond management and homestead production	Women have the less control over the resources, especially ownership of the ponds—and their pond-based activities disrupted following climate hazards.

Indicators	Impacts
	Women who earn homestead-based livelihoods are more affected by climate change related disasters. Their crops are destroyed, lack work opportunities and experience shortage of loans or other facilities to recover from the situation—which consequently make them face chronic nutritional deficiencies.
Limited market accessibility	There are many unions in the Bagerhat Sadar Upazila where the communication system is poor. It was noted that during disaster period, the communication system especially roads are damaged and disrupts transportation and communication and limits accessibility towards markets. Therefore, they cannot sell the produced fish in the local market, even at low price. In this regard, women suffer a lot and have limited ways to recover this vulnerable condition.
Loss of income, savings and employment	Climate change related disasters are adversely affecting people's lives and environment. Women who are involved in fishing, fish farming and related work are adversely affected by natural disaster almost every year. They lose their income, fish ponds/gher are washed away, ponds are damaged and lack of money to recover due to disasters. Besides, during the disaster, job opportunities are limited.
Sickness and disease	The frequency of sickness has increased over the years. Women who are involved in catching fish, are exposed to saline water conditions for a long time which sometimes causes different types of skin diseases and diarrhea. It was noted that during the menstruation period, women fishers face severe gynecologic related diseases. In most cases, they need to go to cities for treatment, which is a financial burden for them. Women and newborn babies also face huge problems due to malnutrition, food insecurity and increase poverty condition.
Social security	Women who engage in outside work face social insecurity and are often subjected to physical and human harassment. Besides, various social taboos lead to neglect and disrespect of women who work outside. Moreover, flood shelters have limited separate facilities for women, aged, and disabled people, but they are not properly maintained.

Sensitivity analysis (**Table: 4.18**) showed Dema union is in high and Bagerhat Paurashava is in low sensitivity zone and rest of the union are medium sensitive for Gender specific fisheries livelihood.

4.4.3 Adaptive capacity

Table 4.17 indicates specific scoring against each Adaptive Capacity Indicator where respondents gave feedback during an FGD meeting. The table shows that the respondents in this region know about each indicator. The highest number of respondents, around 100%, said they have access to flood shelters during floods and got training about climate change. Among the three indicators with the lowest response is smartphone usage with or without internet and training on resilient climate house and pond management, where the score is zero. About 33% of women received training on poultry farming, aquaculture, animal husbandry, handicraft, tailoring, and homestead vegetation for involving in Alternative Income-generating Activities (IGA).

It is difficult for female fishers to adapt during the disaster and post-disaster periods as they do not have easy access to loans, do not have direct ownership of fish ponds, have inadequate mortgages, have weaker communication skills, and cannot provide required documents. As a result, they carry out businesses by their own, which is always tough for them following any disaster. The FGD findings depicted that about 83% respondents of the FGD have good understanding of climate change impact, local fisheries techniques and disaster early warnings.

Table 4.17: Status of adaptive capacity of women involved in fishing and fish farming

Adaptive Capacity Indicators	Status (%)
Understanding on Climate Change Impact	83
Knowledge on Fisheries Techniques	83
Knowledge on Pet and Diseases on Fish	50
Receive Early Warning Message Regularly	83
Watching Television or Social Media	83

Having Cell Phone	75
Having Smart Phone but No Internet	42
Having Smart Phone with Internet	33
Watching Television Once a Week	83
Accessibility to Shelter during Cyclone/Floods	100
Knowledge on Hygiene during Menstrual and Pregnancy Period	83
Knowledge on Drinking Water Boiling or Chlorination	50
Training Received on Climate Change	50
Training on Alternate Livelihood	33
Training on Climate Change Impact and Adaptation	42
Knowledge on Reducing Salinity from Drinking Water	0
Training on Climate Resilient Housing, Pond Management and Infrastructures	33

Adaptive capacity assessment (**Table 4.18**) showed every area of Bagerhat Sadar Upazila have low adaptive capacity for gender specific fisheries livelihood except Bagerhat Paurashava.

4.4.4 Vulnerability

Using impact chains developed for Southwest region, vulnerability for gender-based livelihood was also assessed for Bagerhat Sadar Upazila. Vulnerability assessment (**Table 4.18**) showed Dema union was highly vulnerable. While Bagerhat Paurashava was in lower vulnerable zone. Unions with high vulnerability have low adaptive capacity and high sensitivity level. Rest of the unions were found to be in medium vulnerability level.

