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of the United Nations

Dumuria 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



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Resilience Action Plan for Aquatic Ecosystem

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Table of Contents

List of Figures	iii
List of Tables	iv
Abbreviations	v
Executive Summary	ix
1 Introduction	1
1.1 Background	1
1.2 Study objectives	1
1.3 Approach of the study.....	1
1.4 Limitations of the study	3
2 Description of Project Area	5
2.1 Geographical features.....	5
2.2 Hydrological system.....	5
2.3 Aquatic ecosystem and its services	7
2.4 Fisheries resources.....	7
2.5 Demographic characteristics.....	7
3 Climate Change Induced Hazards	9
3.1 Climate change scenarios.....	9
3.1.1 Temperature	9
3.1.2 Rainfall variability	9
3.1.3 Evaporation	10
3.2 Climate hazards and its impacts	11
3.3 Hazard wise impact matrix based on community perception.....	14
3.4 Multi-hazard mapping for Dumuria upazila	15
4 Climate Risk and Vulnerability	17
4.1 Aquatic ecosystem.....	17
4.1.1 Exposure	17
4.1.2 Climate sensitivity of aquatic ecosystem	17
4.1.3 The capacity of aquatic ecosystem to adapt.....	21
4.1.4 Vulnerability of aquatic ecosystem.....	22
4.1.5 Risk of aquatic ecosystem	22
4.2 Capture fisheries.....	23
4.2.1 Exposure	23
4.2.2 Sensitivity	25
4.2.3 Fishers adaptive capacity.....	31
4.2.4 Vulnerability	32
4.2.5 Risk.....	33
4.3 Culture Fisheries.....	34

4.3.1	Exposure	34
4.3.2	Sensitivity	35
4.3.3	Adaptive capacity	39
4.3.4	Vulnerability	41
4.3.5	Risk.....	41
4.4	Gender	42
4.4.1	Exposure	43
4.4.2	Sensitivity	44
4.4.3	Adaptive capacity	45
4.4.4	Vulnerability	46
4.4.5	Risk.....	46
5	Climate Resilience Action Plan	49
6	Conclusions and Recommendations.....	67
	References.....	69
	Glossary.....	73
	Annex I: CRVA framework and selected indicators	77
	Annex II: SWOT Analysis of Aquatic Ecosystem	85
	Annex III: Photo Album of FGDs, KIIs, Community Survey and In-situ Test	94

List of Figures

Figure 2.1: Hydrological system and location of primary survey	6
Figure 3.1: Average minimum (left) and Average maximum (right) temperature of Khulna station	9
Figure 3.2: Dry and wet season rainfall at Khulna station	10
Figure 3.3: Monthly variation of rainfall and evaporation in Khulna station	10
Figure 3.4: Frequency of climatic hazards on the capture fisheries	11
Figure 3.5: Distribution of high intensity cyclone along the Bangladesh coastline	12
Figure 3.6: Salinity intrusion in Dumuria Upazila	13
Figure 3.7: Multi hazard maps in Dumuria Upazila	15
Figure 4.1: Waterbody changes in Dumuria Upazila	18
Figure 4.2: SWOT results of aquatic ecosystem services	19
Figure 4.3: SWOT outcome for river and ponds/gher ecosystem	20
Figure 4.4: Climate risk of aquatic ecosystem in Dumuria Upazila	23
Figure 4.5: Species composition (A) and Biodiversity Index (B) of the instantaneous catch of different unions of the Dumuria Upazila	25
Figure 4.6: Habitat sensitivity to natural mortality in the SSP1-2.6 and SSP5-8.5 scenarios	27
Figure 4.7: Magnitude of Breeding/Spawning success of the available fish species	28
Figure 4.8: Migration extent of different migratory fish species	29
Figure 4.9: Growth coefficient and natural mortality of the available fish species in the instantaneous catch	30
Figure 4.10: Magnitude of growth performance of the available fish species	30
Figure 4.11: Availability of mechanized boats	32
Figure 4.12: Climate risk of capture fisheries in Dumuria Upazila	34
Figure 4.13: Average water depth and vegetation coverage in the fish ponds and shrimp/prawn/fish farms in different unions of the Dumuria Upazil	37
Figure 4.14: Exposure of shrimp and fin fishes to major climate induced hazards	37
Figure 4.15: Climate risk for culture fisheries in Dumuria Upazila	42
Figure 4.16: Monthly average income in fish related activities	44
Figure 4.17: Climate risk of gender (women)engaged in F&A in Dumuria Upazila	47

List of Tables

Table 3.1: Hazard ranking by local community	11
Table 3.2: Hazard wise impact matrix based on community perception	14
Table 4.1: Surface water quality in Dumuria.....	21
Table 4.2: Summary of climate vulnerability assessment for aquatic ecosystem in Dumuria Upazila.....	22
Table 4.3: Area of riverine habitat in different Unions of Dumuria Upazila	23
Table 4.4: Breeding and spawning season of the available fish species in the instantaneous catch	27
Table 4.5: Capture fish production under different climate change scenario.....	31
Table 4.6: CPUE of mostly available fishing gears during the study period.....	32
Table 4.7: Summary of climate vulnerability assessment for capture fisheries in Dumuria Upazila	33
Table 4.8: Status of aquaculture farm in different Unions of Dumuria Upazila.....	34
Table 4.9: Composition of cultured fish species in the shrimp/prawn/fish farm.....	35
Table 4.10: Stress magnitude of the shrimp/prawn/fish farm ecosystem in the Dumuria Upazila	36
Table 4.11: Production loss due to climate induced disease	38
Table 4.12: Aquaculture fish production under different climate change scenario.....	38
Table 4.13: Aquaculture production system in different unions of Dumuria Upazila	39
Table 4.14: Adaptive measures for farm management	40
Table 4.15: Adaptive measures for disease control.....	40
Table 4.16: Summary of climate vulnerability assessment for culture fisheries in Dumuria Upazila	41
Table 4.17: Distribution of engagement in fish related activities with family members dependency.....	43
Table 4.18: Impacts of hazards on gender.....	45
Table 4.19: Status of adaptive capacity of women involved in fishing and fish farming	46
Table 4.20: Summary of climate vulnerability assessment for F&A based women in Dumuria Upazila	46
Table 5.1: Risk of cyclone, storm surges, salinity intrusion flood, Tidal flood and wave action on capture fisheries with adaptation options	50
Table 5.2: Risk of drought, lightning, and heat stress on capture fisheries with adaptation options	55
Table 5.3: Risk of cyclone, storm surges, salinity intrusion, flood, tidal flood and wave action on culture fisheries with adaptation options	58
Table 5.4: Risk of drought, lightning and heat stress on culture fisheries with adaptation options.....	61
Table 5.5: Risk on women with adaptation options	64

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
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
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
WARPO	Water Resources Planning Organization
WSS	White Spot Syndrome
WT	Water Temperature
WTP	Willingness to Pay



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 Dumuria Upazila of Khulna 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 8 m, 3% area is lying below Mean Sea Level (MSL) and about 65% of the area is lying between 0-2 m. These low-lying areas are subjected to flood, tidal flood, sea level rise which inundate, 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 Dumuria 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, 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 and seasonal water bodies in Dumuria Upazila were found to have increased from 1990 to 2020 by 50% and 94% respectively. The reasons behind these changes are many, including sea level rise and consequent increase of intertidal area, which usually create temporary waterlogged areas in low lying regions. The increasing of water body may also be due to the massive shrimp farming in the region. Salinity levels in the ponds are rising, especially during the pre-monsoon and winter seasons, which results in the disappearance of local species from the water bodies. Particularly the homeostasis of the pond environment may be negatively impacted by the coupled or combined effects of temperature and salt. This is due to the synergistic effect of both rising temperatures and an increase in salt, which further deteriorates the environment for fish species' survival.

The water quality tests undertaken found that DO (Dissolve Oxygen) values were suitable for the growth of fisheries. 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 Atlia, Bhandar Para, Dhamalia, Gutudia, Rudaghara unions were moderately 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, Dhamalia, Atlia, Bhandar Para, Magurkhali and Rudaghara unions were found to be high climate risk unions for both time periods.

The study further estimated that the magnitude of temperature induced stress on river seasonal migratory fishes will be increased in the 2036-2065 and 2070-2100 under SSP1-2.6 scenario by 0.41% and 0.22% respectively with increasing 1°C mean water temperature. However, this magnitude decreased by 0.19% with an 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 both capture and culture fisheries was assessed through indicator-based analysis and Rudaghara union was found to be highly sensitive to climate change-induced hazard. Adaptive capacity assessment revealed that Atlia, Dhamalia, Dumuria, Gutudia, Kharnia, Magurkhali, Maguraghona, Raghunathpur and Rangpur unions had high adaptive capacity for capture fisheries whereas Bhandar Para, Dhamalia, Dumuria, Gutudia, Kharnia, Magurkhali, Maguraghona, Raghunathpur and Rangpur unions had high adaptive capacity for culture fisheries. Climate change induced hazard risk for capture fisheries impact chain analysis showed Raghunathpur, Rudaghara, Maguraghona, Atlia, Magurkhali and Bhandar Para unions under high risk for the base period whereas, in 2050s, Dhamalia, Rangpur and Gutudia unions will be in high risk zone along with the high-risk union at the base period. For culture fisheries, Maguraghona, Magurkhali, Rudaghara, Raghunathpur and Rangpur unions are in high risk for both time periods.

Most of the women in Dumuria are involved in household related activities, with only a few of them (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. Gender sensitivity analysis to climate change revealed that Atlia, Dumuria, Gutudia, Kharnia, Magurkhali, Maguraghona and Raghunathpur union were highly sensitive while Dhamalia had medium sensitivity and rest of the unions had low sensitivity for Gender specific fisheries livelihood. Adaptive capacity assessment showed Atlia, Dumuria, Gutudia, Kharnia, Magurkhali, Maguraghona Rangpur, Rudaghara and Raghunathpur unions have a moderate adaptive capacity for gender-based livelihood. Only Dhamalia union showed high adaptive capacity gender and rest of the unions had moderate adaptive capacity.

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

1 Introduction

1.1 Background

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

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

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

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

1.2 Study objectives

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

1.3 Approach of the study

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

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

were used: Focused Group Discussions (FGDs), Community Surveys, and Key Informant Interviews (KIIs). The study conducted 3 FGDs with Community based Organizations led by Women, capture fisheries group and culture fisheries group/fish farm owner. Senior Upazila Fisheries Officer (SUFO), fish trader and Gher Owner were interviewed for KIIs. Three community surveys at Akhra, Sarafpur, Keoragate 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 Dumuria Upazila with mostly groups of people from the fishing community to collect qualitative information regarding hazards, exposure, vulnerabilities, existing coping mechanism or adaptation practices, and challenges of gender for risk reduction, livelihood mapping, ecosystem vulnerability assessment etc. The primary focus of the FGDs was to customize of the impact chain, particularly for their project site and extract weights of identified elements by them. For FGDs, about 12 people, both male and female. Aged between 25-65 years were chosen.

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

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

where, WT = Water Temperature and AT = Air Temperature

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

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

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

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

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

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

1.4 Limitations of the study

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

- Limited availability of adequate data and information to desired spatial and temporal level for different indicators
- Lack of gender or sex-disaggregated datasets
- Limited resources resulted in few representative sampling. 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 Dumuria Upazila, highlighting the geographical setting, hydrology, climate, land cover, demography of fisheries communities etc. Further, prevailing aquatic ecosystem and its services are outlined.

2.1 Geographical features

The Dumuria is located in Khulna district of Khulna Division of Bangladesh. It shares boundary with Phultala Upazila on the north, Batiaghata and Paikgacha Upazilas on the south, Batiaghata and Sonadanga thanas on the east, Tala Upazila of Satkhira and Keshobpur, Monirampur, Abhaynagar of the Jashore district on the west. The land elevation of Dumuria Upazila mostly varies between 2 to 8 m, 3% of the area is lying below Mean Sea Level (MSL) and about 65% 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 454.23 sq. km. Fresh water aquaculture dominates among the landuse types in Dumuria upazila which accounts for about 38% of the total land cover. Rural settlement (20% of the total land cover) is observed to be the second most dominant type among the other classes. Total water body combining brackish water aquaculture, river and khals, contains about 17% (6064.8 ha) of the upazila, these water bodies are source of fresh and brackish water fisheries. Besides, the other remaining land types are less dominant compare to these land classes which are namely brickfield, built up non-linear, orchards and other plantation etc.

2.2 Hydrological system

The main rivers of Dumuria Upazila are Bhadra river, Salta River, Hari River. The 43-kilometer-long, meandering Bhadra river originates in the Haporkhali river of the Khornia Union of the Dumuria Upazila and flows into the Haborkhali River of the Deluti Union of the Paikgacha Upazila. On the other hand, Salta River originates as well as falls into the Bhadra river. The river flows through Dumuria and Batiaghata Upazila. The Hari River originates from Muteswari Teka river of Abhaynagar Upazila of the Jashore district and flows through Abhaynagar, Monirampur, Keshobpur and Dumuria Upazila. The effect of tide prevails in these rivers. **Figure 2.1** illustrates the hydrologic system of Dumuria.

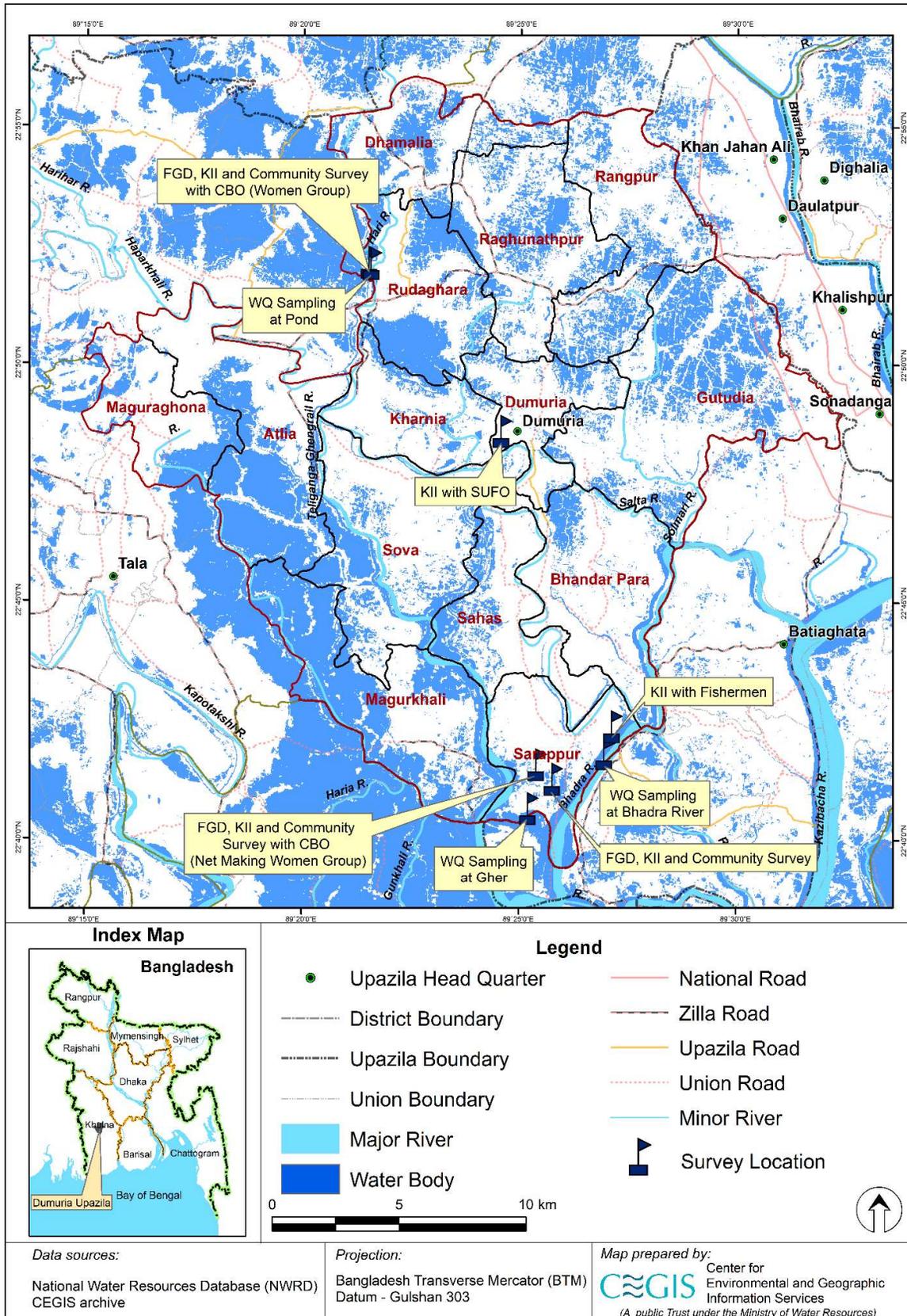


Figure 2.1: Hydrological system and location of primary survey

2.3 Aquatic ecosystem and its services

The major aquatic ecosystem within consists of river and fish pond. In addition to the major rivers, there are 103 Jalmahals, numerous gher and ponds in Dumuria Upazilla. 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, transports freshwater, irrigation water for agriculture and flows for navigation purposes; supports diversified flora and fauna; Additionally, it promotes tourism.

2.4 Fisheries resources

Dumuria Upazila is rich in fisheries resources due to having multiple rivers, connecting khals, and huge aquaculture area including shrimp farm and pond. The Upazila has vast water area covering 485 ha river, 957 ha khal, 400 ha floodplain, 1,608 ha pond, 6,792 ha Bagda farm, 11,146 ha Golda farm, 82 ha borrow pit and 6,799 ha crab fattening farm which contribute about 16,220 MT of fish and 10,353 MT of shrimp annually (Upazila Fisheries Office, Dumuria, 2021). The Upazila has 5,498 registered fishers who are involved directly in fishing activities. Moreover, a good number of people, both male and female, engage in fishing activities in the nearer rivers and khals. In addition to this, a good number of people involve in the shrimp processing and trading related activities.

