ANALYSIS OF THE CURRENT STATE OF WATER SALINITY AND ITS EFFECT ON THE LOCAL PLANT DIVERSITY OF THE BAKKHALI RIVER, COX'S BAZAR

A Project Thesis Submitted to Faculty of Science and Information Technology, Daffodil International University, Dhaka, Bangladesh in partial fulfillment of the requirements for the degree of Bachelor of Science in Environmental Science and Disaster Management

Course Title : Project Thesis

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DECLARATION

I do hereby declare that the entire work submitted as a thesis entitled **''ANALYSIS OF THE CURRENT STATE OF WATER SALINITY AND ITS EFFECT ON THE LOCAL PLANT DIVERSITY OF THE BAKKHALI RIVVER, COX'S BAZAR''** towards the partial fulfillment for the degree of Bachelor in Environmental Science and Disaster Management at the Daffodil International University, is the result of my own investigation and this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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CERTIFICATION

This is to certify that the research work presented in this thesis entitled **''ANALYSIS OF THE CURRENT STATE OF WATER SALINITY AND ITS EFFECT ON THE LOCAL PLANT DIVERSITY OF THE BAKKHALI RIVVER, COX'S BAZAR''** was carried out by the final year examine bearing Student ID: 162-30-138, Session: 2016-2020 under my supervision has been accepted as partial fulfilment of the requirement for the degree of Bachelor of Science in Environmental Science and Disaster Management.

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The thesis entitled **''ANALYSIS OF THE CURRENT STATE OF WATER SALINITY AND ITS EFFECT ON THE LOCAL PLANT DIVERSITY OF THE BAKKHALI RIVVER, COX'S BAZAR''** By Shehab Mahmud, Student ID: 162-30-138, Session 2016-2020, submitted in partial fulfillment of the requirement for the degree of Bachelor of Science in Environmental Science has been approved for necessary steps.

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DEDICATION

My loving parents

Shameema Islam Rosee

Md. Majrul Islam

My sibling

Maj Mumtahina Islam Rakhy (BA)

My respected teachers

Dr. A. B. M. Kamal Pasha, PhD

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ABSTRACT

Climate change has led to an unprecedented rate of sea-level rise (SLR) over the past few years. With hundreds of rivers flowing through the region, Bangladesh is a deltaic plain. Most of them end their journey by accumulating in the Bay of Bengal (BoB). The rising sea level tends to increase river salinity due to the changing climate, which directly affects the associated eco-systems and vegetation coverage.

During the COVID-19 pandemic in the monsoon season, this research was conducted. The study evaluates the current plant diversity and river salinity status of Cox's Bazaar's Bakkhali River, which concluded in a hypothesis on how the local plant-diversity is affected by the river salinity.

On site, the water salinity level was measured. The estimated plant diversity status was measured using the diversity index for both Simpson (D) and Shannon (H). Statistical analysis was carried out on the results of the impact of river salinity on the plant diversity of the riverside. From the water samples collected from the sampling locations, total dissolved solids (TDS) and electrical conductivity (EC) were measured.

From all the statistical research it was found that when salinity increases, the plant diversity decreases. There were less human footprints because of the pandemic. Also the salinity level was lower than expected due to the monsoon season. Via physical observation, it was shown that pollution had less effects.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol or Unit	Name of the Symbol or Unit
'	Second
º	Minute
ºC	Degree Celsius
µS/cm	Micro Siemens Centimeter
mS/cm	Milli Siemens Centimeter
dS/cm	Deci Siemens Centimeter
ppt	Parts Per Thousand
ppm	Parts Per Million
m	Meter
m2	Meter Square
km	Kilometer
sq.km	Square Kilometer