Table 4.18: Summary of climate vulnerability assessment for gender (women) engaged in F&A-specific livelihood in Bagerhat Sadar Upazila

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Barai Para	High	Medium	Low	Low
Bemarta	High	Medium	Low	Low
Bishnupur	High	Medium	Low	Low
Dema	High	High	Low	High
Gota Para	High	Medium	Low	Medium
Jatrapur	High	Medium	Low	Low
Kara Para	High	Medium	Low	Medium
Khanpur	High	Medium	Low	Low
Rakhalgachhi	High	Medium	Low	Low
Shat Gambuj	High	Medium	Low	Low
Bagerhat Paurashava	Low	Low	High	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 Bagerhat, 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 Bemarta, Bishnupur and Barai Para unions, the wage rate of women is shockingly low than men. Salinity intrusion is affecting their health adversely. Lack of proper hygiene knowledge and WASH facility further aggravate their health issues.

Risk assessment shows all the unions except Bisnupur union and Bagerhat Paurashava are in high risk for gender-based livelihood for base time period. For SSP5-8.5 scenario all the unions are in high risk for gender specific fisheries livelihood. Initially Bishnupur union was in moderate risk at the base period but in 2050s due to increased impact of climate change induced hazard it showed high risk.

Following **Figure 4.19** shows the risk on gender (women) engaged on F&A based livelihood in Bagerhat Sadar Upazila.

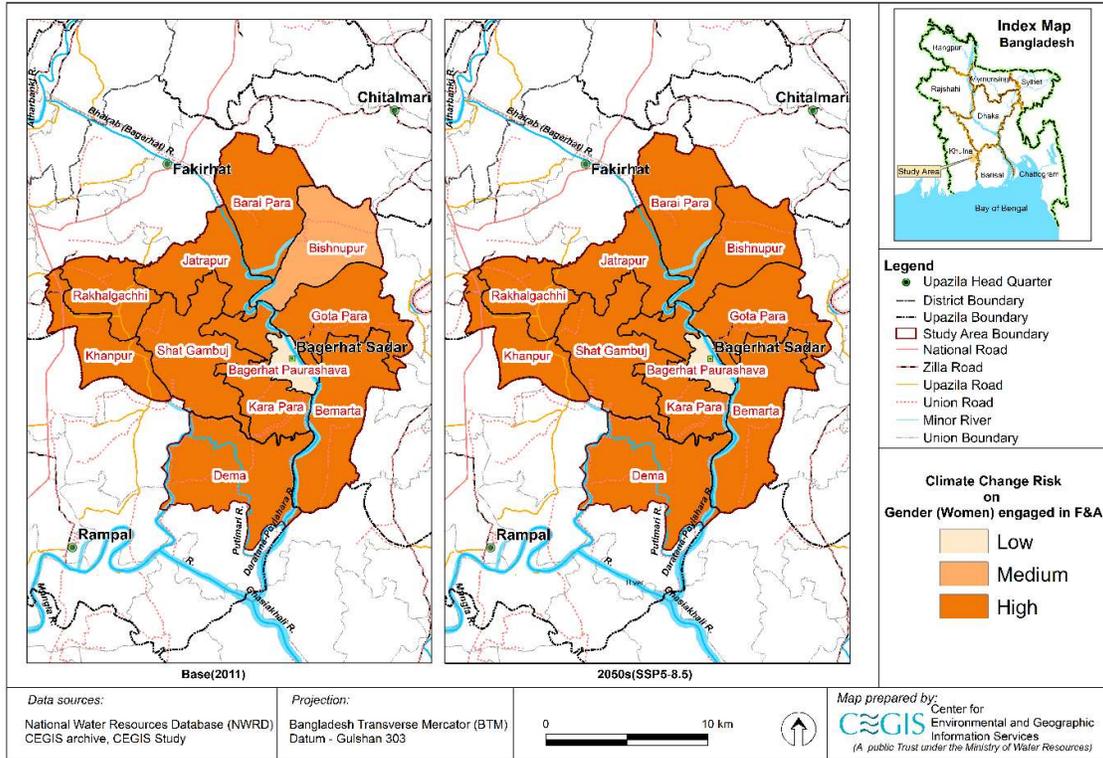


Figure 4.19: Climate risk of gender (women) engaged in F&A in Bagerhat Sadar Upazila

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 Bagerhat Sadar 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 Bagerhat Sadar 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 Bagerhat Upazila and identified their risk.