2.5 Demographic characteristics

The Upazila has a population of 3,05,675 people; 50.01% male and 49.91% female. It has 14 unions, 204 mouzas/mahallas and 237 villages. The total number of the households is 77,205 with an average household size of 4.4. The population density is 610 per sq km. Average literacy in the Upazila is 55.66%. Main occupation include agriculture, agricultural labor, wage laborer, forestry, fishing, commerce, service and transport. About 1.8% people are associated with fish culture and capture. People in this area are dependent on both capture and 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.

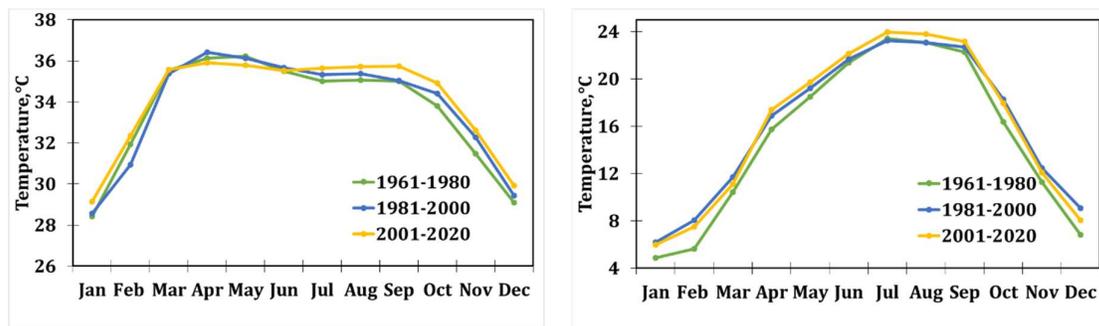
3.1 Climate change scenarios

3.1.1 Temperature

Temperature data analysis from 1961 to 2020 for Khulna Station of Bangladesh Meteorological Department (BMD) 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, 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, 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 the 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

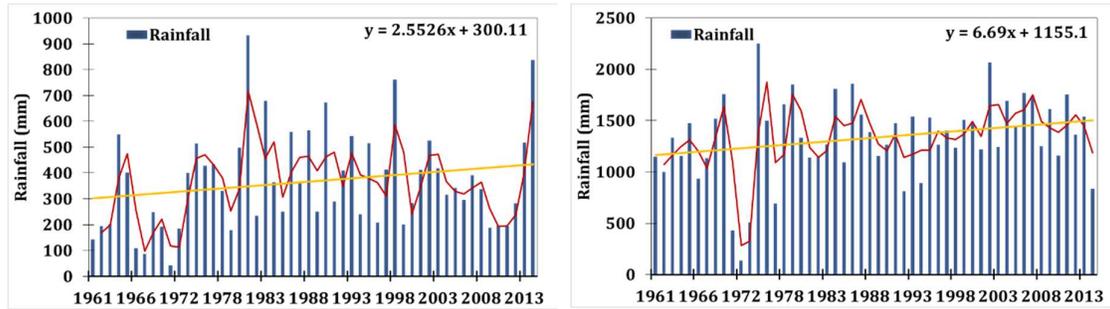
Figure 3.1: Average minimum (left) and Average maximum (right) temperature of Khulna station

3.1.2 Rainfall variability

Rainfall data analysis (1961-2020) for the dry season (October to March) and wet season (April to September) is shown in **Figure 3.2**. It 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). The area experiences distinct seasonal variations: the winter season (DJF), which is generally dry and contributes 2 percent of the total annual rainfall; the rainy season (JJAS) 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 pre monsoon hot season (MAM) perceives 17 percent of convective thunderstorms or northwester (locally known as Kalbaishakhi).

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.

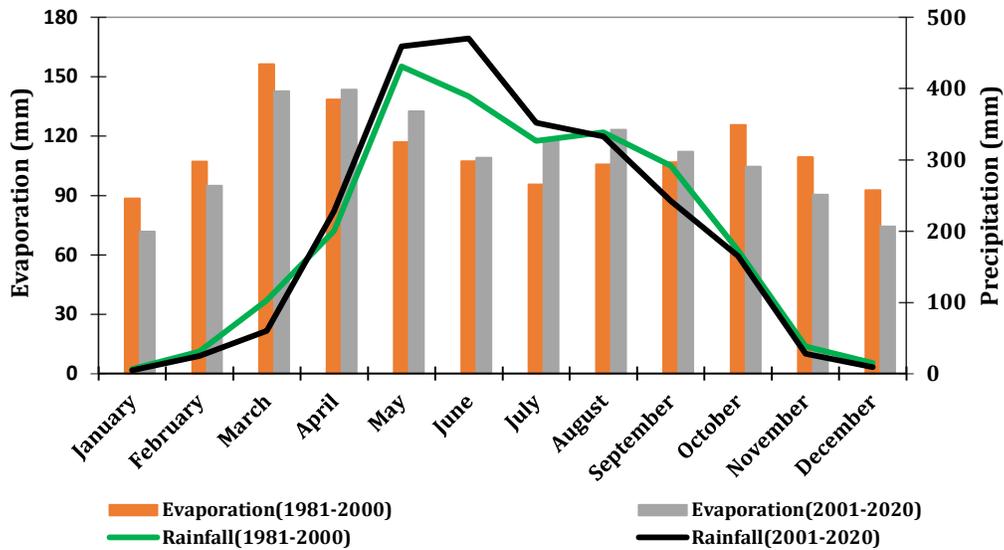


NWRD, BMD

Figure 3.2: Dry and wet season rainfall at Khulna station

3.1.3 Evaporation

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



NWRD, BMD

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

3.2 Climate hazards and its impacts

Dumuria Upazila is particularly vulnerable to flood, cyclone, storm surge, drought, extreme hot days, salinity intrusion, thunder storm, severe cold days etc. Total 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 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/Tidal Flood	2	↔	2
Cyclone	3	↑	3
Storm Surge	4	↑	1
Drought	7	↔	2
Extreme Hot Days	1	↑	3
Salinity Intrusion	5	↑	2
Thunder Storm	8	↑	2
Severe Cold Days	6	↑	2

CEGIS Field Survey, 2022

The present study identified five major climatic hazards for fisheries and aquaculture as found in Dumuria Upazila (**Figure 3.4**). Among the hazards, heavy rainfall is identified as the most prominent hazard for capture fisheries. Moreover, fishing activities are highly exposed to extreme hot days. Furthermore, most fishermen have been facing problems in fish handling and transportation to the existing fish landing sites and even fish markets due to heavy and erratic rainfall.

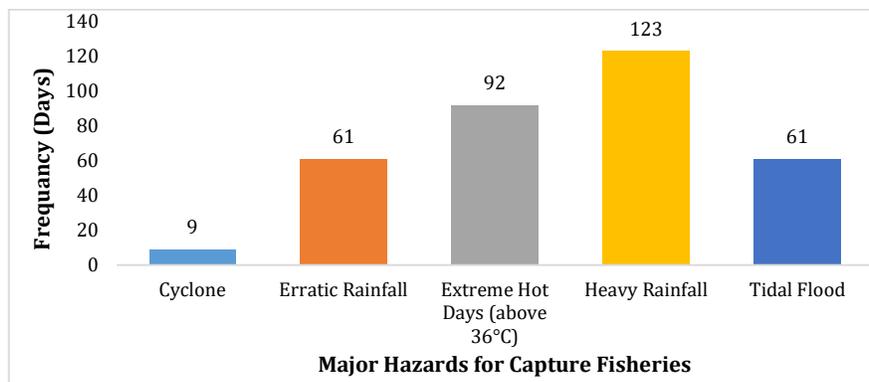


Figure 3.4: Frequency of climatic hazards on the capture fisheries

CEGIS Field Survey, 2022

According to the hazard calendar developed by the fishing community, in recent years, extreme hot days are causing problem in fish culture. Less rainfall accompanied by extreme heat cause the water temperature to get higher which create hostile environment for fish species. Flood is lasting longer in recent times. In the past, flood used to occur during the Bangla month of Boishakh to Sraban. Intensity and frequency of cyclone are increasing in recent time. Effect of saline water is less in the region. Other than the heat stress and cyclone the intensity of each hazard is moderate and intensity of drought is low. Storm surge, cyclone, occupies the same duration of occurrence.

Cyclone and storm surges

Being located in the south-western coastal region of Bangladesh, Dumuria Upazila in Khulna districts has faced numerous catastrophic severe cyclone events, especially in the last two decades, including Sidr, Fani, Mora, Aila, Rashmi, Roanu, Amphan and others. It appears that 38 cyclonic events affected South-West coast between 1877 and 2010. Between 1970 and 2010, seven severe cyclones (>90 km/hours wind speed) devastated south-west coast and the local communities. 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 Maguraghona, Magurkhali, Sarappur, Sova, Bhandar Para, Gutudia, Rangpur, Kharnia and Atlia in Dumuria Upazila 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 Maguraghona, Magurkhali, Sarappur, Bhandar Para, Gutudia Union.

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 ghers as well as privately owned fishing gear like boats and nets are among the damages to the fishery subsector. The cost of these damages was estimated at Tk463 million (\$6.7 million) for the ten most impacted areas including coastal areas of Khulna District.

On May 25, 2009, Aila struck Bangladesh's southwest coastal regions, affecting 15 districts, 76 Upazilas, and 491 Unions. At least 30 kilometres of embankment have been partially damaged in Dacope, Botiaghata, Paikgasa, and Dumuria upazilas due to Aila. Fish farms of 1,545 hectares of land in 24 unions of coastal Koyra, Dacope, Paikgachha, Batiaghata and Dumuria upazilas of Khulna have been damaged by the tidal surge caused by cyclone Yaas in 2021. 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 forests and shrimp farms in Dumuria were flooded with seawater due to this cyclone. The frequency and impacts of such extreme events are reported to be increased under climate change scenarios.

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. 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.

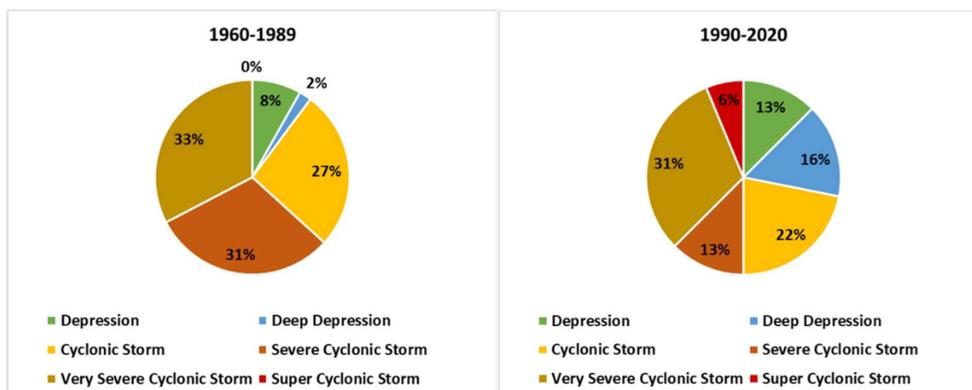


Figure 3.5: Distribution of high intensity cyclone along the Bangladesh coastline

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 Dumuria 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 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 of the CEGIS Bay of Bengal model (2020) reveals that Dumuria Upazila will be intruded by more than 9ppt surface water salinity by 2050s under extreme climate change scenario i.e. SSP5-8.5. As presented in the **Figure 3.6** below, 4 out of 14 unions of Dumuria Upazila are experiencing surface water salinity near 9ppt and rest of the union are above 25ppt. By 2050 all the union of Dumuria Upazila will be experiencing salinity over 9ppt and 9ppt isohaline line will shift on average 18.7 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 Dumuria Upazila for base period 2011 and future (2050) under SSP 5-8.5.

About 68% area of Dumuria is affected by salinity due to occurrence of storm surge (Islam and Gnauck 2010). In 2020, around 50 hectares of farmland were flooded with salt water after a dam broke in Kulbaria area in Dumuria upazila, Khulna.

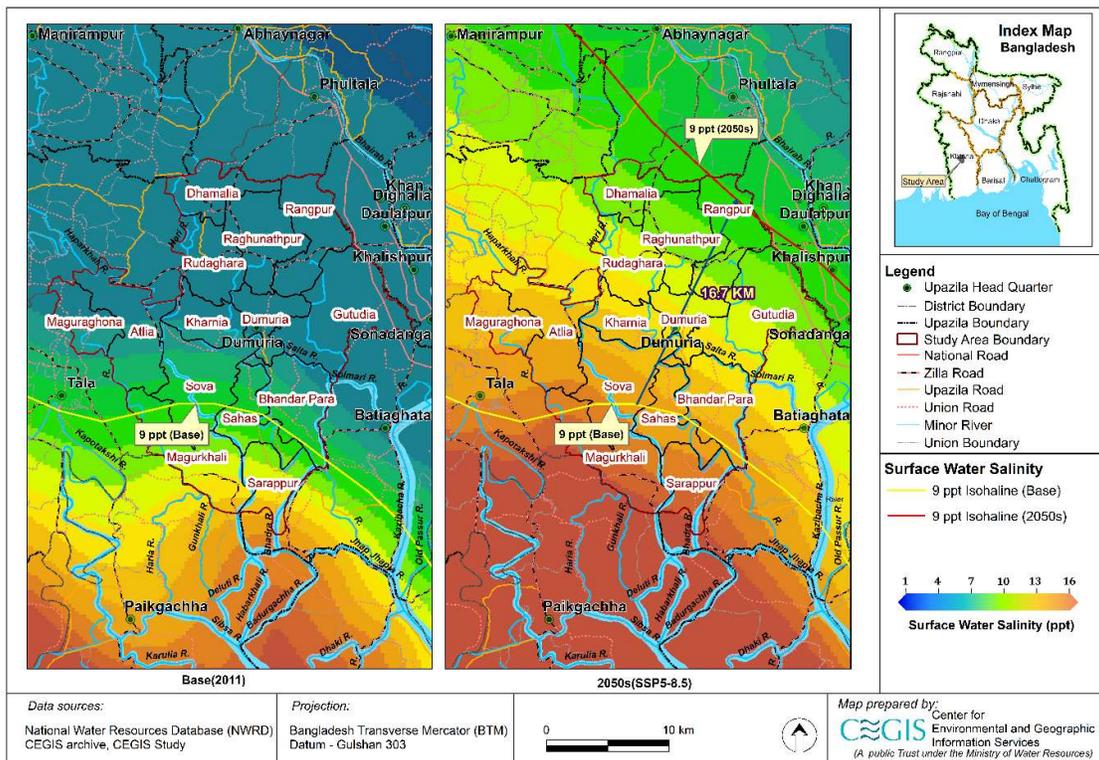


Figure 3.6: Salinity intrusion in Dumuria Upazila

Heat wave

Heat wave frequency and severity are expected to increase in the future (Kirtman et al. 2013). About 39 heat waves in the 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 Dumuria are facing numerous challenges, most importantly various viral, bacterial and fungal diseases (Islam et al. 2018).

Floods

Almost every year, many shrimp farms in Dumuria Upazila get flooded. River bank erosion, mainly due to floods, is causing river siltation in Hari, Salta and Bhadra River in Dumuria 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 and fishers who used to go fishing around the Sundarbans by boat, capture fishes in floodplains during the floods.

Drought

Droughts associated with high temperature and low rainfall have adverse impacts on aquaculture and inland open water fisheries in some areas in Dumuria 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 locality of Dumuria. This is now also affecting affects migration, breeding and growing of fish and other aquatic animals. Boro production has been reduced due to increasing drought events in this area.

Lightning

CEGIS (2022) analysed lightning susceptibility of Bangladesh based on historical human death toll due to lightning based on BMD data. It depicted that the lightening susceptibility of SW zone is comparatively less than another zone of Bangladesh. Reportedly, untimely lightning and thunderstorm is increasing all over the country, which are anticipated to affect the spawning and breeding of fisheries. Besides this, lighting damages infrastructure in fish-cultivated areas. There is some evidence that fishermen and fish farm owners get injured and die due to 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	Cyclone	SLR	Drought	Storm Surge	River Erosion	Extreme hot temperature	Salinity Intrusion	Lightning	Wave Action
Bio physical	Salinity Increase	Yellow		Green	Red	Red		Red			
	Area Inundated	Red		Green		Green	Yellow				
	Low water availability	Green			Yellow			Yellow	Green		
Ecosystem	Extensive Algae Bloom (FW)							Green			
	Decreased flora & Fauna	Yellow		Red	Yellow						Yellow
	Stress on aquatic species abundance and distribution	Yellow	Yellow								
	Infrastructure damage										

3.4 Multi-hazard mapping for Dumuria upazila

A multi-hazard scenario for Dumuria Upazila was assessed using field finding, community perceptions and available secondary data layer and is presented in **Figure 3.7**. Salinity intrusion, Flood, Cyclone, Storm Surge, Drought, Extreme Hot Days, Sea Level Rise, 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, sea level rise and temperature data are projected for 2050s and other hazards are considered constant as base period during multi-hazard mapping using geo-spatial techniques. Almost all the unions of Dumuria Upazila are found exposed to multiple climate hazards. Maguraghona, Atlia, Sova, Bhandar Para, Magurkhali and Sarappur unions were found to be in highest severity and Dhamalia, Rangpur, Gutudia, Raghunathpur, Rudaghara, Dumuria, Kharnia and Sahas unions are found under moderate risk for multi-hazards in the base period. For future 2050s under extreme climate change scenario, except Dumuria, Gutudia, Kharnia unions, the remaining unions will also fall under high risk of multi hazards. **Figure: 3.7** below highlight the multihazards outlook for 2050 based on 2011.