Abbreviation	Full Form of the Abbreviation
BoB	Bay of Bengal
CCC	Climate Change Cell
CCZ	Central Coastal Zone
CLD	Casual Loop Diagram
COP	Conference of the Parties
DAE	Department of Agricultural Extension
DIU	Daffodil International University
EC	Electrical Conductivity
ECA	Environmentally Critical Areas
ECZ	Eastern Coastal Zone
EPA	Environmentally Protected Areas
ESDM	Environmental Science and Disaster Management
GBM	Ganges-Brahmaputra-Meghna
GIS	Geographic Information System
GPS	Global Positioning System
KII	Key Informant Interview
MoEF	Ministry of Environment and Forest
NAPA	National Adaptation Programme of Action
SAARC	South Asian Association for Regional Cooperation
SL	Sampling Locations
SLR	Sea Level Rise
SMRC	SAARC Meterological Research Centre
SRDI	Soil Resourece Development Institute
TDS	Total Dissolved Solids
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank
WCZ	Western Coastal Zone

Chapter 1 – Introduction

1.1. Background

As the world's largest deltaic plane, Bangladesh introduces a physical topography of low layers with exceptions in the north-east and south-east regions. Bangladesh has been vulnerable to climate change and sea level rise due to the complex morphology, delta system and air landscape (CCC 2016).

The Bay-of-Bengal gave Bangladesh a huge coastline consisting of 19 districts along with the largest unbroken sea shore (Figure). Twelve of them are referred to as the exposed coast and seven are chosen as the inner coast. All these coastlines occupy about 32 percent of Bangladesh's land area (Huq & Rabbani, 2014).

Bangladesh's Land of Rivers has more than 700 rivers that flow through it. The three great rivers are the Brahmaputra, the Ganges, and the Meghna. 57 transboundary rivers pass through it, including 54 shared with India and 3 shared with Myanmar (Parveen and Hasan, 2018).

1.2. Problem statement

Scientists have encountered extraordinary increases in the salinity level of soil and water. Widespread shrimp farming and other anthropogenic factors, along with SLR, contribute to greater salinity intrusion in the Bangladesh coastal region. This has influenced the coastal zone's

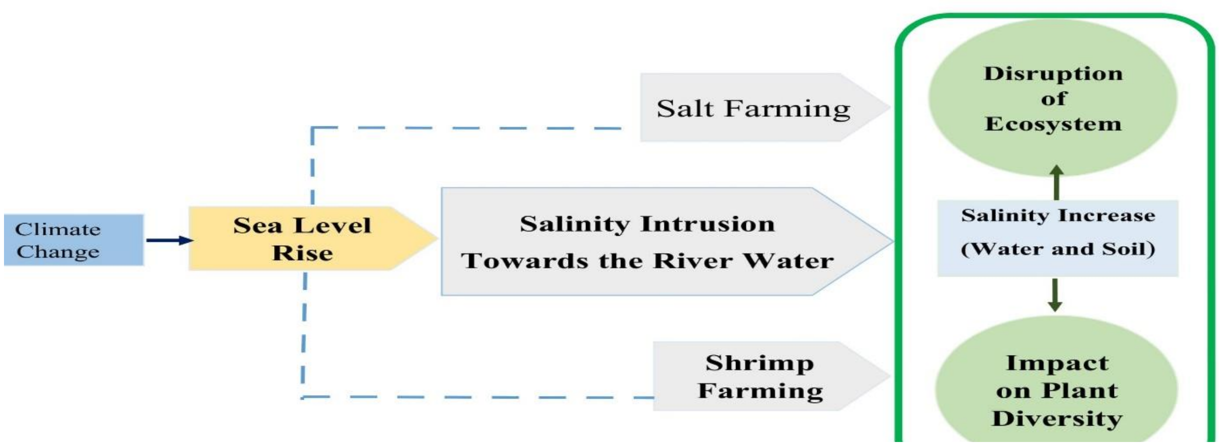

Photo 1 Flow Chart of Increase in River Water Salinity

eco-system and biodiversity. Intrusion of salt water into the inland causes a significant effect on local plant diversity and diversity (Basar, 2012).