Open water fisheries

The **Table 5.1** below outlines the risks related to cyclones, storm surges, salinity intrusion, flood, and tidal flood 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 cyclone, storm surges, salinity intrusion flood, Tidal flood and wave action on capture fisheries with adaptation options

Cyclone, Storm surge, Salinity Intrusion, Flood, Tidal Flood, 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 cyclone, storm surge, floods, tidal 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, 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

Cyclone, Storm surge, Salinity Intrusion, Flood, Tidal Flood, Wave action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder(s)	When to Implement
		<ul style="list-style-type: none"> Repair fishing and 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 and beel habitats due to siltation and habitat condition degradation after floods/tidal floods	<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	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	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	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, cyclone/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, 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

Cyclone, Storm surge, Salinity Intrusion, Flood, Tidal Flood, 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, sea level rise and salinity	<ul style="list-style-type: none"> Integrated coastal zone and mangrove management 	<ul style="list-style-type: none"> Protection of fish biodiversity and increase fish production combating impacts of climate change 	DoF, BFRI, BFD, WARPO, BWDB, LGED, LGIs, MoDMR, MoEFCC, DSS, DYD	Within 3 years and continue
		<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, Knowledge Institutes, Academia	Within 3 years and continue
		<ul style="list-style-type: none"> Research and monitoring of movement of salinity front, 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"> Increase freshwater flow from upstream of coastal rivers 	<ul style="list-style-type: none"> Reduce salinity and disruptions in migrations 	MoWR, NRCC, LGED, MoS, WARPO, JRC	Within 3 to 5 years
		<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

Cyclone, Storm surge, Salinity Intrusion, Flood, Tidal Flood, Wave action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder(s)	When to Implement
		<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	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"> 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 C&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 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
7	Aquatic habitat degradation and decreased water quality due to flood and salinity	<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

Cyclone, Storm surge, Salinity Intrusion, Flood, Tidal Flood, Wave action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder(s)	When to Implement
		<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	Annually
		<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	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	Within 3 years and continue
		<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	Within 3 to 5 years
8	Disruption in post-harvest storage management, damage of infrastructures and communication facilities due to floods/cyclone or storm surge	<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
		<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 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	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	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 	DoF, BFRI, LGIs, Knowledge Institutes, Academia	Within 3 years and continue

Drought, Lightning, Heat Stress					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
			and plan accordingly for fisheries risk reduction		
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 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 facilities to recover disaster risk 	<ul style="list-style-type: none"> Improve financial stability of fishermen to recover any losses 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, Insurance companies, Bangladesh Banks and Private Sectors	Within 3 years and continue

Drought, Lightning, Heat Stress					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
			incurred from damages due to climate hazards		
		<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 cyclones, storm surges, salinity intrusion, flood, tidal 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 cyclone, storm surges, salinity intrusion, flood, tidal flood and wave action on culture fisheries with adaptation options

Cyclone, Storm Surge, Sea Level Rise, Salinity Intrusion, Flood, Tidal Floods & Wave action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
1	Pond and gher dykes may get damaged and overflowing of fishes due to storm surge, floods or tidal 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 storm surge, 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 Reduce gender discrimination and inequality 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, Insurance companies	Within 3 to 5 years

Cyclone, Storm Surge, Sea Level Rise, Salinity Intrusion, Flood, Tidal Floods & Wave action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
		<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 to sea level rise, tidal floods and salinity ingressión	<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
		<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, Knowledge Institutes, 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, Knowledge Institutes, Academia	Within 3 years and continue
		<ul style="list-style-type: none"> Heighten dikes of freshwater retention ponds to halt salinity ingressión 	<ul style="list-style-type: none"> Safeguard fish species and production Secure income 	DoF, BFRI, LGIs, Knowledge Institutes, Academia	Within 3 years and continue

Cyclone, Storm Surge, Sea Level Rise, Salinity Intrusion, Flood, Tidal 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 salinity/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, Knowledge Institutes, 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, Knowledge Institutes, Academia	Within 3 years and continue
4	Mortality of fry/Juvenile of fish due to floods/flash floods or storm surge	<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
5	Pond habitats degradation due to siltation after floods or storm surge	<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	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	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 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	Within 3 years and continue