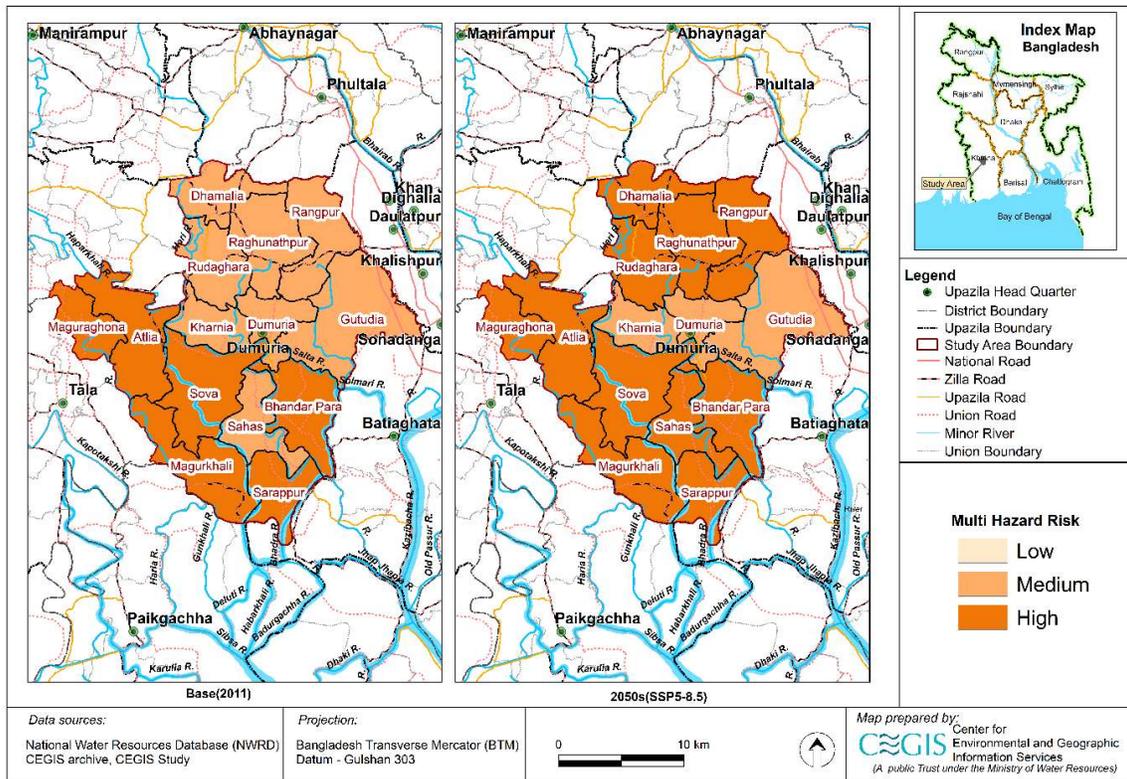


Figure 3.7: Multi hazard maps in Dumuria Upazila

4 Climate Risk and Vulnerability

This chapter presents the key outcomes of the study, which is climate risk and vulnerability for the Dumuria 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. Following sections describe the key elements of risk and vulnerability separately for these four priority focus areas, which are, exposure, sensitivity, adaptive capacity, vulnerability and risk. Risk and vulnerability assessment is done based on blended approach of participatory appraisal techniques and scientific analysis for base and 2050s under extreme climate change scenarios.

4.1 Aquatic ecosystem

4.1.1 Exposure

Almost every year, the 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 Dumuria (Annex I). The exposure status of hazards to aquatic ecosystem in Atlia, Bhandar Para, Dhamalia, Gutudia, Rudaghara, Kharnia, Magurkhali, Maguraghona, Raghunathpur and Rangpur are identified as high (**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 unfavourable and severely disrupt the ecosystem services. The study analysed the ecosystem climate sensitivity (change in habitat area, disruption of ecosystem services and aquatic habitat condition) of both River and Pond/gher ecosystem.

Change in habitat area

The change of perennial and seasonal waterbodies assessed provides information of the intra-annual behaviour of such waterbodies. **Figure 4.1** shows the change in waterbody extent from 1990-2020. Dumuria Upazila shows considerably higher extent of surface water increase. The permanent water bodies in Dumuria are found to be increasing from 1990 to 2005. The seasonal waterbodies also increased between 1995 and 2015. Increasing trends of the permanent and the 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. The increasing of water body may also be due to the massive shrimp farming in the region. In the coastal areas climate and water related disasters such as floods, cyclone, storm surges and tsunamis may cause inundation which leads to increase in waterbodies. Overall, this assessment revealed that increased saline or brackish water habitat and overall increase in waterbody and, therefore, adaptation in fish farming practices need to be planned accordingly.

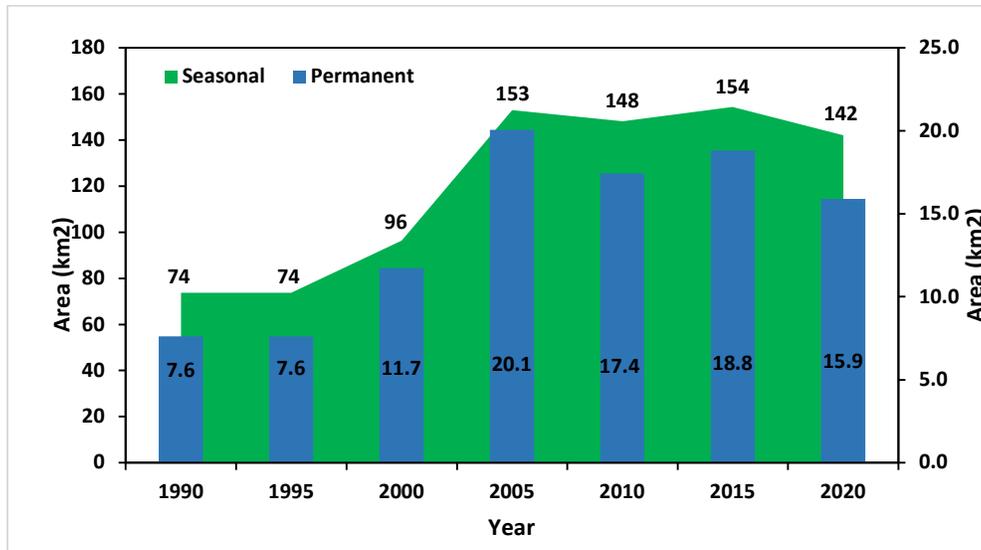


Figure 4.1: Waterbody changes in Dumuria Upazila

Disruptions of ecosystem services

The aquatic ecosystem of the study area provides numerous ecosystem services as reported by the communities during FGDs and community survey. Potential ecosystem services found are food, fuel, timber, medicines, ornamental resources, and clay soil. Aquatic organisms commonly found in rivers and ponds are kuche fish/Gangetic Mudeel, (*Monopterus cuchia*), Shol/Snakehead Murrel (*Channa striatas*), Magur/Torrent Catfish (*Gagata youssoufi*), Shing fish/Asian stinging catfish (*Heteropneustes fossilis*) etc. are used for food and medicine production. Among the plants in aquatic ecosystem, Thankuni/Asiatic pennywort (*Centella asiatica*), Durba ghash/ Bermuda grass (*Cynodon dactylon*), Akand/ Crown flower (*Calotropis gigantean*), Arjun (*Terminalia arjuna*), Neem/ Indian Lilac (*Azadirachta indica*), Tulshi (*Ocimum tenuiflorum*), etc. are used as medicinal plants.

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 is 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, withdrawal of water for daily use. 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 providing, regulating and supporting services as described above, local communities reported that aquatic ecosystem in Dumuria also provides opportunities for cultural services such as revenue earning from eco-tourism. Being surrounded by different rivers, many tourist's attraction places are developed beside the river in this Upazila which attract tourists all year round to observe the scenic beauty, serenity, unique and diversified animals, tranquility and for their relaxation.

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

of 0-15 representing low value, 16-30 representing medium value, and 31-45 representing high value. The results show that both the river and pond ecosystem are in moderate conditions but the pond ecosystem has higher strengths-opportunities and lower weakness- threats because of their natural land-cover types and ideal water quality. The results also showed that the river has more weakness and threats and low strengths-opportunities due to rapid urbanization and environmental pollution and encroachment.

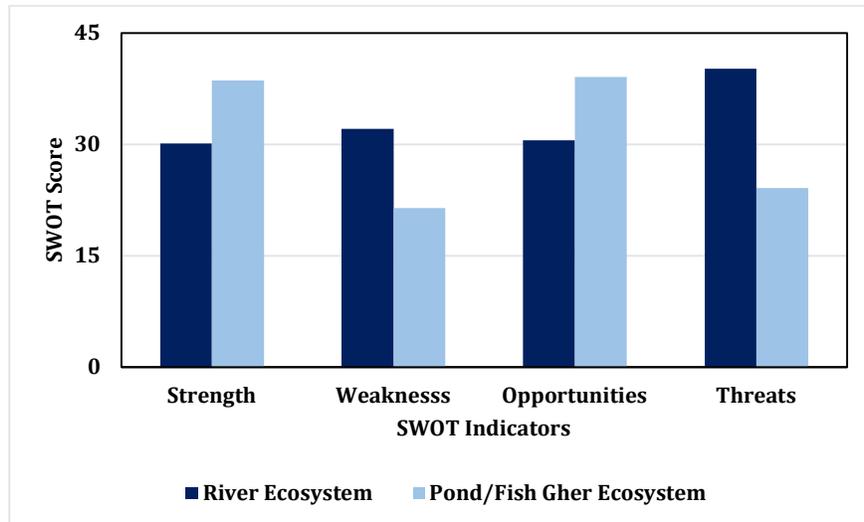


Figure 4.2: SWOT results of aquatic ecosystem services

To enhance the ecosystem services from both rivers and fish pond ecosystem, identified weakness and threats will need to be addressed to increase the related benefits sustainably. Therefore, ecosystem approaches for aquaculture (EAA) or ecosystem approach to fisheries (EAF) should be followed to manage fishery ecosystem and its climate sensitivity in a sustainable way. Integration of fishery ecosystem during structural or non-structural intervention design for adaptation and resilient building is needed to be mainstreamed 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 the four categories for the river and pond. 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.

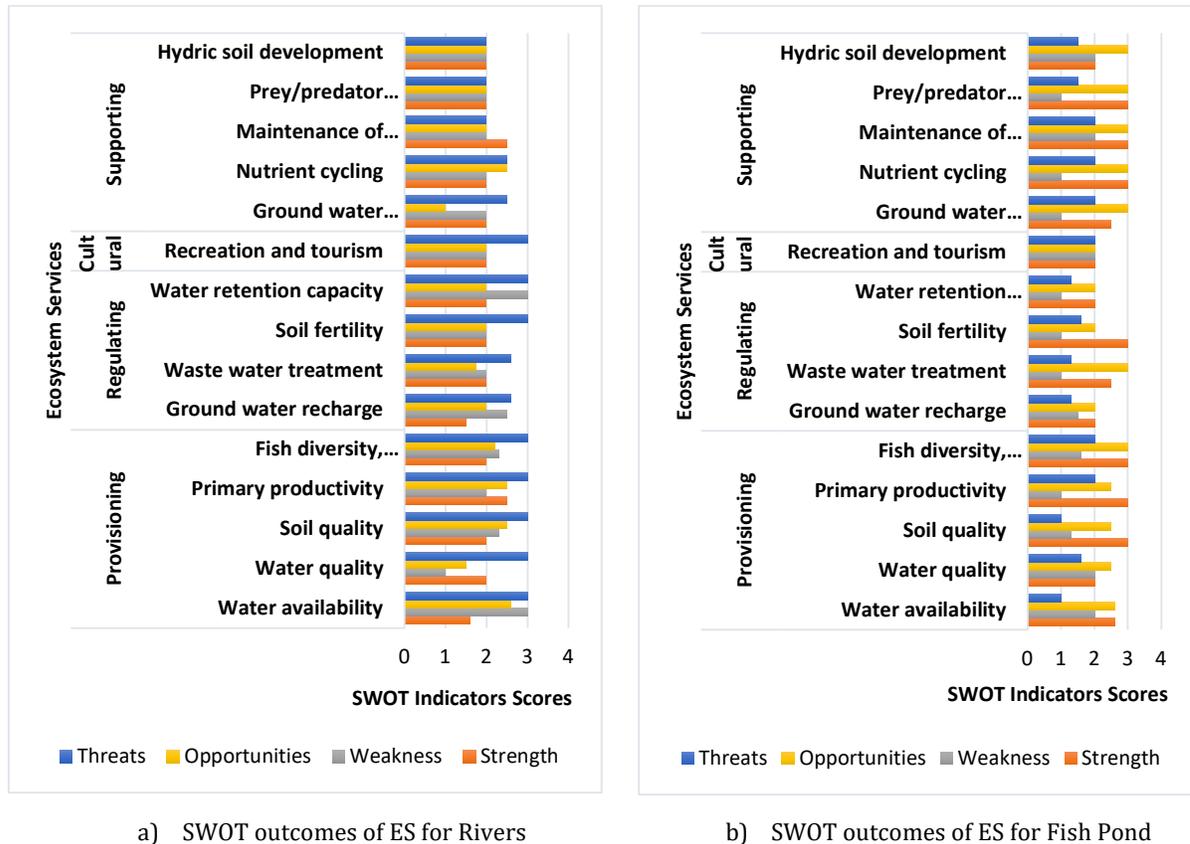


Figure 4.3: SWOT outcome for river and ponds/gher ecosystem

Aquatic habitat condition

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

EC values of river and fish pond water samples were 5960µS/cm and 73200µS/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 for river and fish pond are not suitable for fish culture. TDS of water mainly indicates the presence of various minerals and the 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 either.

A Total of 6 phytoplankton species have been recorded from Bhadra River. Out of which, *Protoperidinium cyst* and *Astasia cylindrical Pringsheim* are found abundant in the river water. In case of fish pond, total 5 phytoplankton species have been recorded where *Chroomonas coerulea* and *Astasia cylindrical Pringsheim* species are found in abundant. 2 zooplanktons species have been identified from the Bhadra river systems and lotic waterbodies within the study area where *Brachionus quadridentatus* species has the higher abundance. Only *Brachionus rubens* zooplankton species has been identified from the fishpond ecosystem. Communities during surveys reported that algal blooms occur frequently due to increased water temperature that causes fish mortalities specialty during summer. In addition, during the pre-monsoon and winter seasons, raising trend of salinity usually results in the disappearance of local species from the water

bodies. Apart from climatic factors, farmers reported water quality deterioration land degradation, water pollution and decreased water levels are deteriorating habitat and production of fish in river. Beds of the rivers and nearby canals have been silted up those results in 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 in Dumuria

Sample ID & Unit	Physical and Aggregate Properties of Surface Water Resource								
	pH	Temp	DO	EC	TDS	BOD	COD	Nitrate	Salinity
	-	°C	mg/l	µS/cm	mg/l	mg/l	mg/l	ppm	ppt
River	8.4	30.7	6.9	5960	2900	1.06	20	9.1	8.0
Fish pond	9.3	32.3	9.8	7320	3530	1.96	162.5	4.2	4.92
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	(5.18-9.72) 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 different study source and Red color shows the parameters which exceed the standard reference value or threshold

The combined sensitivity analysis (**Table 4.2**) using the habitat extent, condition and ecosystem services related indicators, it has been found that Atlia, Bhandar Para, Dhamalia, Gutudia unions were highly sensitive ecosystem whereas Kharnia, Magurkhali, Maguraghona, Raghunathpur, Rangpur unions were found as moderately sensitive ecosystem.

4.1.3 The capacity of aquatic ecosystem to adapt

Rapid restoration and regeneration of plankton and vegetation; abundance of flora and animals; soil health; decomposition of leafs and plant parts and co-management of biodiversity; 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 capacity of river and pond 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

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

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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.

sediments and nutrients, and source of food and habitat. On the other hand, Pond ecosystems also have some inherent ability to change, like cope with climate hazards. Apart from the system's inherent ability to cope with the nature, field survey revealed that people generally use fencing and netting around ponds to prevent the escape of stocked fish as well as invasion of predator fish during floods. Local people harvest rainwater with storage facilities for aquaculture in the dry season. Using rainwater for fish culture and pond-dike cropping increases water use efficiency. According to KIIs survey, pond-dike cropping can help to cope with increased water temperature. Plantation of suitable trees on pond-dikes can provide shade on water for fish and stabilize soil. Local people are practicing Ecosystem-based Adaptations (EbAs) in the pond ecosystem. To increase the primary productivity of the ponds, local people normally use urea; triple super phosphate (TSP); muriate of potash (MP); gypsum, and zinc sulphate (ZnSO₄). Lime CaO, Ca(OH)₂ and CaCO₃ are being used to improve biological activity, oxygen, decomposition, maintain pH of pond water 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 Rudaghara have high adaptive capacity compared to remaining unions which have low adaptive capacity. Adaptive capacity of the ecosystem of these unions can be increased through wetland conservation, pollution control through regular monitoring and maintenance. A reserved wetland could be a sanctuary for the fauna and other aquatic habitat, it may work as a safe haven for their reproduction purpose.

4.1.4 Vulnerability of aquatic ecosystem

Vulnerability of ecosystem is obtained analyzing adaptive capacity and sensitivity of the system. From the assessment (**Table 4.2**), it is found that Atlia, Bhandar Para, Dhamalia, Gutudia, Rudaghara unions are moderately vulnerable to climate change induced hazards. These union have high sensitivity and low adaptive capacity to cope with the hazards. The other unions ecosystem are found low vulnerable to climate change induced hazards.