Since then, cultivable land along the coast has been in decline. Plant and crop development has been jeopardized. This limits the overall growth of plants and the production of crops in coastal areas, contributing to soil infertility. A major problem that restricts the production of food grains in our coastal regions is increased salinity along the coast (Mahmuduzzaman et al., 2014). Increased salinity due to the intrusion of salt water into the interior causes changes in the crop and plant pattern in the Bangladesh coastal belt (Soil Resource Development Institute, 2010).

In non-saline inland areas and areas vulnerable to salinity, there are many noticeable variations. In a salinity-prone region, crop production, crop intensity, production level and livelihood quality of people are much lower than in our country's non-saline areas (Ahsan & Bhuiyan, 2010).

The Bakkhali River went through the Cox's Bazar district's southern coastal area and plunged through the Maheshkhali Channel into BoB. The conjugated areas of the Bakkhali River are heavily influenced by salinity. It explicitly endangers the local ecological environment. The pattern of plant species and plant diversity of the Bakkhali river in particular (CCC, 2016).

1.3. Justification of the study

Several studies on the effect of salinity on different variables in Bangladesh's western and coastal area have been performed. Studies on river salinity and its effects on Bangladesh's coastal area, however are very limited. There were no studies on the rivers of the Chottogram division within which Cox's Bazar is situated at the time of this study.

The research into the Covid-19 pandemic was completed in around 5 months. A lower human footprint has demonstrated a worldwide increase in ecological health. Which is why this research on this particular river has been undertaken to further examine the effect of rising or decreasing salinity on the local plant species as one of Cox's Bazar's major rivers.

1.4. Objectives

This analysis focuses on the goals written below.

1. To determine the difference in the level of river salinity between the sampling position of the Bakkhali River downstream region.
2. Assess the diversity of floral species in the above-mentioned situation between the sampling locations of the downstream region of the Bakkhali River.
3. To measure and calculate the effect of river salinity on the diversity of local floral species and soil.

1.5. Structure of the the study report

This study is divided into five parts.

*Chapter **1** Introduction*

The introductory information on the research project has been mentioned in this section. There was a brief discussion of the context, the problem statement and the purpose of the study. Here the framework of the analysis is illustrated. In sum, there are 5 parts here.

*Chapter **2** Literature review*

Relevant studies have been addressed in this chapter on river water salinity, salinity infiltration, causes and variables, climate change and its relationship with the salinity level of coastal areas. In sum, there are 4 parts here.

*Chapter **3** Methodology*

A detailed overview of the field of research and the different study methods used in the conduct of this study has been discussed here. This chapter has 5 main components.

*Chapter **4** Result and discussion*

In this section, a broad debate on the research results was addressed in conjunction with the research aim. In this chapter, organized observations and understanding of the results are included. In this chapter, there are 5 parts.

*Chapter **5** Conclusion and Recommendation*

In this section, the rationale of research goals is further explained. In an attempt to help potential researchers better understand the pre-existing conditions of this field, some recommendations are being made. In this chapter, there are 2 parts.

Chapter 2 – Literature review

There are many reports on river water salinity and salinity intrusion, as well as adaptation of these factors to climate change. These considerations are explored in this section in a systematic way to explain the context of the study.

2.1. Water salinity

Salinity, measured in parts per thousand, is the relative proportion of salt in soil or water (PPT). Water salinity is also the relative proportion of salt dissolved in water. Salt is applied to the river water by the internal flow of ocean water. This causes salinity in the river water, known as the salinity of river water. Owing to the landward movement of salt water from the sea, known as