Cyclone, Storm Surge, Sea Level Rise, Salinity Intrusion, Flood, Tidal Floods & Wave action					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
				Knowledge 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/ ghers, 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	Annual and periodic

Drought, Lightning, and Heat Stress					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
		<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 salinity and 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
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 ghers 	<ul style="list-style-type: none"> Protection of fisheries and reduce production losses 	DoF, BFRI, LGD, LGED, LGIs, Private Sectors	

Drought, Lightning, and Heat Stress					
ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
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
		<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

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 				

ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
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 organizations/institutes, CBO, NGOs, CSOs	Before and After Disaster
		<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 		
		<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 	<ul style="list-style-type: none"> • 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
		<ul style="list-style-type: none"> • Training on IGAs with diseases management of livestock and poultry products 	<ul style="list-style-type: none"> • Ensuring support in livelihood during disasters • Ensuring sustainability of income and livelihood 		
		<ul style="list-style-type: none"> • 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 		
4		<ul style="list-style-type: none"> • Required training for emergency response team from Community, NGOs and GOs Level 		MoWCA, DoF, DDM, MoSW, DYD, NILG,	During and after Disaster

ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
	Violence and accidental occurrences towards women	<ul style="list-style-type: none"> • 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 	CreLIC, CBOs, NGOs and CSOs.	
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 • 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 • Safe evacuation before disaster • Protection of livestock and property 	DoF, BMD, FFWC, DDM	Before and during Disaster

6 Conclusions and Recommendations

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

Cyclone, coastal flooding, saline water intrusions, river bank erosion, sea level rise and drought were found to have severely affected the people lives in this region. The region experiences cyclone accompanied with high storm surge almost every year which inundates ponds and fish farms. Fish farmers in Bagerhat Sadar Upazila are faced with a number of difficulties as a result of the dramatic increase in perceived temperature in the south-western 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 Bagerhat Sadar Upazila. Fish and/or other aquatic species migration, reproduction, and growth are also being impacted by the drought conditions usually experience in the area.

From risk assessment, Bemarta, Barai Para and Rakhalgachhi union were in high risk zone in the base period and will likely continue to remain the same in 2050s for capture fisheries. For Culture Fisheries, Dema, Shat Gambuj and Khanpur union were in high risk for the base period whereas in 2050s Gota Para, Bisnupur and Barai Para union will be in high risk zone along with the high-risk union at the base period. The SWOT analysis shows that both the river and pond ecosystem are in good condition and has balanced strength and opportunities, because their buffer areas are characterized by natural land-cover types and optimum water qualities. The results also draw attention to the weaknesses of the river ecosystem, which are more threatened by urbanization and environmental pollution.

A climate resilience action plan has been prepared following the principles of the climate resilience framework; ecosystem approaches to fisheries and aquaculture. Community preferences of actions for 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 Bagerhat Sadar Upazila smoothly. Different ecosystem-based adaptation options, technical/financial incentives, and alternative livelihood 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 the climate adaptation process for the F&A, raising women's voices from the micro level to the 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. Implementing 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 ecosystems. 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 Bagerhat Sadar 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.

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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 events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability and hazard.
Climate sensitivity	Climate sensitivity refers to the change in the annual global mean surface temperature in response to a change in the atmospheric CO ₂ concentration or other radiative forcing.
Climate vulnerability	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.
COD	Chemical oxygen demand (COD) is the amount of oxygen needed to oxidize the organic matter present in water.
Community based Organization	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.
Culture fisheries	Culture fisheries is the cultivation of selected fishes in confined areas with utmost care to get maximum yield.
Disaster	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.
Disaster risk reduction (DRR)	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.