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

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Atlia	High	High	Low	Medium
Bhandar Para	High	High	Low	Medium
Dhamalia	High	High	Low	Medium
Dumuria	High	High	Low	Medium
Gutudia	High	High	Low	Medium
Kharnia	High	Medium	Low	Low
Magurkhali	High	Medium	Low	Low
Maguraghona	High	Medium	Low	Low
Raghunathpur	High	Medium	Low	Low
Rangpur	High	Medium	Low	Low
Rudaghara	High	Low	High	Medium
Sahas	Low	Low	Low	Low
Sarappur	Low	Low	Low	Low
Sova	Low	Low	Low	Low

4.1.5 Risk of aquatic ecosystem

Climate change risk (**Figure 4.4**) on ecosystem in Dumuria has been calculated for both base period and 2050s following the CRVA framework (attached in Annex I). At present, Maguraghona, Atlia, Sova, Magurkhali, Sarappur and Bhandar Para unions are found highly exposed to multi-hazard risk. In future, Sahas, Dhamalia, Rudaghara, Raghunathpur and Rangpur unions also fall under high multi hazard risk. These various hazards affect the aquatic ecosystem negatively throughout the year in these unions. Both the permanent and seasonal waterbody in Dumuria have been reported to increase in recent years which may be due to the increasing shrimp farming or SLR. 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, gher, 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, Dhamalia, Rudaghara, Atlia, Magurkhali and Bhandar Para unions are found under high risk in both time slices. Similarly, Dumuria, Sova, Sahas and Sarappur union is found under low risk in both time slices and the remaining unions are found under moderate risk in both time slices.

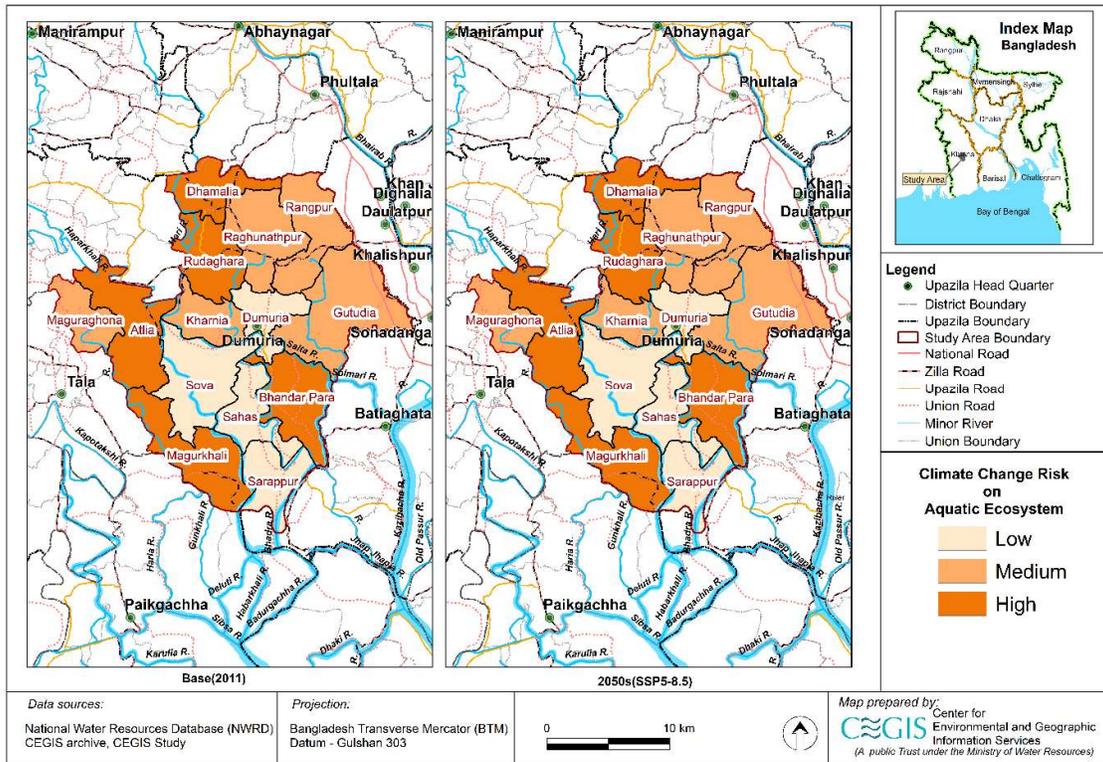


Figure 4.4: Climate risk of aquatic ecosystem in Dumuria Upazila

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 Upazila possesses a riverine habitat of about 485 ha, union-wise distribution of the riverine habitat is given in the **Table 4.3** below.

Table 4.3: Area of riverine habitat in different Unions of Dumuria Upazila

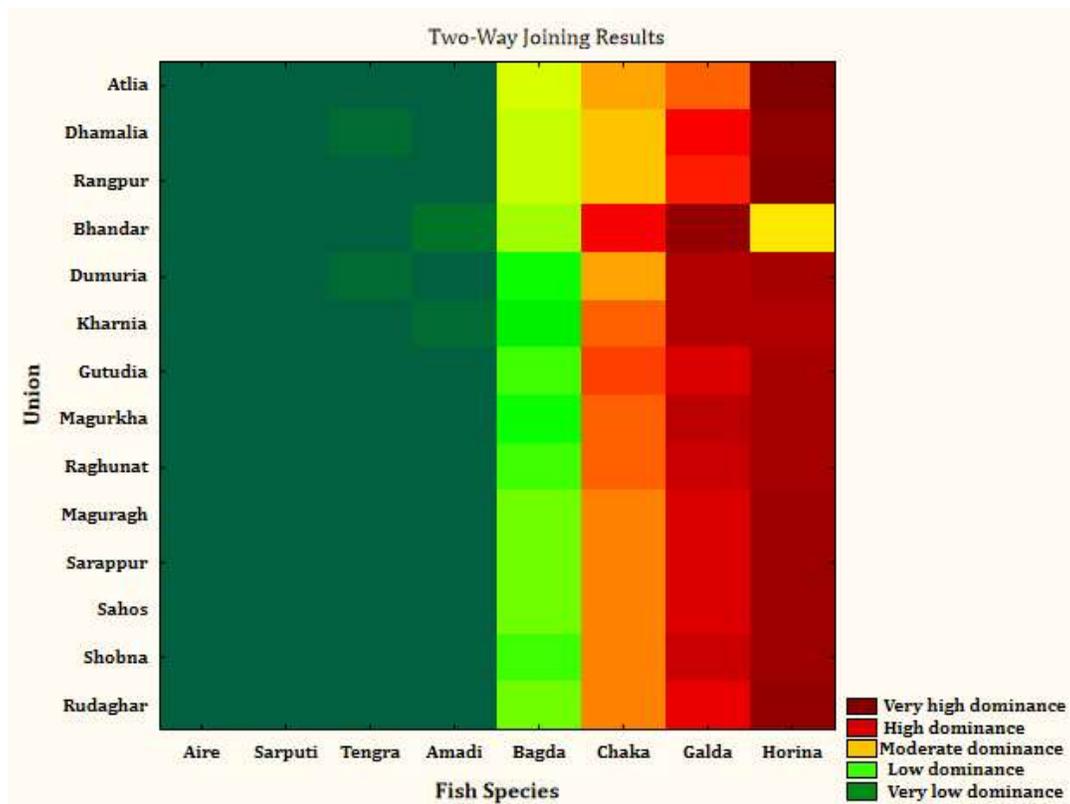
Unions	Water area (ha)
Atlia	38
Bhandar Para	67
Dhamalia	5

Unions	Water area (ha)
Dumuria	7
Gutudia	48
Kharnia	22
Maguraghona	73
Magurkhali	5
Raghunathpur	1
Rangpur	15
Rudhagora	24
Sahas	35
Sarappur	86
Sova	59
Total	485

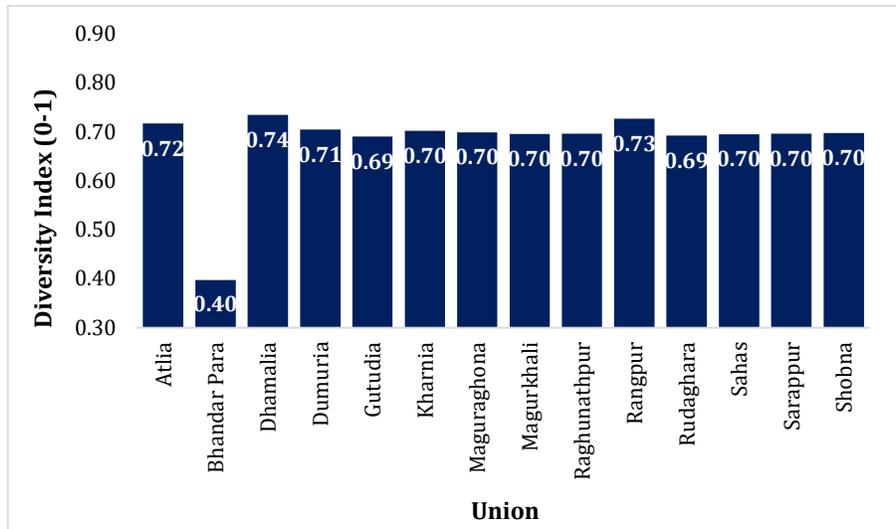
Satellite image 2019 and CEGIS Field Survey (KII with Upazila Fisheries Office), 2022

Fish diversity

The riverine ecosystem is characterized by the mesohaline, which can support euryhaline and some salt tolerant fish species. The Two-way Cluster Analysis was applied in this study to present the distribution pattern of available fish species found in the instantaneous catch among the unions in Dumuria Upazila. The present study found that the instantaneous catch is highly dominated by Horina, Galda and Chaka 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.



(A)



(B)

Figure 4.5: Species composition (A) and Biodiversity Index (B) of the instantaneous catch of different unions of the Dumuria Upazila

CEGIS Catch Assessment Survey, 2022

This study analyses the Shannon-Weiner Index (Bio-diversity Index) in order to assess the species evenness in the riverine ecosystem (**Figure 4.5-B**). The values of this index range from 0 to 1. The fractal intervals of the index values can be used to characterize the various magnitude of evenness in distribution, i.e., the value 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 Dumuria Upazila.

Livelihoods

According to Dumuria Fisheries office, about 5,187 fishermen live in this Upazila among which 5084 are male fishermen. On the other hand, there are 103 females who are involved in capture fisheries in all the unions. Women in the study upazila are considerably engaged in fish related economic activities, parallel to their male counterparts, though mostly they are involved in household activities. Only 5.7% of women (BBS, 2012) are in employment category in which 1.2% women involve in fish culture and capture related activities. It is found that fishermen catch fish mostly in open water bodies (i.e. River, Canal etc.). Field finding shows that the average monthly income of male fisher's household is BDT. 12,000 to BDT. 20,000. The income of women fishermen in all the unions lies between BDT. 7,000 to 15,000.

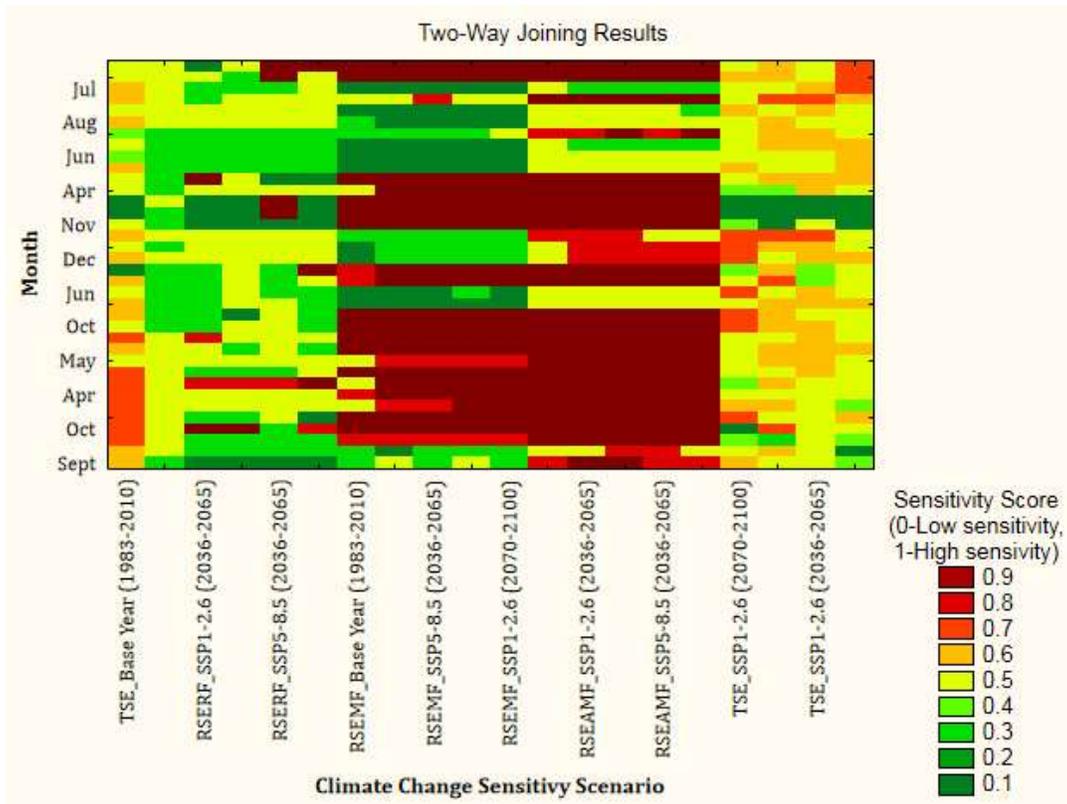
Indicators for abundance of species in open waterbodies, migratory route, and number of endangered species etc. were considered for exposure assessment. Exposure assessment results (**Table 4.7**) found that Atlia, Bhandar Para, Gutudia, Kharnia, Magurkhali, Maguraghona, Raghunathpur, Rudaghara unions are highly exposed to climate change induced hazards which may be due to high presence of river ecosystem within. Dhamalia, Munshiganj, Dumuria, and Rangpur unions are moderately exposed. Rest of the unions have comparatively lower exposure for capture fisheries.

4.2.2 Sensitivity

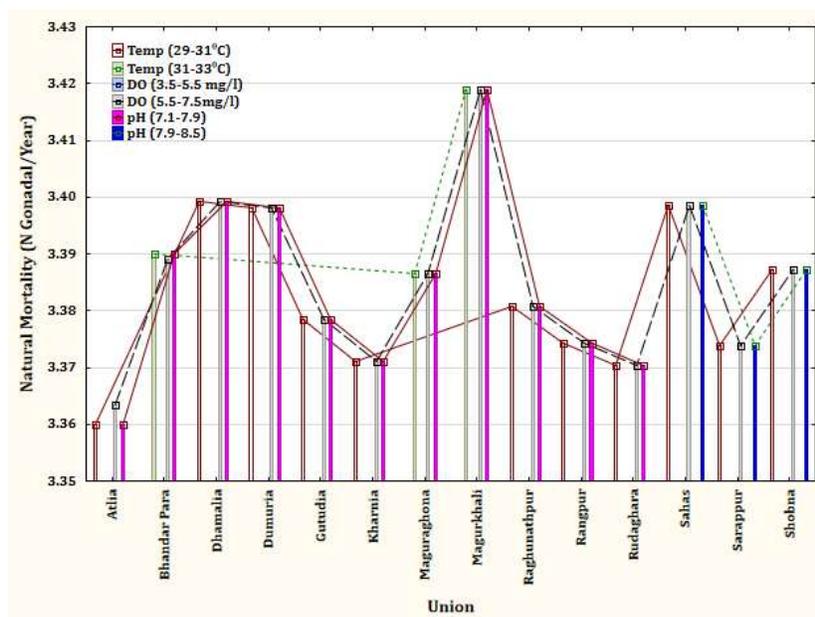
Habitat under threshold

According to the SWOT analysis on the provisioning services of the riverine ecosystem, a strong water availability condition was observed in the study area because of ensuring 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 along with 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 in **Figure 4.6-A**) 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.



(A)



(B)

Figure 4.6: Habitat sensitivity to natural mortality in the SSP1-2.6 and SSP5-8.5 scenarios

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

The investigated water quality parameters have been found to have minimum influence on the growth coefficient of the available fish species in the instantaneous catch. Moreover, natural mortality for a fish population in the riverine ecosystem is highly sensitive to a combined effect of high-water temperature (above 29°C), TDS (>1200mg/l), DO (<5mg/l) and pH (8) (Figure 4.6-B). Natural mortality in the Dhamalia and Dumuria unions is highly sensitive to pH and DO.

Fish Breeding/Spawning

Most species use river as breeding and spawning ground. On the other hand, 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 season of both Galda and Bagda is in the month of January and spawning season during February-April. Aire start breeding 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). During the rainy season, fish migrates from one place to another for spawning and breeding purposes. Timing of rainfall is a crucial factor for gonadal development which may trigger the freshwater species for successful spawning and breeding. Climate change may alter the timing of rainfall, so fish spawning time may also shift which may result in decreased fertilization rate.

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

Species	Locality	Breeding season	Spawning Season
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

Species	Locality	Breeding season	Spawning Season
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 changing scenario of water temperature and rainfall pattern play an important role in changing the phenological events of different fish groups, including fishes of euphotic, despotic and aphotic zones, river resident, and also migratory fish groups. It has been found that the magnitude of breeding/spawning success might be significantly decreased in case of Bagda and hilsa in the SSP1-2.6 scenario (Figure 4.7).