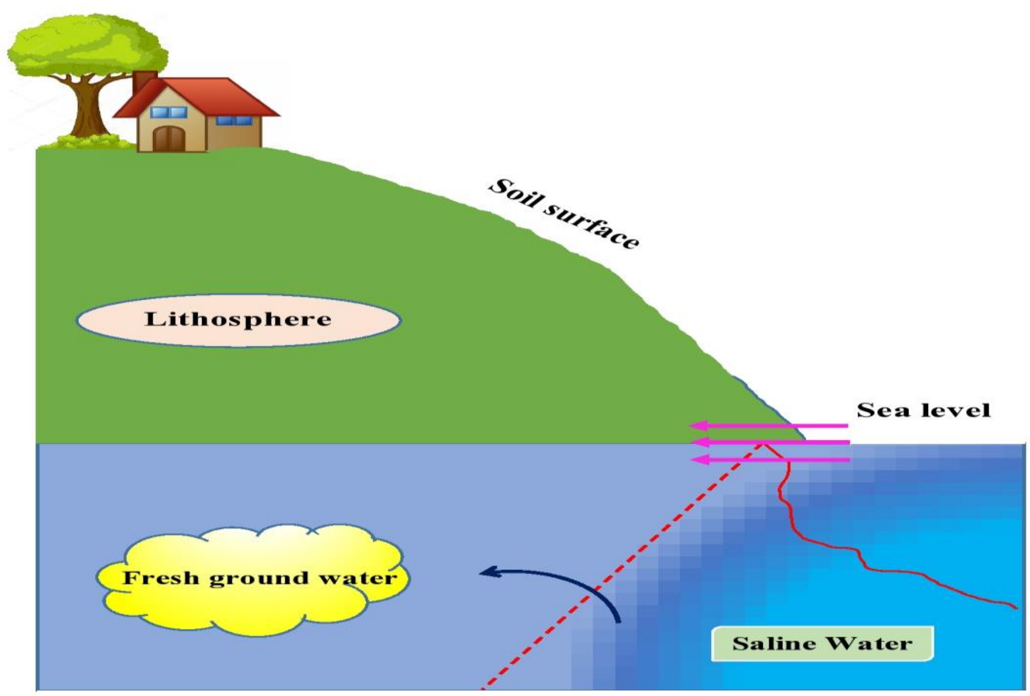

Photo 2 Conceptual Diagram of Salinity Intrusion Towards the Land

saline water intrusion, salinity occurs or rises (Gain et al., 2014).

Saline water appears to migrate inland, which is called saline water intrusion, because of the difference in density and pressure between saline water and fresh water. There is a higher percentage of dissolved minerals in salt water than in fresh water, resulting in higher pressure on the same amount of water. Because of this, salt water often appears to pass under the freshwater into the interior (Duan, 2016)

The salinity of river water primarily depends on three major phenomena (Dasgupta et al., 2015):

1. Amount of discharges of freshwater from the upstream region of the river
2. The ocean salinity along the coast
3. The pattern of coastal water circulation caused by ocean currents and heavy tidal currents

2.2. Causes of Salinity in the Rivers of Coastal Bangladesh

The floodplain is about 80 percent of Bangladesh and has a very low elevation above sea level. The average elevation is 4-5 m for the southeast coastal areas, and 1-2 m for the southwest coastal areas (CCC, 2016).

Table 1 Land Area Under Various Elevation of the Coastal Area

Elevation (m)	Area* (sq km)	Area* (% of the country)	Area* (% of Coastal)
0 – 1	8, 459	6	21
1 – 2	11, 158	8	27
2 – 3	7, 019	5	7
3 – 4	9, 411	7	13
4 – 5	8, 789	7	8
Total	**44, 836**	**33**	**76**

2.2.1. Geographical Location

Bangladesh's Southern Region hosts one of the world's most active ecosystems. Several rivers are active in this area, including the Ganges-Brahmaputra-Meghna (GBM) river system. All other regions of our country are plain land with an enormous river network system and char land, except for this southern region of our country (Sarwar, 2005).

According to (Islam, 2001), Coastal zone of Bangladesh has divided into three main regions:

1. Eastern Coastal Zone (ECZ)
2. Central Coastal Zone (CCZ)
3. Western Coastal Zone (WCZ)

Bangladesh's Eastern Coastal Zone (ECZ) is a very narrow area with a series of small hills running parallel to this portion of it. Starting from Bodormokamam, this coastal zone (the southern tip of the mainland to the estuarine area of the Feni river). The rivers Karnafully, Matamuhury, Naf and Sangu cross the area and fall into the BoB. The River Naf separates Bangladesh and Myanmar (Islam, 2001).