Early warning systems (EWS)	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)]
Ecologically Critical Area	Areas or ecosystems affected adversely or endangered to reach a critical condition by the changes brought through various human activities.
Ecosystem services	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.
Epizootic Ulcerative Syndrome	Epizootic ulcerative syndrome (EUS) is considered to be an infection with the oomycete known as Aphanomyces invades.
Equity	A principle that ascribes equal worth to all human beings, including equal opportunities, rights, and obligations, irrespective of origins.
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 <p>1. Prepare implementation plan</p>	<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 <p>2. Review and stocktake</p>	<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 <p>3. Brainstorm adaptation measures to reduce the risk</p>	<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 <p>4. Finalise the impact chain for next step</p>	<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	<p>5. Data collection, database construction and linking relevant data to chosen indicators</p>	<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 <p>6. Inventory preparation with unit for each indicator</p>	<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	7. 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 8. 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 9. 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 10. 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 11. 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) 12. 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 <p>13. Update (if necessary) and publish the finalised CRV maps</p>	<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 Bagerhat Sadar 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 Bagerhat Sadar 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 Bagerhat Sadar Upazila

 Indicators excluded In CRVA

	Factor	Indicator	
Cultures 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 Bagerhat Sadar Upazila

 Indicators excluded In CRVA

	Factor	Indicator
Culture Fisheries	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	
Capture Fisheries	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	Availability 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	2.6	2	2	2	The strength of water availability received high score due to better condition of availability of optimum water in the dry season and good water retention time and diversified water use when water stays sweet after monsoons. Weakness scores medium condition because of good surrounding hydrological system, average ground water table depletion in dry season but the main delicacy is channel connectivity is lost due to siltation. There are good opportunities to increase water availability through dredging or re-excavation practices, high opportunities for law enforcement of IUU fishing. Moderate levels of encroachment, resources extraction and plan of upstream development due to rapid urbanization are the main threats that scored medium.
	Water quality	3	1	2	2	Water quality received a high score for strength as the Optimum Physio-Chemical Parameters (Temperature, DO, TDS, pH) from the field test are good for water quality and water can be used for multipurpose when the water salt concentration changes to low levels. As the physio-chemical parameters is under threshold range, so the weakness of water quality is scored low. However, EbA interventions for dust management and the presence of law enforcement and co-management are good opportunities for water quality improvement but the presence of functional ETP is absent there so, the opportunities received medium scores. 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 industry causes the water quality more vulnerable so threats scored medium here.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
	Soil quality	2	1.6	2.5	1.3	The strength of soil quality is scored medium as the optimum soil nutrients is in good condition due to the vegetation coverage. The weakness of the soil quality scored low due to presence of ordinary peat soil which is a very soft soil with low shear strength and high compressibility exists in an unconsolidated state. Soil is also polluted by anthropogenic activities. Opportunities for soil quality improve assigned high scores because of increasing vegetation coverage and land use practice. There are low threats to soil quality as chemicals and pesticides used in surrounding crop field and fish gher and low amount of industrial discharge and waste dumping.
	Primary productivity	2.33	1	2.5	2	Availability of high plankton, good sediment retention, export and floodplain fertility provide good strength scores for primary productivity. Weakness for primary productivity scored low as less 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 increasing forest, vegetation coverage and EbA interventions. However, Threats scored medium due to unsustainable harvest of the ecosystem resources.
	Fish diversity, community dynamics and production	3	1	2.3	2	This indicator received highest scored for strengths as water for integrated use for fishery, crop and nature is sufficient and water quality and soil quality is suitable for fisheries. Moreover, primary productivity is high. Weakness is scored low due to good water retention capacity and less time needed to regenerate primary productivity. Presence of green coverage is good, fishing ban period is strictly maintained, community based activities is active, Dolphin migration route is present which are good opportunities and received medium score. Frequent climate extreme event are the main threats to fish diversity, community dynamics and production. However, Limited access to climate and hydrology information also a big threat and received moderate score