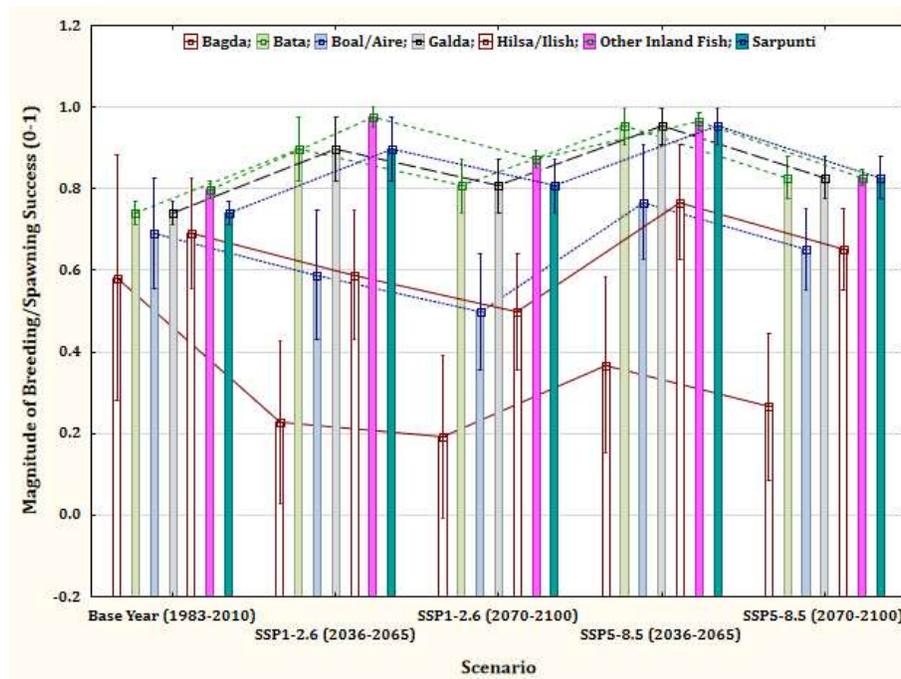


Figure 4.7: Magnitude of Breeding/Spawning success of the available fish species

CEGIS Field Survey, 2022

Fish migration

The rivers of the Dumuria Upazila provide necessary ecological demand for feeding, breeding/spawning and nursing of fries and juvenile fishes of different migratory fish species. According to the local fisher and Upazila Fisheries Officials, major longitudinal migratory fishes in the rivers are Pangas (*Pangasius pangasius*), Koral (*Lates calcarifer*), Ramchos (*Polynemous paradiseus*), and Poma (*Otolithoides pama*). The lateral migration occurs mostly for small fishes like Tengra (*Mystus bleekeri*), Guli (*Mystus gulio*), Failsha (*Liza Persia*). And small shrimp/prawn are mostly limited between the rivers and Khals. This study analysed the magnitude of the migration extent for available fishes from the instantaneous catch among the unions of the upazila (Figure 4.8-A). The values ranging from 0 to 1 are divided into five (05) 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 Harina has very high migration extent, distributing all the rivers of all the unions (**Figure 4.8-A**). According to the SSP5-8.5 (2036-2065) scenario, the migration rate for Hilsha, Aire, Bata, Sarpunti, and Galda will expand. The future scenarios, however, would not affect the migratory rates of Bagda and other inland fish.

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 for 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 alter the timing of rainfall impacting fish spawning time 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 migration route.

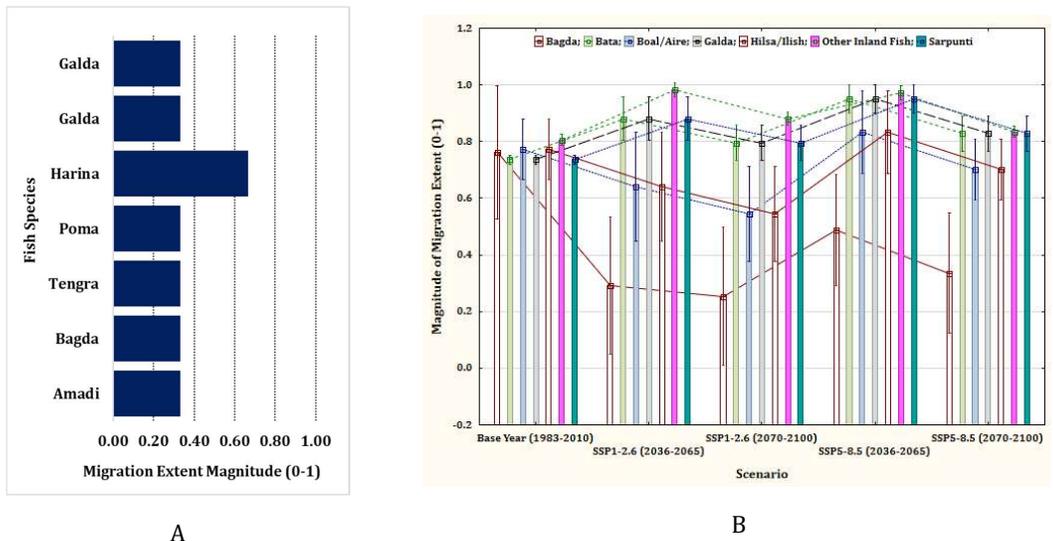


Figure 4.8: Migration extent of different migratory fish species

CEGIS Field Survey, 2022

Growth coefficient and natural mortality

The present study calculated the Growth Coefficient (K) of each available fish species found in the instantaneous catch during the study period. The Growth Coefficient is a parameter of the von Bertalanffy growth function, expressing the rate (1/year) at which the asymptotic length is approached. This value was calculated through using the maximum length of the studied fish species according to the formula of Pauly et al. (1998). Bagda has a higher growth coefficient (3.5), whereas the majority of fish species have a lower growth coefficient (1.0). 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 Aire and Horina 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).

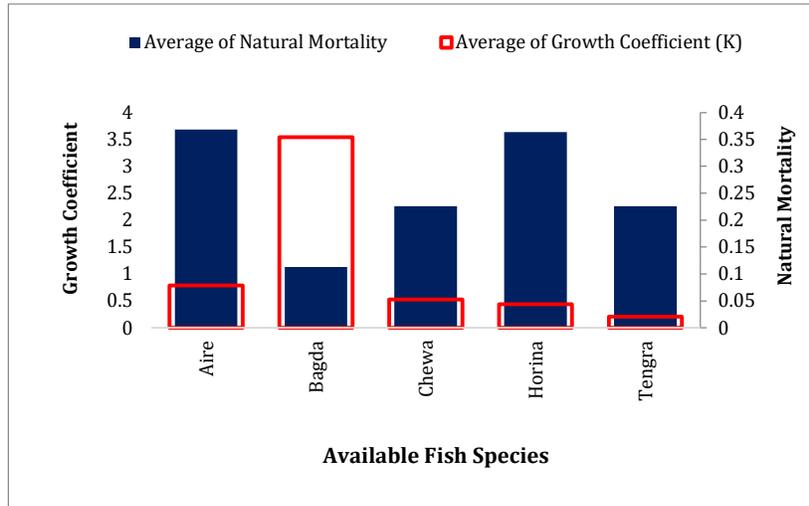


Figure 4.9: Growth coefficient and natural mortality of the available fish species in the instantaneous catch

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

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

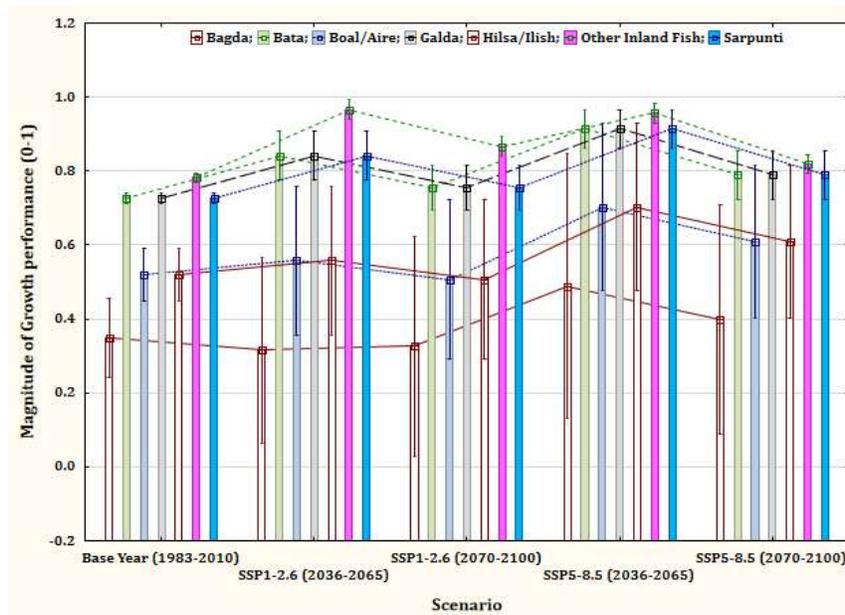


Figure 4.10: Magnitude of growth performance of the available fish species

Impact Chain Analysis, CEGIS (2022)

Fish production

The above-mentioned changes in habitat condition, fish diversity, fish migration and fish biology in respect of different climate change scenarios, total fish production in different unions of the Dumuria Upazila would be about 60 MT 61MT, 63 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

Unions	Fish Production (MT)				
	Base Year	SSP1-2.6 (2050)	SSP1-2.6 (2100)	SSP5-8.5 (2050)	SSP5-8.5 (2100)
Atlia	5	5	5	5	5
Bhandar Para	8	8	8	8	8
Dhamalia	1	1	1	1	1
Dumuria	1	1	1	1	1
Gutudia	6	6	6	6	6
Kharnia	3	3	3	3	3
Maguraghona	1	1	1	1	1
Magurkhali	8	8	9	9	9
Raghunathpur	0	0	0	0	0
Rangpur	2	2	2	2	2
Rudaghara	3	3	3	3	3
Sahas	5	5	5	5	5
Sarappur	9	9	10	10	10
Sova	7	7	7	8	8
Total =	60	60	61	63	63

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.

As a part of the risk assessment, sensitivity of fisheries sector in Dumuria Upazila was also assessed (**Table: 4.7**). Rudaghara Unions was found highly sensitive to climate change induced hazard. Only Magurkhali union was found to be in moderately sensitive zone and rest of the unions were in low sensitive zone for capture fisheries. 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 boat

The fishers face increased frequency of climate induced hazardous events like cyclone, storm surge, etc. in carrying out fishing activities. In this context, they have limited capacity to adapt with the mentioned climatic events as most of the fishers are poor and having narrow scope of coping with the hazardous situation. However, fishers usually undertake various initiatives to cope with such environment 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 Dumuria Upazila is shown in **Figure 4.11**.

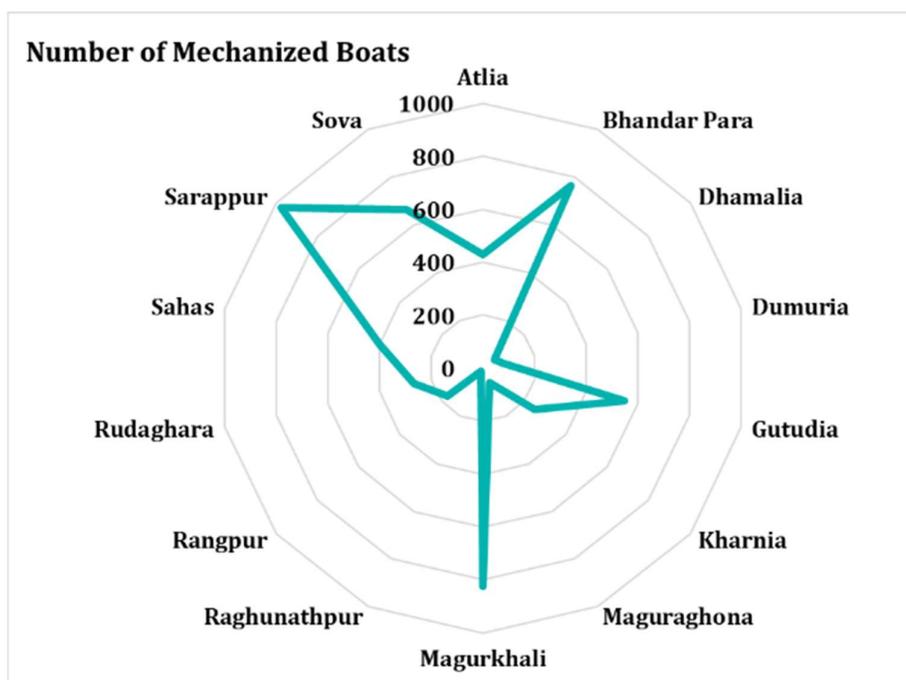


Figure 4.11: Availability of mechanized boats

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	36	32	3	0.1	36	32	10	0.3
Vesal Jal	135	45	6	0.13	135	45	11	0.24

CEGIS Field Survey, 2022

Similar to exposure and sensitivity assessment, adaptive capacity was assessed for Dumuria Upazila through indicator-based impact chain analysis. This assessment (**Table 4.7**) reveals that Atlia, Dhamalia, Dumuria, Gutudia, Kharnia, Magurkhali, Maguraghona, Raghunathpur and Rangpur unions have high adaptive capacity for capture fisheries. Bhandar Para and Rudaghara unions have moderate adaptive capacity for capture fisheries in this region. Rest of the unions are in low adaptive capacity zone.

4.2.4 Vulnerability

The study assessed vulnerability of capture fisheries of Dumuria 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**) Atlia, Dhamalia, Dumuria, Gutudia, Kharnia, Magurkhali, Maguraghona, Raghunathpur, Rangpur, and Rudaghara unions were found to be moderately vulnerable.

These unions had moderate to low sensitivity and high to moderate adaptive capacity. Rest of the unions were found to be in low vulnerable zone.

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

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Atlia	High	Low	High	Medium
Bhandar Para	High	Low	Medium	Low
Dhamalia	Medium	Low	High	Medium
Dumuria	Medium	Low	High	Medium
Gutudia	High	Low	High	Medium
Kharnia	High	Low	High	Medium
Magurkhali	High	Medium	High	Medium
Maguraghona	High	Low	High	Medium
Raghunathpur	High	Low	High	Medium
Rangpur	Medium	Low	High	Medium
Rudaghara	High	High	Medium	Medium
Sahas	Low	Low	Low	Low
Sarappur	Low	Low	Low	Low
Sova	Low	Low	Low	Low

4.2.5 Risk

The study also assessed the risk associated to capture fisheries for base and 2050s time period. At present, Maguraghona, Atlia, Sova, Magurkhali, Sarappur and Bhandar Para unions are found highly exposed to multi-hazard risk. In future, Sahas, Dhamalia, Rudaghara, Raghunathpur and Rangpur unions also fall under high multi hazard risk. This affects capture fisheries activities negatively throughout the year in these unions. Rivers Bhadra, Salta, Hari run through unions Dhamalia, Rudaghara, Gutudia, Bhandar Para, Atlia, Sova, Sahas, Maghurkhali unions 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 Magurkhali, Sarappur, Sova and sahas 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 for capture fisheries, most of the unions in the east of Dumuria Upazila as such Raghunathpur, Rudaghara, Maguraghona, Atlia, Magurkhali, Goalini, and Bhandar Para were found to be in high risk in the base period. In 2050s, Dumuria, Sahas, Sarappur, Sova will be in low-risk zone, Kharnia will be in moderate risk zone and the remaining unions will be in high risk zone. The income and livelihoods of high-risk unions will face more losses and damages due to recurrent climatic extreme event. Following **Figure 4.12** shows the risk of capture fisheries in Dumuria Upazila.

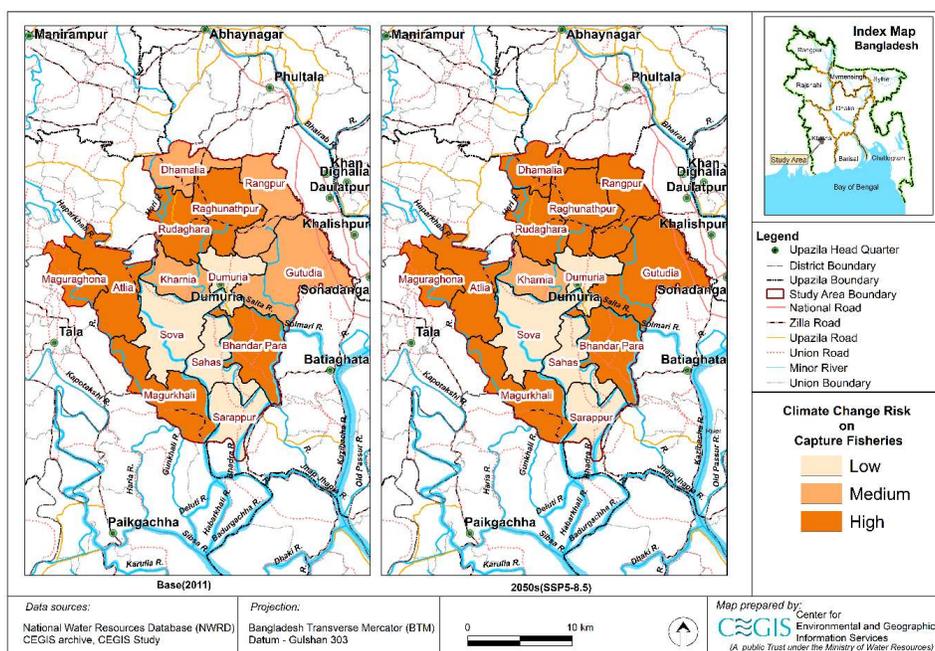


Figure 4.12: Climate risk of capture fisheries in Dumuria Upazila

4.3 Culture Fisheries

4.3.1 Exposure

The aquaculture habitat includes shrimp/prawn/crab/fish farm and fish pond. The habitat assessment of these aquaculture habitat and cultivable fish species are briefly described in respect of the exposure indicators in the following sections.

Habitat

In total 22,130 ha area of aquaculture farm including shrimp/prawn/fish farm exist in Dumuria Upazila. In the shrimp farm, Bagda (*Penaeus monodon*) along with other shrimp and fish are cultured all the year-round, and in the prawn/golda farm, where Golda and white fish (major carp, tilapia, etc.) are cultured in mix way in the wet season following poly-culture technology. The aquaculture status of different unions in Dumuria Upazila is shown in **Table 4.8**.