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Regulating	Ground recharge water	2	2	1	2	The strength for ground water recharge is moderate because of low sandy soil type but adequate vegetation coverage. Clay soil type is the main weakness and scored medium here due to low water holding capacity. As this is a natural ecosystem so there are few opportunities for ground water recharge. Main threats are rapid urbanization, unsustainable use of forest and poor management of domestic waste which is scored moderate.
	Waste treatment water	3	1.5	2.25	2	The strength of waste water treatment received highest score due suitable condition of aquatic vegetation and presence of molluscs. Weakness scored medium condition because of average dense turbidity. Presence of co-management, awareness of the role of ecosystem for climate resilience and law enforcement are good opportunities for this indicator and received medium scores. Poor management of domestic waste and increased dependence on forests are the main threats that scored medium.
	Soil fertility	3	1	2.25	1.8	Strength for soil fertility scored highest as existing biodiversity makes the soil fertile by decomposing organic materials which provide suitable habitat. So, the weakness gets poor score. Opportunities for soil quality improve assigned good scores because of increasing forest and vegetation coverage and sustainable management. Presence of embankment and agro-chemicals use in the surrounding gher, moderate water management structure, low deforestation are the main threats to soil fertility which scored medium.
	Water capacity retention	2.5	3	2	1.3	Water retention and conveyance capacity is good and strength for this indicators scored high though siltation is the greatest weakness and received highest score. There are average opportunities for dredging and new hydrological connection so it scored medium. Presence of embankment and poor deforestation slightly disrupt water retention so the threats scored lowest.
Cultural	Recreation and tourism	2.3	2	2	2	High resource availability, scenic beauty and sustainable management provide satisfying score for cultural services but the main weakness is ecotourism is not so planned and lack sustainable management which received moderate score. Opportunities received good score for community based livelihood. The main threats are environmental pollution by the tourist and overexploitation of resources which received an average score.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Supporting	Ground water replenishment	2	2	1	3	The strength for ground water replenishment is moderate because of low sandy soil type and good vegetation coverage. Clay soil type is the main weakness and scored medium here due to low water holding capacity. As this is a natural ecosystem so there are few opportunities for groundwater recharge which received less score. Main threats are management of domestic waste and unplanned urbanization which is scored high.
	Nutrient cycling	3	1	2.5	2	Nutrient cycling gets highest score due to existing biodiversity which makes the soil fertile by decomposing organic materials and enrich nutrients to the soil. So, the weakness gets poor score. Opportunities for nutrient cycling received highest score because of increasing forest and vegetation coverage and sustainable management. Disasters, rapid urbanization, encroachments are the main threats for nutrients cycling which received poor scores.
	Maintenance of floodplain fertility	2.5	2	2	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 received a good 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	3	1	2.5	2	Strength and opportunities for this indicator are high for multitrophic interaction and high species & genetic diversity as both fresh and brackish water species is 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

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
	Hydric soil development	1.5	2	2	1	The strength of this indicator is moderate because of good vegetation coverage. Clay soil type 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 poor scores.
Total	Total Service=15	37.73	24.1	30.8	28.4	

SWOT scoring and outcomes for Pond/Fish farm ecosystem

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Provisioning	Water availability	2.33	1.6	2.6	2	The strength of water availability received medium score due to ordinary condition of availability of optimum water in the dry season and average water retention time but water use is for domestic purpose is high. Weakness scored medium because of lack of surrounding hydrological system, moderate sandy bed materials and average ground water table depletion. There are high opportunities to increase water availability by rainwater harvesting, re-excavation practices and community based management. Overuse of ponds and increase plan of upstream development are the main threats that received moderate scores.
	Water quality	3	2	2.5	1.6	The strength for water quality received a high score as the Optimum Physio-Chemical Parameters (Temperature, DO, TDS, pH) from the field test are good for water quality and water can be used for multipurpose. Weakness for water quality is scored very medium as the physio-chemical parameters is under threshold range but occurrence of algal bloom due to climate change. However, EbA interventions, increase vegetation coverage and community based management are good opportunities for water quality improvement so the opportunities received medium scores. Heat and drought due to climate change are the main threats to water quality deterioration but has limited impact. Moreover, chemicals and pesticides used in surrounding crop field and fish gher deteriorate water quality so, threats received moderate score.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
	Soil quality	2	1.5	2.5	1.5	The strength of soil quality is scored moderate as the optimum soil nutrients is in suitable condition due dominance of herbs, shrubs and trees. The weakness of the soil quality scored low due to good litter decomposition and vegetation coverage but the soil is also polluted by anthropogenic activities. 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 gher and household waste discharge to the ponds.
	Primary productivity	3	1	2.5	2	Presence of superior aquatic vegetation and plankton provides high strength scores for primary productivity. Weakness for primary productivity scored low as comparatively few time needed to restore plankton and aquatic vegetation after disasters because of soil fertility. Opportunities for primary productivity get high score for increasing awareness to plant suitable tree, vegetation coverage and EbA interventions. However, moderate threats on productivity due to unsustainable harvest of the ecosystem resources received medium score.
	Fish diversity, community dynamics and production	3	1	2	1.6	This indicator received highest scored for strengths as water for integrated use for fishery, crop and nature is sufficient and water quality and soil quality is suitable for fisheries. Moreover, primary productivity is high. Weakness is scored low due to good water retention capacity and less time needed to regenerate primary productivity. Presence of green coverage is sufficient, community based activities is active, awareness on the role of ecosystem for climate resilience increase which are the good opportunities and received medium score. Frequent climate extreme event and disruption of environmental flow of the ecosystem are the main threats for fish diversity, community dynamics and production which received low score

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Regulating	Ground recharge water	2.5	1	1.5	2	The strength for ground water recharge is high because of moderate sandy soil type and high vegetation coverage. Sandy clay soil type is the main weakness and scored low here due to low water holding capacity compare to sandy soil. There are few opportunities for ground water recharge by altering soil condition and planting suitable crops. Main threats are high dependence on vegetation, unsustainable use of water, and unplanned urbanization which is scored moderate.
	Waste treatment water	3	1	2.3	2	The strength of waste water treatment received high score due improved condition of aquatic vegetation and abundance 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 good scores. High dependence of vegetation, management of domestic waste and unplanned urbanization are the main threats which scored medium for this indicator.
	Soil fertility	3	1	2	2	Strength for soil fertility score highest due to abundance of flora and fauna. So, the weakness gets lowest score for high abundance of flora and fauna. Opportunities for soil quality improve assigned good score by increasing suitable tree and vegetation coverage, sustainable management and increase awareness on the role of ecosystem for climate resilience. Re-excavation, overuse of resources and agro-chemicals use are the main threats for soil fertility which scored medium.
	Water retention capacity	2	0	2	1.5	Water retention and conveyance capacity are good and strength for this indicators scored medium. There are good opportunities for re-excavation and connecting with new hydrological system so it scored medium. Threats scored medium due to low deforestation and poor water management structure.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Cultural	Recreation and tourism	2	2	1	2	Existing biodiversity, scenic beauty and unsustainable management provides average satisfying score for cultural services and the main weakness is the ecosystem is not so planned and scored average. Opportunities received low score for poor community based livelihood. The main threats are environmental pollution and over exploitation of resources and received moderate score for threats.
	Ground water replenishment	2	2	2	2	The strength for ground water replenishment is moderate because of low sandy soil type and high vegetation coverage. Sandy clay soil type is the main weakness and scored average here due to low water holding capacity. There are few opportunities for ground water recharge by increasing vegetation and modifying soil texture which received medium score. Main threats are management of domestic waste and unplanned urbanization which scored moderate.
Supporting	Nutrient cycling	3	1	2	2	Nutrients cycling gets high score due to rich of biodiversity which makes the soil fertile by decomposing organic materials. So, the weakness gets lowest score due to improve nutrients cycling. Opportunities for nutrient cycling received moderate score because of increasing suitable tree and vegetation coverage and sustainable management. Frequent climate extreme event are the main threats for nutrients cycling which scored medium.
	Maintenance of floodplain fertility	2	2	2	2	The strength for this indicator received average 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 good 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	2	2	1.5	Strength and opportunities for this indicators is high for multitrophic interaction, species and genetic diversity. Weakness for this indicator received medium score due to abundance of flora and fauna. Frequent climate extreme event are the main threats for Prey/predator relationships which received average score.
	Hydric soil development	2	2	2	1.5	The strength of this indicator is medium because of good vegetation coverage. Sandy clay soil type is the main weakness and scored medium here due to low water holding capacity. Opportunities received good score due to community based management and EbA interventions. Rapid urbanizations is the main threat for hydric soil development which scored medium.
Total	Total Service=15	37.83	21.1	30.9	27.2	

Annex III: Photo album of FGDs, KIIs, community survey and in-situ test

FGD at Bagerhat Sadar Upazila



FGD With CBO (Women Group) at Sarkardanga-1



FGD With CBO (Women Group) at Sarkardanga-2



FGD With Capture Fisheries Group at KB Bazar-1



FGD With Capture Fisheries Group at KB Bazar-2



FGD with Culture Fisheries Group at Barakpur-1



FGD with Culture Fisheries Group at Barakpur-2

KIIs, community surveys and water quality sample collection



KII with Pond Owner at Sarkerdanga



Community Survey with Shrimp Farm Owner
Kashimpur



KII with SUFO at UP



KII with Fisherman at Sarkardanda



WQ Sampling at Bhairab River



Tourist at Pauro Park Bridge