Table 4.8: Status of aquaculture farm in different Unions of Dumuria Upazila

Unions	Water area (ha)
Atlia	2,194
Bhandar Para	1,063
Dhamalia	1,478
Dumuria	886
Gutudia	3,843
Kharnia	800
Maguraghona	2,347
Magurkhali	637
Raghunathpur	2,387
Rangpur	2,169
Rudhagora	1,849
Sahas	723
Sarappur	319

Sova	1,435
Total	22,130

CEGIS estimation based on LandSat8 image 2019

Cultured fish species

Sarpunti and Rui were found to be highly cultivable fish species in Dumuria Upazila (**Table 4.9**). The farm owners mainly cultivate fin fishes in order to cope with the production loss from Golda and have high market demand and low mortality rate due to temperature and other climatic stress condition.

Table 4.9: Composition of cultured fish species in the shrimp/prawn/fish farm

Species name	Species composition (%)
Bagda	17.7
Catla	3.9
Golda	8.4
Grass carp	2.1
Rui	26.3
Sarpunti	26.8
Silver Carp	3.1
Tilapia	11.7
Total	100

CEGIS Field Survey, 2022

Livelihoods

It is observed that a significant number of employed population of Dumuria Upazila are engaged in fishing and aquaculture-related occupation. The remaining are involved in private businesses, agriculture, services and other sources of income. In addition, secondary occupations or supporting earning sources are also observed, as their main income source could not function throughout the year due to the climatic factors. In this regard, they engaged in some food hawker business, auto-bike/rickshaw riding and different laboring activities for maintaining their families. In terms of exposure on livelihoods, gher and pond owner who are dependent on this aquaculture sector are in risk due to climatic events. Though with the increase of multiple business opportunity including the shrimp, road communication is required to be developed. But it is observed that with occurrence of cyclone and storm surge, roads and growth centres are also affected which potentially causes problems in getting market accessibility. In this aspect, gher livelihoods are being exposed with the changing climatic shocks and events.

Pond fish farmer were faced with various types of economical, technical, social and environmental problems during culture period. Majority of farmers regarded seasonal flood, cyclone and storm surge as the most vital disasters that make more vulnerable. Lack of money for pond management, insufficient water in dry season, non-availability of fish fry, and fish disease also adds to their vulnerability.

The study further made an assessment to understand the culture fisheries exposure to climate induced hazards in Dumuria Upazila and eleven exposure indicators were selected (Annex I) and mapped following the impact chain analysis. **Table 4.16** below shows the exposure status of Dumuria Upazila. From the assessment Magurkhali, Maguraghona, Raghunathpur, Rangpur and Rudaghara unions were found to be highly exposed and Gutudia and Kharnia were 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

Shrimp/Prawn/Fish farm 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 of the 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 in most of the unions, whereas in terms of water temperature it is very slightly beyond optimal range for 4 unions (**Table 4.10**). It has been predicted that extreme temperatures coupled with erratic rainfall patterns have direct impacts on fish physiology, growth, feeding behaviour and mortality in the aquaculture habitat. Moreover, excessive rainfall will breach the dyke of the shrimp/fish farm and increase the natural mortality due to depletion of pH.

Table 4.10: Stress magnitude of the shrimp/prawn/fish farm ecosystem in the Dumuria Upazila

Unions	PH	TDS (gm/l)	Water Temperature (°C)	DO (mg/l)	BOD (mg/l)
Atlia	8.2	692	30	5.4	3.04
Bhandar Para	8.25	1233	30	7.2	1.00
Dhamalia	8.07	1174	30.9	6.53	3.30
Dumuria	8.53	384	30	5.74	1.00
Gutudia	8.18	1243	30.9	6.58	3.14
Kharnia	8.19	1270	30.9	6.47	3.52
Magurkhali	7.47	244	30	7.18	1.20
Maguraghona	8.18	621	30.9	8.11	2.71
Raghunathpur	7.42	704	30	5.18	7.60
Rangpur	7.79	288	30	4.95	0.81
Rudaghara	8.16	1368	30	6.59	3.09
Sahas	8.20	692	30	5.4	3.04
Sarappur	8.25	1233	30	7.2	1.00
Shobna	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	<5

SGR: Specific Growth Rate

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 Dumuria Upazila (**Figure 4.13**). Furthermore, more than 20% vegetation coverage (considering both the floating and sub-merged vegetation) was found in most of the unions (**Figure 4.13**). The farms having moderate coverage of submerged vegetation are expected to produce high abundance of methanotrophs, which can act as a biological sink for the greenhouse gas methane according to L. Fan et al. (2019).

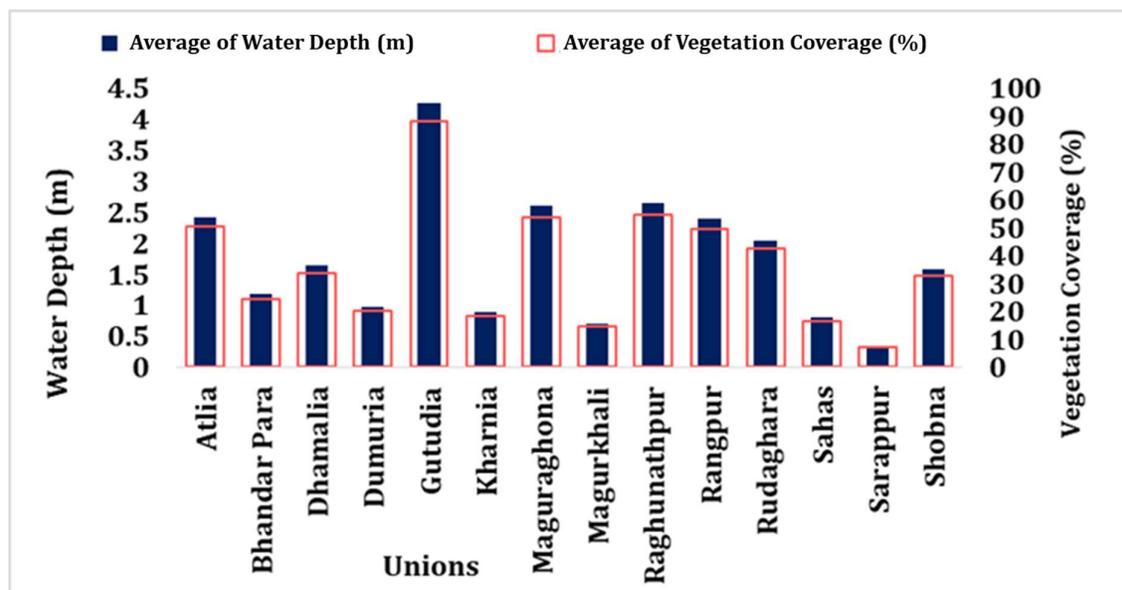


Figure 4.13: Average water depth and vegetation coverage in the fish ponds and shrimp/prawn/fish farms in different unions of the Dumuria Upazil

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 Bagda (about 0.25cm per day). However, the highest mortality has also been found in case of Bagda (Figure 4.14). From the survey, this mortality is mainly as a result of viral infection accelerated by increasing temperature.



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

CEGIS Field Survey, 2022

Production loss due to climate-induced disease

The farms in different unions of Dumuria Upazila were estimated to lose about 7.89 MT of fish annually (Table 4.11) due to climate-induced disease and different extreme events. During field survey, three climate induced diseases have been identified, among them antenna cut and White Spot Syndrome (WSS)

are caused by extended days of extreme high temperature and, Epizootic Ulcerative Syndrome (EUS) as a result of extended days of severe cold temperature.

Table 4.11: Production loss due to climate induced disease

Unions	Fish production loss (MT)
Atlia	0.78
Bhandar Para	0.38
Dhamalia	0.53
Dumuria	0.32
Gutudia	1.37
Kharnia	0.28
Magurkhali	0.23
Maguraghona	0.84
Raghunathpur	0.85
Rangpur	0.77
Rudaghara	0.66
Sahas	0.26
Sarappur	0.11
Shobha	0.51
Total	7.89

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 Dumuria Upazila would be about 29,703 MT 23,076MT, 28,248 MT and 30,350 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 4.12**.

Table 4.12: 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)
Atlia	2,634	2,945	2,288	2,800	3,009
Bhandar Para	1,276	1,426	1,108	1,357	1,457
Dhamalia	1,775	1,984	1,541	1,887	2,027
Dumuria	1,064	1,190	924	1,132	1,216
Gutudia	4,614	5,158	4,007	4,905	5,270
Kharnia	961	1,074	835	1,022	1,098
Maguraghona	765	855	664	813	874
Magurkhali	2,819	3,151	2,448	2,996	3,219
Raghunathpur	2,867	3,204	2,489	3,047	3,274
Rangpur	2,604	2,911	2,262	2,769	2,975
Rudaghara	2,220	2,481	1,928	2,360	2,535
Sahas	868	970	754	923	991
Sarappur	383	428	333	407	437
Shobna	1,723	1,926	1,496	1,831	1,968
Total=	26,573	29,703	23,076	28,248	30,350

Impact Chain Analysis, CEGIS (2022)

Livelihoods

It is noted that, Shrimp farming is a profitable and attractive occupation among the fish farmers. On an average farmer earn BDT. 20,000+ (monthly) from shrimp farming or gher. This income level varies in terms of the size of operated water bodies of shrimp farmers or gher. Export demand and improved communication facilities expedite the scope of earnings in shrimp culture in Dumuria Upazila. The shrimp farming communities apply specific strategies to continue fish farming in this area. From pond preparation to harvesting they have to do a lot of work. For shrimp farming, fry collection is one of the most important works whereas fish or gher owner collect PL from the Sundarbans is the pre-monsoon months of April–June or buy them from the market. Every year cyclones hit this area and fry collector often encounter problems.

The price fish farm owners get from the shirmp contribute to reduce the level of poverty. Besides, technology-based govt. training on aquaculture and cluster farming is providing opportunities in which capabilities of fish farmers are increasing along with earning opportunities for alleviating poverty.

On the other hand, small farmers who are dependent on the aquaculture production face problems in selling because of regularly occurred disasters. Sometimes, their production loss and washing out of ponds force them to take loan from NGOs and local lenders. Apart from that, disrupted communication makes some problems in selling, even getting proper price from the market. In this way, regular disaster and communication problem do not let them rid themselves out of poverty cycle. In this aspect, choosing resilience and AIGs are becoming challenging for them to cope with the changing condition.

Other than above assessments, an indicator-based sensitivity analysis (**Table 4.16**) was also made to identify sensitive unions of Dumuria Upazila. Total thirteen indicators were used to represent the sensitivity of ecosystem in Dumuria. According to the sensitivity analysis, Rudaghara union is found to be highly sensitive and Sahas, Sarappur, Sova are found to be moderately sensitive. The rest of the unions were found to be in low sensitive zone 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 climatic extreme events in the unions of the Dumuria Upazila. One includes farm management and another is the disease control as discussed below.

Aquaculture production system

The present study found that the farm owners of all the unions take about 61 days (from November to December) for land preparation. They use about 251kg fertilizer and 129kg lime per hectare on average for their farm management (**Table 4.13**). Stocking rate of these farms mainly depends on the farm area and water depth. Vegetation coverage have also influence on the farm management. Union wise fertilizer and lime use in the Upazlia is given in the **Table 4.13**.

Table 4.13: Aquaculture production system in different unions of Dumuria Upazila

Union	Land Preparation (Days)	Fertilization (kg/ha)	Lime (kg/ha)
Atlia	61	255	130
Bhandar Para		260	135
Dhamalia		245	140
Dumuria		245	125
Gutudia		265	135
Kharnia		250	140
Magurkhali		260	130
Maguraghona		250	120
Raghunathpur		245	125
Rangpur		240	120

Rudaghara		245	125
Sahas		260	130
Sarappur		250	125
Sova		245	125

CEGIS Field Survey, 2022

Farm management against natural hazards

The present study found that the local aquaculture farm owners have very limited adaptive capacity against the extreme climate induced extreme events. They frequently take only two measures to tackle the extreme hot days, including pumping water and using coconut leaves over ponds to make shade. During the drought period, fish farmers mainly use groundwater (Table 4.14). They use fine net surround their farm to protect their fishes from overtopping during tidal flood. In the study, a survey was conducted on 60 participants where 66% took no adaptive measures for heavy rainfall, cyclone, erratic rainfall and wet days.

Table 4.14: 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 	17
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 premature stage before flooding to some extent. 	14
Heavy Rainfall	Fish farmers usually do not take any measure in case of these hazards.	66
Cyclone		
Erratic Rainfall		
Wet Days		

CEGIS Field Survey, 2022

Climate-induced disease control measures

Three climate induced diseases were identified during the field survey, among them antenna cut and White Spot Syndrome (WSS) are caused due to extended days of extreme high temperature and, Epizootic Ulcerative Syndrome (EUS) is happened because of extended days of severe cold temperature. The local aquaculture farm owner frequently uses aqua medicine and liming for antenna cut and White Spot Syndrome and aqua-medicine, liming and salt for controlling WSS and EUS (Table 4.15). A considerable number of fish farmers (about 25%) who do not take measures for disease control because of lack of knowledge about diseases outbreak. Sometimes farmers reside distantly from the fish feed and medicine outlets thus taking timely necessary measures become difficult. The marginal farmers claimed that the price of medicine is too high to purchase. Their inability of purchasing necessary medicines compels them to rely on the natural cure of fish for the diseases. This in turn causes the farmers a capital loss.

Table 4.15: 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
	WSS		43
Extended days of severe cold temperature	EUS	Using Aqua-medicine, Liming and Salt	7
		No measures	36

Union wise adaptive capacity was also assessed (**Table 4.16**) through different indicator-based impact chain. These indicators mainly demonstrate the coping mechanism of the culture fisheries in hostile condition induced by climate change. However, the culture fisheries scenario assessment in this study followed 17 adaptive capacity indicators. Although due to study limitation, the study team could cover only three unions during field visit. Study team assessed union wise condition by consulting with SUFOs, key informants, secondary data sources, and expert judgment. Set of indicator lists are attached (Annex I). From the adaptive capacity assessment of the culture fisheries in Dumuria, it was found that Bhandar Para, Dhamalia, Dumuria, Gutudia, Kharnia, Magurkhali, Maguraghona, Raghunathpur, and Rangpur unions are highly adaptive for culture fisheries whereas Atlia and Rudaghara unions are moderately adaptive for culture fisheries.

4.3.4 Vulnerability

Vulnerability of culture fisheries (**Table 4.16**) of Dumuria Upazila was also obtained through validated impact chain analysis. Generally high vulnerability occurs when for particular union sensitivity is high but adaptive capacity is low. From the assessment Dhamalia, Dumuria, Kharnia, Magurkhali, Raghunathpur, Rangpur and Rudaghara unions were found to be in moderate vulnerability zone. These unions had low sensitivity and high adaptive capacity. Atlia, Bhandar Para, Gutudia, Maguraghona, Sahas, Sarappur, and Sova unions were found to be in low vulnerable zone.

Table 4.16: Summary of climate vulnerability assessment for culture fisheries in Dumuria Upazila

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Atlia	Low	Low	Medium	Low
Bhandar Para	Low	Low	High	Low
Dhamalia	Low	Low	High	Medium
Dumuria	Low	Low	High	Medium
Gutudia	Medium	Low	High	Low
Kharnia	Medium	Low	High	Medium
Magurkhali	High	Low	High	Medium
Maguraghona	High	Low	High	Low
Raghunathpur	High	Low	High	Medium
Rangpur	High	Low	High	Medium
Rudaghara	High	High	Medium	Medium
Sahas	Low	Medium	Low	Low
Sarappur	Low	Medium	Low	Low
Sova	Low	Medium	Low	Low

4.3.5 Risk

Climate change induced hazard risk for culture fisheries was obtained through impact chain analysis for base and 2050s time period. Atlia, Gutudia, Raghunathpur, Rangpur and Maghuraghona unions contain the highest number of aquaculture farms in Dumuria. However, these unions also faced highest amount of production loss. As these unions are adjacent to the rivers, they face inundation and salinity intrusion which affects freshwater aquaculture negatively. During cyclone and flood events major portion of Dumuria Upazila gets inundated due to its low lying topography and lack of proper cyclone and flood protection infrastructure. Fish farmers often elevate the banks of their ponds to prevent saline water intrusion during flood. 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 found Raghunathpur, Rangpur, Rudaghara, Magurkhali, and Maguraghona unions to be in high risk in both time slices. Kharnia and Gutudia unions were in moderate

risk at the base period and will continue to be the same in 2050s. The rest unions were found to be in low risk for both the time slices. Following **Figure 4.15** shows the risk of culture fisheries in Dumuria.

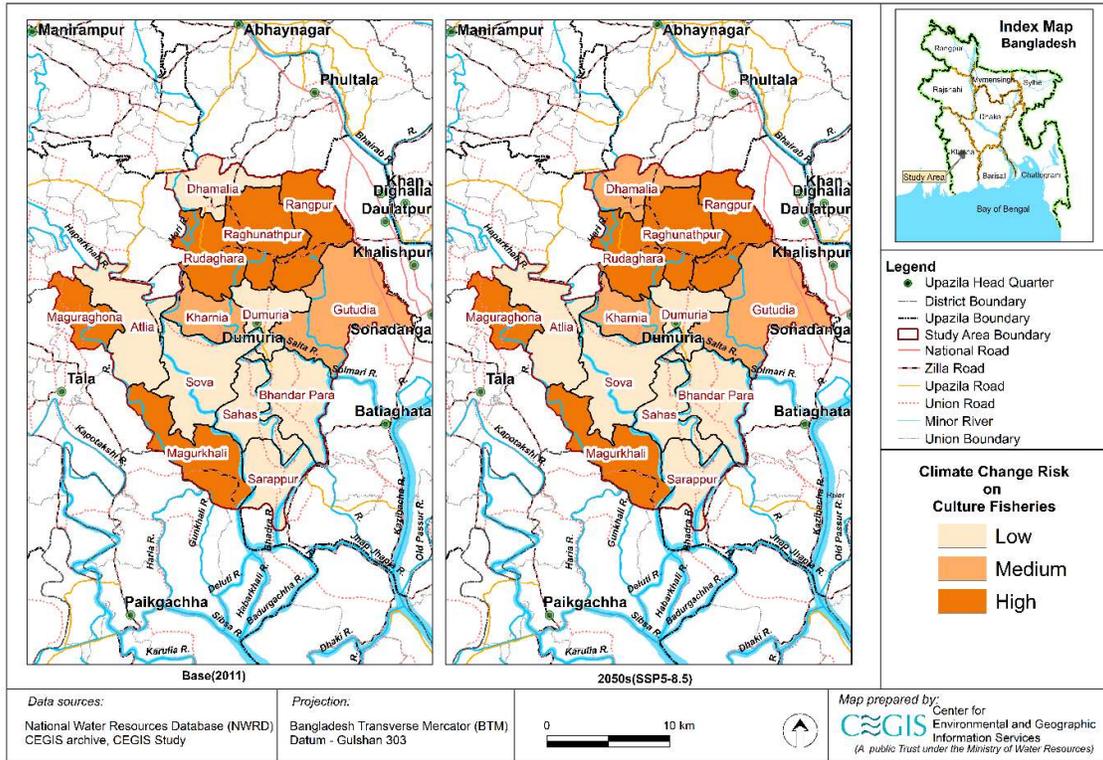


Figure 4.15: Climate risk for culture fisheries in Dumuria Upazila

4.4 Gender

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

Dumuria Upazilla is located at the coastal region, which has several social, financial, environmental and physical impacts due to climatic risks and hazards. Fisheries is one of the major sources of livelihood in this area. Cyclone, storm surge, extreme heat, tidal flood/erosion, water logging and salinity intrusion disrupt the income and livelihood of these fisheries dependent occupants. Women are involved both in fish capture culture related activities in this Upazila. Among capture fisheries activities, they usually involve in fry collection and net making; while in terms of fish culture, pond preparation, feeding, harvesting, and marketing are the main activities in which women are highly involved. These contributions of the female have huge contribution in the family earning, though their farm/pond ownership status is quite poor compared to the male counterparts.

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 influences the occurrence of various hazards in erratic mode. In climate change aspect, exposure of fisheries sector determines the risks on fisheries resources (i.e. Ponds, Fishing Gear, Boats) and dependent vulnerable communities who become affected due to climate change. The Dumuria Upazila selected for this study is exposed to the high dependency of income and livelihood of the local people on fishing, fish farming, and related activities. Segregated exposure for the fish capture and fish culture households in the study area are as follows:

Capture fish

The capture fisheries sector often faces threat due to climate factors. Here, in Dumuria Upazila, the number of women involved in capture is very low. It is found that very small percentages (2%, 103 out of 5187 fishers) of women directly involved in fishing, where some women involved in making fish gears/nets and some other supporting activities in line with role and responsibility of their daily household chores.

Culture fish

Women are mainly involved in household work but assist men in all activities related to fish farming such as pond preparation, feeding, harvesting, fertilizer application, take care of the pond etc. Women who are involved in such activities spend about 3/5 hours daily for these activities. Due to the disasters, reduced working hour and decreased fish production in the fish farms impact to the household income which is higher for female owning or leasing out ponds.

It was found that a small number of women are involved in fishing related activities across all unions (**Table 4.17**). Magurkhali is the union where the highest number of women and lowest number of men are involved in fish related activities. About 2.4% women and 97.7% men are involved in fish related activities there. On the other hand, the lowest women involvement and highest for men was found in two unions which are Maguraghona and Rudaghara. The number stands at 1.4% on both Unions for women and 98.6% for men. The Dependency rate (The dependent population ratio is the ratio of the population defined as dependent i.e., the population aged 0-14 and 60 and over) has been calculated, which includes both male and female. The dependent family members and gender participation in fish activities are shown in **Table 4.17** below.

Table 4.17: 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 (%)
Atlia	98.2	1.8	34.4
Bhandar Para	98.5	1.5	35.1
Dhamalia	97.8	2.2	38.0
Dumuria	98.4	1.6	36.4
Gutudia	98.0	2.0	35.2
Kharnia	98.3	1.7	36.1
Magurkhali	97.7	2.3	32.4
Maguraghona	98.6	1.4	37.0
Raghunathpur	98.3	1.7	35.4
Rangpur	97.8	2.2	33.5
Rudaghara	98.6	1.4	37.2
Sahas	98.1	1.9	36.9
Sarappur	98.4	1.6	36.8
Sovna	98.3	1.7	34.7

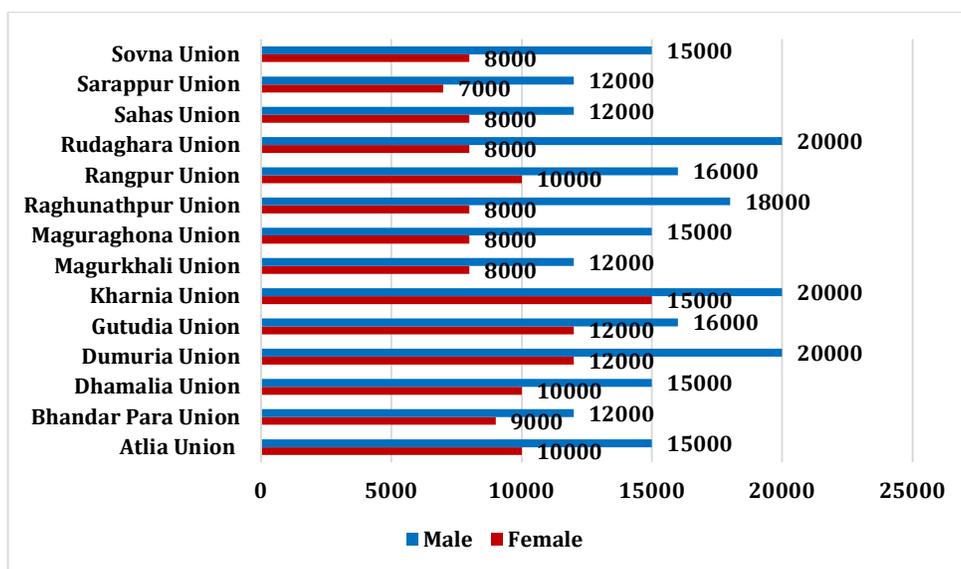
BBS 2012 and estimated through Field Survey, 2022

Based on the indicators of exposed elements by combining all data of exposed elements, it is found that Dumuria, Gutudia, Kharnia, Magurkhali, Maguraghona and Raghunathpur unions are highly exposed to the climatic hazards in comparison with other unions (**Table 4.20**). Sahas, Sarappur, and Sova unions are less exposed than other unions. Rest of the unions are found as moderately exposed by the risks of cyclone, storm surge and other hazards occurred in this area.

4.4.2 Sensitivity

Poverty conditions, mobility, gender-based risks, health and physical condition are the more sensitive receptors for the regular occurrence of cyclone, storm surges, salinity intrusion, extreme heat, and tidal effects where women, children, aged and physically challenged people are highly exposed to these disasters. All these hazards are not equally affecting the exposed community; it depends on the resistance capacity and accessibility to the support service for the community people.

In the fishers and fish farm households, with lessening income, poverty is increased which causes lack of vitamins and minerals intakes which is also a sensitive issue caused by the effects of climate change. The following **Figure 4.16** shows the average monthly income of men and women in all the unions from capture fisheries. Women was found to earn BDT. 7000-15000 monthly on average whereas their male counterparts earn BDT. 12000-20000 monthly on average. Women stated that their income level is not too high to maintain their family, therefore they have inevitable dependency on male counterpart. In most of the cases, women hand over the lion share of their income to their husbands, and husbands take control over the expenditure of this amount while they are not bound to discuss with female counterparts in this regard. Also, social and religious restriction on women to work outside, limits the scope of exploring IGAs for the poor women. These obstacles make them more sensitive to the changing climatic conditions.



Literature review and CEGIS Field Survey, 2022

Figure 4.16: Monthly average income in fish related activities

Wage rate variation is significantly observed in Dumuria Upazila. Wage rate varies according to the types of activities (agriculture labors, fish labors, livestock rearing, poultry farm labor etc.). Overall, women's average wage rate is BDT 280 – BDT 350 per day (BDT 8400 - BDT 10500 per month) against BDT 400 to BDT 450 (BDT 12000 to BDT 13,500 per month) for male. Nationally, this variation is calculated in monthly income where male earns BDT 13600 and female earns BDT 12300 per month (Source: BBS, 2018), which shows insignificant variation compared to the study area. In fish capture and culturing activities, women's labor is used in fish pond preparation, fry collection, feeding and harvesting. In this regard, women labourers are paid on average BDT 250 to 300 per day where men get tk 350 to 400 per day. This variation leads to less income of the women headed households in the study area. Also, less availability of natural resources in Dumuria Upazila creates a very limited scope of income for the poor people in terms of crisis. In addition, women's poor physical and health condition play significant role for the sensitivity in this disaster-prone area. The following **Table 4.18** shows the indicators and its impact that are analysed identifying the sensitivity of Gender.

Table 4.18: Impacts of hazards on gender

Indicators	Impacts
Housing and homesteads	The natural disaster causes huge negative impact every year in Dumuria. Floods, storm surges, cyclones, heavy rainfall, heat wave and salinity have increased in the region. As a result, it causes damage to houses, crop fields, crops, fisheries and more. Many families are even forced to migrate every year due to the impacts of the disasters.
Limited access to market	There are many unions in the Dumuria Upazila where the communication system is poor. It was noted that during disaster period, the communication system especially roads are damaged which disrupts transportation and communication and limits accessibility towards markets. Therefore, fishers 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 from 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 there is 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 diarrhoea. It was noted that during the menstruation period, women fishers face severe gynaecology related diseases. In most cases, they need to go to cities for treatment, which is a financial burden for them. Women and new born babies also face huge problems due to malnutrition, food insecurity and increased 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 physically challenged people, but they are not properly maintained.

Sensitivity analysis (**Table 4.20**) showed Atlia, Dumuria, Gutudia, Kharnia, Magurkhali, Maguraghona Rangpur, Rudaghara and Raghunathpur to be highly sensitive in comparison with other unions of the Dumuria Upazila for gender specific fisheries livelihoods.

4.4.3 Adaptive capacity

Following **Table 4.19** shows the status of people's contribution or access toward the adaptive indicators. It is found that about 58% women responded that they could realize the climate change impact through observing the abnormal weather condition of last few years but they do not have institutional knowledge about how to manage the impacts. Only 17% women have knowledge about reducing salinity of drinking water. About 25% women have training about climate change impact adaptation. It is observed that livestock rearing and poultry farming are almost common for most of the women while a few of them are commercially involved in this sector. Small/marginal land-owning women utilized their land more for farming by introducing multi-farming (fish and vegetable). About 33% of women received training on poultry farming, aquaculture, animal husbandry and homestead vegetation for involving in Alternative Income generating Activities (IGA).

In terms of, early warning receiving, about 92% women receive the message either through TV/mobile phone or by verbal transmission of the community but sometime the messages are not transmitted well ahead of the disasters or not properly describe about the potential intensity of the disasters which causes improper preparation for the protection. Also, they have no easy access to receiving loan from NGOs and banks, due to having insufficient own assets, and lack of communication knowledge which is the main hindrance to develop their own entities as entrepreneurship.

Based on the adaptive capacity score card, it can be stated that women of this area require more training and education on climate change adaptation and alternative livelihoods. Emergency contingency arrangement and credit facilities could be more helpful for sustaining under the climatic hazard and control their vulnerability through the exposure of these hazards.

Table 4.19: Status of adaptive capacity of women involved in fishing and fish farming

Capacity and Knowledge Building Indicators (Female)	Status (%)
Understanding on Climate Change Impact	58
Knowledge on Fisheries Techniques	83
Knowledge on Pest and Disease on Fish	42
Received Early Warning Message Regularly	92
Watching Television or Social Media	83
Having Cell Phone	50
Having smart Phone But No Internet	33
Having Smart Phone with Internet	25
Watching Television Once in a Week	83
Accessibility to Shelter during Cyclone/Floods	83
Knowledge On Hygiene During Menstrual and Pregnancy Period	67
Knowledge on Drinking Water Boiling or Chlorination	83
Training Received on Climate Change	42
Training on Alternate Livelihood	33
Training On Climate Change Impact and Adaptation	25
Knowledge on Reduce the Salinity from Drinking Water	17
Training on Climate Resilient Housing, Pond Management and Infrastructures	17

Adaptive capacity assessment (**Table 4.20**) showed Kunda union had high adaptive capacity for gender-based livelihood. Only Chapartala union showed moderate adaptive capacity and rest of the unions had low adaptive capacity for gender specific fisheries livelihood.

4.4.4 Vulnerability

Using impact chains developed for Southwest region, vulnerability for gender-based livelihood was also assessed for Dumuria Upazila. Vulnerability assessment (**Table 4.20**) showed Sahas, Sarappur and Sova unions to be low vulnerable. While Atlia, Bhandar Para, Dhamalia, Dumuria, Gutudia, Kharnia, Magurkhali, Maguraghona, Raghunathpur, Rangpur and Rudaghara unions were in moderately vulnerable zone.

Table 4.20: Summary of climate vulnerability assessment for F&A based women in Dumuria Upazila

Union	CRVA Elements			
	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
Atlia	High	High	Medium	Medium
Bhandar Para	Medium	High	Medium	Medium
Dhamalia	Medium	Medium	High	Medium
Dumuria	High	High	Medium	Medium
Gutudia	High	High	Medium	Medium
Kharnia	High	High	Medium	Medium
Magurkhali	High	High	Medium	Medium
Maguraghona	High	High	Medium	Medium
Raghunathpur	High	High	Medium	Medium
Rangpur	Medium	High	Medium	Medium
Rudaghara	Medium	High	Medium	Medium
Sahas	Low	Low	Low	Low
Sarappur	Low	Low	Low	Low
Sova	Low	Low	Low	Low

4.4.5 Risk

The study assessed union-wise risk on gender-based livelihood due to climate change induced hazard for two-time period. In Dumuria, 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 Sova, Ridaghara, Rangpur and Maguraghona unions, the wage rate of women is shockingly lower 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 Raghunathpur, Kharnia, Magurkhali, Maguraghona, Atlia, Bhandar Para and Gutudia unions are in high risk for gender-based livelihood for both time periods. Initially Sova union was in low risk at the base period but in 2050s due to increased impact of climate change induced hazard it showed moderate risk. Dumuria, Kaikhali, Ramjan Nagar and Padma Pukur unions were found to be in moderate risk. Rest of the unions were found to be in low-risk zone. Following **Figure 4.17** shows the risk on gender (women) engaged on F&A based livelihood in Dumuria Upazila.

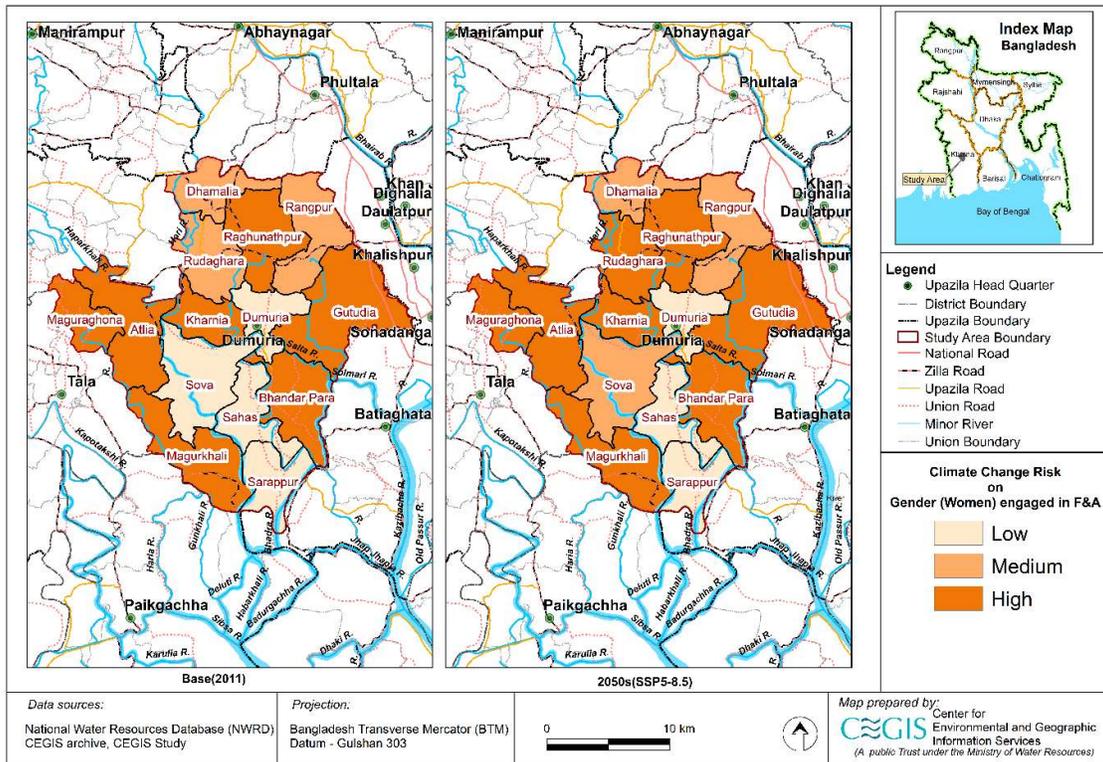


Figure 4.17: Climate risk of gender (women) engaged in F&A in Dumuria Upazila

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 Dumuria 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 Dumuria 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 Dumuria 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 	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
			losses incurred from damages		
		<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 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 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 and plan accordingly for fisheries risk reduction 	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
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 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

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

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 discrimination and inequality 	DoF, BFRI, MoF, MoDMR, MoEFCC, MoWCA, DSS, DYD, Insurance companies	Within 3 to 5 years
		<ul style="list-style-type: none"> Provide climate resilience funds specially focusing on marginal women 	<ul style="list-style-type: none"> Improve financial stability of women to recover any losses incurred from damages due to climate hazards 	DoF, BFRI, MoF, MoDMR, MoEFCC, LGIs	Within 3 years and continue

Gender

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

Table 5.5: Risk on women with adaptation options

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

ID	Risk	Adaptation or Risk Reduction	Motivation	Critical stakeholder	When to Implement
			<ul style="list-style-type: none"> 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 activities generating	<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	Violence and accidental occurrences towards women	<ul style="list-style-type: none"> Required training for emergency response team from Community, NGOs and GOs Level 	<ul style="list-style-type: none"> Stopping violence and accidental occurrence during and after disaster period 	MoWCA, DoF, DDM, MoSW, DYD, NILG, CreLIC, CBOs, NGOs and CSOs.	During and after Disaster
		<ul style="list-style-type: none"> Training on handling the gender sensitive issues during disaster and post disaster 			
5	Inadequate lead time in early warning	<ul style="list-style-type: none"> Instant and direct dissemination of early warning to women staying at home 	<ul style="list-style-type: none"> Safe evacuation before disaster 	DoF, BMD, FFWC, DDM	Before and during Disaster
			<ul style="list-style-type: none"> Protection of livestock and property 		
		<ul style="list-style-type: none"> Transmitting early warning through digital medium i.e mobile SMS, megaphone announcement etc. 	<ul style="list-style-type: none"> Safe evacuation before disaster 		
			<ul style="list-style-type: none"> Protection of livestock and property 		

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 Dumuria 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 Dumuria 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 Dumuria 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 Dumuria Upazila. Fish and/or other aquatic species migration, reproduction, and growth are also being impacted by the drought conditions usually experience in the area.

Climate change induced hazard risk for capture fisheries impact chain analysis showed Raghunathpur, Rudaghara, Maguraghona, Atlia, Magurkhali and Bhandar Para unions under high risk for the base period whereas, in 2050s, Dhamalia, Rangpur and Gutudia unions will be in high risk zone along with the high-risk union at the base period. For culture fisheries, Maguraghona, Magurkhali, Rudaghara, Raghunathpur and Rangpur unions are in high risk for both time periods. The SWOT analysis shows that both the river and pond ecosystem are in moderate conditions but the pond ecosystem has higher strengths-opportunities and lower weakness- threats because of their natural land-cover types and ideal water quality. The results also showed that the river has more weakness and threats and low strengths-opportunities due to rapid urbanization and environmental pollution and encroachment.

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 Dumuria Upazila smoothly. Different ecosystem-based adaptation options, technical/financial incentives, and alternative livelihood generation for fishermen required policy reforms or non-structural 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 Dumuria 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, molluscs, 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 non-profit 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 fibre, (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 <i>Aphanomyces</i> 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, behaviours and roles associated with being a woman, man, girl or boy, as well as relationships with each other.
Global Circulation Model	Global Circulation Model (GCM) is a model that simulates general circulation of planetary atmosphere or oceans. The term general circulation is used to

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

Annex I: CRVA framework and selected indicators

CRVA Framework

Steps	Activities	Agenda	National Level	Local Level
1	Preparing the CRVA	<ul style="list-style-type: none"> Understand context of CRVA, define objectives and possible outcome Define scope (sector, topic), extent (geographic level or vertical level) and timeframe (current and future) Assess resources and stakeholders' involvement requirement Stocktake available information Prepare implementation plan 	<ul style="list-style-type: none"> Capture and Culture Fisheries CRVA on Fisheries Livelihood and Ecosystem Base (2000s) and Future (2050s and 2085s) Climate Change Scenarios (SSP1-2.6 and SSP5-8.5) Up to district level Separate assessment for selected 6 regions National level stakeholders Review and stocktake 	<ul style="list-style-type: none"> Capture and Culture Fisheries CRVA on Fisheries Livelihood and Fish Ecosystem Base (2000) and Future (2050s and 2085s) Climate Change Scenarios (SSP1-2.6 and SSP5-8.5) Up to union level Separate assessment for each project site or Upazila Local level stakeholders, community and gender Review and stocktake
2	Developing Impact Chains	<ul style="list-style-type: none"> Identify climate impacts and risks affecting the system Determine hazards (climate signal and direct impacts) and intermediate impacts Determine vulnerability (i.e. sensitivity and lack of adaptive capacity which are contributing to risk) Determine exposures or elements at 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 Identify recommended adaptation measures including EbA considering gender inclusion and sustainable livelihoods

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

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

Steps	Activities	Agenda	National Level	Local Level
			<ul style="list-style-type: none">• Update (if necessary) and publish the finalised CRV maps	<ul style="list-style-type: none">• 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 Dumuria Upazila

	Factor	Indicator
Hazard	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 Dumuria Upazila

 Indicators excluded In CRVA

	Factor	Indicator	
Culture Fisheries	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	
Capture Fisheries	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	
	Regional fish species	No of Species	

Factor		Indicator
	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

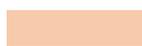
Sensitivity indicators used for Project Level Climate Change Risk and Vulnerability Assessment at Dumuria Upazila

 Indicators excluded In CRVA

Factor		Indicator
Culture Fisheries	Unfavorable soil condition	Soil Nutrient Content
	Unfavorable aquatic condition	Water quality (Ph, TDS, DO, BOD, COD, N2O, Temperature)
	Fish Disease	Type of disease occurring
	Fish Growth	Fish Growth Rate
		Fish Size
	Mortality Rate	Mortality Rate
	Low resistance to Salinity	Fish Growth/Avoidance rate in higher salinity conc
Low resistance to Temperature	Fish Growth/Avoidance rate in higher temperature	
Capture Fisheries	Unfavorable soil condition	Soil Nutrient Content
	Unfavorable aquatic condition	Water quality (Ph, TDS, DO, BOD, COD, N2O, Temperature, Depth, Flow, Velocity...etc)
	Fish Disease	Type of disease occurring
	Fish Growth	Fish Growth Rate
		Fish Size
	Mortality Rate	Mortality Rate
	Low resistance to Salinity	Fish Growth/Avoidance rate in higher salinity conc
Low resistance to Temperature	Fish Growth/Avoidance rate in higher temperature	
Ecosystem	Habitat Condition	Soil condition (Soil Nutrient Content)
		Water Quality ((Ph, TDS, DO, BOD, COD, N2O, Temperature, Depth, Flow, Velocity...etc)
	Community Composition	No of Species/Abundance of species

Factor	Indicator
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 Dumuria Upazila

 Indicators excluded In CRVA

Factor	Indicator
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
Culture 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
Capture Fisheries	

	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	1.6	3	2.6	3	The strength of water availability received low score because of decrease of availability of optimum water in the dry season and moderate water retention time and decrease diversified water use when water stays sweet during monsoons. Weakness scores highest because poor connecting of surrounding hydrological system, connectivity obstructed due to high siltation. There are good opportunities to increase water availability through dredging or re-excavation practices, high opportunities for law enforcement of IUU fishing and support alternative livelihoods so, the opportunities scored high. High encroachment by brick kilns run by local influential, Plan of upstream development due to rapid urbanization and overuse the water and presence of dam makes the river more threatened that scored high.
	Water quality	2	1	1.5	3	Water quality received a moderate score for strength as the Optimum Physio-Chemical Parameters (Temperature, DO, TDS, pH) from the field test are average 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 average than threshold range, so the weakness of water quality is scored lowest. However, EbA interventions for dust management and the presence of law enforcement are good opportunities for water quality improvement but the presence of functional ETP is absent and co-management is poor so, the opportunities received low 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 infrastructures causes the water quality more vulnerable so threats scored high here.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
	Soil quality	2	2.3	2.5	3	The strength of soil quality is scored medium as the optimum soil nutrients is in moderate condition due to the vegetation coverage. The weakness of the soil quality scored medium due to high presence of ordinary peat soil which is a very soft soil with low shear strength and high compressibility exists in an unconsolidated state and soil is also polluted by anthropogenic activities but litter decomposition and forest characteristics are good. Opportunities for soil quality improve assigned high scores because of increasing vegetation coverage and land use practice. There are high threats on soil quality as chemicals and pesticides used in surrounding crop field and fish gher and household discharge and waste dumping to the river, so threats scored high here.
	Primary productivity	2.5	2	2.5	3	Availability of plankton, presence of aquatic vegetation's provides good strength scores for primary productivity. Weakness for primary productivity scored medium as moderate time needed to restore plankton and aquatic vegetation after disasters. Opportunities for primary productivity get high scores because of increasing forest, vegetation coverage and EbA interventions. However, Threats scored high due to overmuch unsustainable harvest of the ecosystem resources.
	Fish diversity, community dynamics and production	2	2.3	2.2	3	This indicator received average score for strengths as water for integrated use for fishery, crop and nature is moderate and water quality and soil quality is good for fisheries. Moreover, primary productivity is medium. Weakness is scored medium due to average water retention capacity and less time needed to regenerate primary productivity but water quality is deteriorating over time. Presence of green coverage is moderate, fishing ban period is strictly maintained, community involvement, EbA activities is less active but Dolphin migration route is present in Bhadra river which are good opportunities and received medium score. Frequent climate extreme event are the main threats to fish diversity, community dynamics and production. However, Disruption of environmental flow of the ecosystem due to infrastructure and upstream development, climate variability and siltation are the main threats and received highest score

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Regulating	Ground water recharge	1.5	2.5	2	2.6	The strength for ground water recharge is low because of silty clay soil type and moderate vegetation coverage. Clay soil type and land degradation are the main weakness for ground water recharge and scored high 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 natural resources and poor management of domestic waste which is scored high.
	Waste water treatment	2	2	1.75	2.6	The strength of waste water treatment received moderate score due moderate condition of aquatic vegetation and presence of molluscs. Weakness scored medium condition because of average dense turbidity and flora, fauna. Lack of co-management, medium awareness of the role of ecosystem for climate resilience, maintain law enforcement, absence of functional WTP are some of the opportunities for this indicator and received medium scores. Rapid urbanization, unsustainable use of natural resources and poor management of domestic waste are the main threats which is scored high.
	Soil fertility	2	2	2	3	Strength for soil fertility scored medium because of moderate abundance biodiversity which makes the soil fertile by decomposing organic materials and provide suitable habitat. So, the weakness also gets medium score. Opportunities for soil quality improve assigned good scores because of chance to increase forest and vegetation coverage and by increasing awareness of the people. Presence of embankment and agro-chemicals use in the surrounding gher, poor water management structure, moderate deforestation are the main threats to soil fertility which scored high
	Water retention capacity	2	3	2	3	Water retention and conveyance capacity is medium and strength for this indicators scored medium though siltation is the main weakness and received highest score. There are high opportunities for dredging but difficult to form new hydrological connection so it scored medium. Presence of embankment and moderate deforestation and high land degradation disrupt water retention so the threats scored high.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Cultural	Recreation and tourism	2	2	2	3	Resource availability, scenic beauty provides satisfying score for cultural services but the main weakness is wetland ecosystem for recreation and tourism are not so planned and lack of sustainable management which received moderate score. There are good Opportunities for community based livelihood and received average score. The main threats are encroachment, environmental pollution and overexploitation of resources which received high score.
Supporting	Ground water replenishment	2	2	1	2.5	The strength for ground water replenishment is moderate because of silty clay soil type and good vegetation coverage. So, weakness for ground water replenishment scored medium here due to moderate 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 waste and unplanned urbanization which is scored highest.
	Nutrient cycling	2	2	2.5	2.5	Strength for soil fertility scored medium because of moderate abundance biodiversity which makes the soil fertile by decomposing organic materials and provide suitable habitat. So, the weakness also gets medium score. Opportunities for soil quality improve assigned good scores because of chance to increase forest and vegetation coverage and by increasing awareness of the people. Presence of embankment and agro-chemicals use in the surrounding ghers, poor water management structure, moderate deforestation are the main threats to soil fertility which scored high
	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

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
	Prey/predator relationships	2	2	2	2	Strength and opportunities for this indicator are moderate for multitrophic interaction and medium species & genetic diversity as both fresh and brackish water species is supporting the ecosystem. Weakness for this indicator received moderate score due to rapid urbanization and infrastructure development which may disturb to prey/predator relationship. Frequent climate extreme events and deforestation due to urbanization are the main threats for Prey/predator relationships which received a medium score
	Hydric soil development	2	2	2	2	The strength of this indicator is moderate because of good vegetation coverage. Siltation 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 medium scores.
Total	Total Service=15	30.1	32.1	30.55	40.2	

SWOT scoring and outcomes for Pond/Fish farm ecosystem

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
Provisioning	Water availability	2.6	2	2.6	1	The strength of water availability received high score as availability of optimum water in the dry season and good water retention time, moreover, water can be used for household purposes. Weakness scored medium as fish pond is connected with surrounding hydrological system which support water availability in dry season and pond bed materials is silty clay which can holds certain amount of water. There are high opportunities to increase water availability by rainwater harvesting, re-excavation practices and community-based management. Overuse of ponds is the main threat that received lowest scores as pond is well managed by the owners and locals.
	Water quality	2	2	2.5	1.6	The strength for water quality received average 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

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
						quality is scored medium as the physio-chemical parameters is average but algal bloom occur 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 high 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 slightly deteriorate water quality so, threats received moderate score.
	Soil quality	3	1.3	2.5	1	The strength of soil quality is scored high 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, so the soil is less polluted. Opportunities for soil quality improve assigned high score due to increasing suitable crops and vegetation coverage. There are medium threats on soil quality as chemicals and pesticides used in surrounding crop field and fish gher.
	Primary productivity	3	1	2.5	2	Presence of abundant aquatic vegetation and plankton provides high strength scores for primary productivity. Weakness for primary productivity scored low as comparatively few times 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.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
	Fish diversity, community dynamics and production	3	1.6	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 sufficient, community-based activities is active, awareness on the role of ecosystem for climate resilience increase which are the good opportunities and received high 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 medium score
Regulating	Ground water recharge	2	1.5	2	1.3	The strength for ground water recharge is medium because of silty clay type and high vegetation coverage. Clay soil type is the main weakness which influence ground water recharge and scored low here due to low water holding capacity compare to sandy soil. There are some opportunities for ground water recharge by altering soil condition and planting suitable crops. Main threats are unplanned urbanization which is scored low.
	Waste water treatment	2.5	1	3	1.3	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 less turbidity. EbA interventions, community-based management and awareness raising are good opportunities for this indicator and received high scores. Main threats are unplanned urbanization which is scored low.
	Soil fertility	3	1	2	1.6	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 and agro-chemicals use are the main threats for soil fertility which scored medium.

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
	Water retention capacity	2	1	2	1.3	Water retention and conveyance capacity are good and strength for this indicator scored medium. Siltation during flood is the main weakness and received medium score. There are good opportunities for re-excavation and connecting with new hydrological system so it scored medium. Threats scored low due to presence of embankment, low deforestation and moderate water management structure.
Cultural	Recreation and tourism	2	2	2	2	Existing biodiversity, scenic beauty provides average satisfying score for cultural services and the main weakness is unsustainable management of the wetland ecosystem for recreation and scored average. Opportunities received medium score for social relations and inspirational values. The main threats are environmental pollution and over exploitation of resources and received moderate score for threats.
	Ground water replenishment	2.5	1	3	2	The strength for ground water replenishment is high because of silty clay soil type and high vegetation coverage. So, weakness scored low here due to moderate water holding capacity and high vegetation coverage. There are few opportunities for ground water recharge by increasing vegetation and modifying soil texture which received highest score. Main threats are management of domestic waste and unplanned urbanization which scored moderate.
Supporting	Nutrient cycling	3	1	3	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 high 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	3	2	3	2	The strength for this indicator received high score because floodplains are sometimes highly fertile as sediment is rich in organic matter and nutrients. Floodplains are home to some of the most biologically rich habitats on Earth. They provide opportunities of spawning grounds for fish and critical areas of

Ecosystem Service Type	Indicators	Strength	Weakness	Opportunities	Threats	Remarks
						rest and foraging for migrating waterfowl and birds. So, opportunities received high score. Weakness and Threats received average score as stream bank erosion, which can undermine the stability of nearby pond infrastructure or disperse or degrade quality soils necessary for nutrient cycling and vegetative viability
	Prey/predator relationships	3	1	3	1.5	Strength and opportunities for this indicator are high for multitrophic interaction, species and genetic diversity. Weakness for this indicator received low 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	3	1.5	The strength of this indicator is medium because of good vegetation coverage. Silty clay soil type is the main weakness and scored medium here due to medium water holding capacity. Opportunities received high score due to community-based management and EbA interventions. Rapid urbanizations is the main threat for hydric soil development which scored low.
Total	Total Service=15	38.6	21.4	39.1	24.1	

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

FGD at Dumuria Upazila



FGD at Sarafpur with Culture Fisheries Group



FGD at Sarafpur with Culture Fisheries Group2



FGD at Akhra with Capture Fisheries Group



FGD at Akhra with Capture Fisheries Group2



FGD at Keoragate with Woman Group (CBO)



FGD at Keoragate with Woman Group (CBO)-2

Community Survey and Water Quality Sample Collection



KII with Local people



KII with Fish Farm Owner



Water Sample Collection



KII with Local Knowledgeable people



Catch Assessment Survey



Ecosystem Survey at Akra