From Cox's Bazar to Teknaf, the submerged sand formed a 145 km long sandy sea beach. From a tourism perspective, Patenga and Cox's Bazar Sea Beach are the two most significant sea beaches in the world. For its tourism activities, this coastal zone is extremely significant. But the other main economic activities of this coastal zone are salt cultivation, fishing and fish farming as well (Sarwar, 2005).

2.2.2. Sea Level Rise (SLR)

The abundant human population of this area is under tremendous threat due to SLR because of the country's dense population. The sea level will increase by 1.5 m, according to the United Nations Environment Program (UNEP). In 2030, this will cover about 16% of the total land and impact about 15 million Bangladeshi citizens (Seal & Baten, 2012). Another study estimated that the sea level would increase by 10 cm by 2020, 25 cm by 2050 and 1 m by 2100, which would overtake our country's land by around 2%, 4% and 17.5% respectively (World Bank, 2000).

In response to the resolution of the 7th session of the Conference of the Parties (COP7) of the United Nations Framework Convention on Climate Change (UNFCCC), the Ministry of

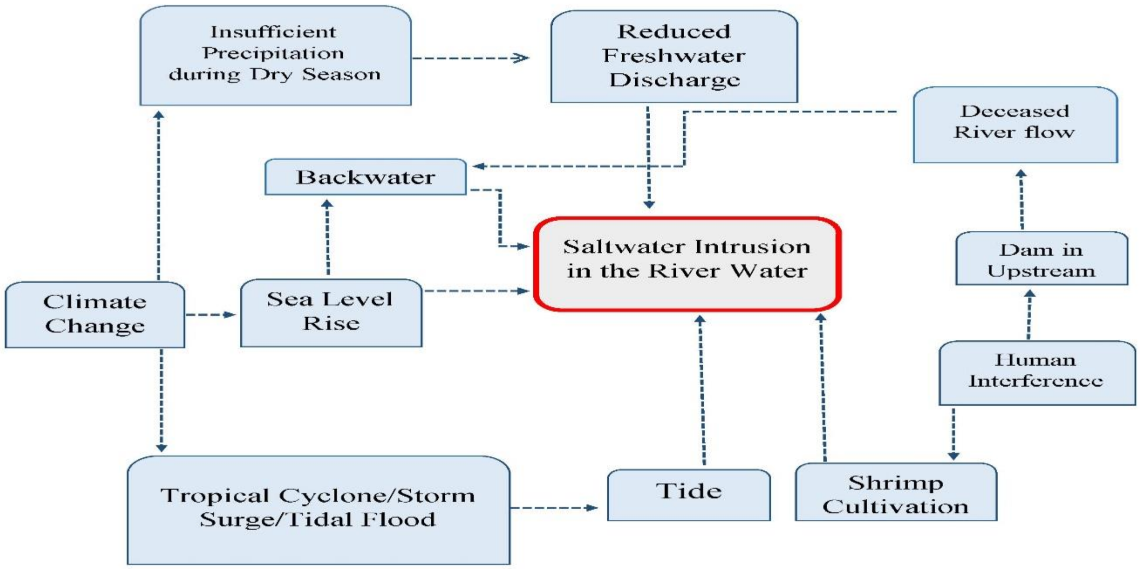

Photo 3 Causes of Salinity in the Rivers of Coastal Bangladesh

Environment and Forestry (MoEF) of Bangladesh has prepared a National Adaptation Programme of Action (NAPA) (CCC, 2016). In 2003, the Regional Cooperation South Asian Association (SAARC).

The annual tidal gauge from 1977-1998 was observed by the Meteorological Research Centre (SMRC) and found that the tidal level rose in three points of Bangladesh (Hiron Point, Char Changa, and Cox's Bazar) (Table 02). The Eastern Coastal Zone tidal level (ECZ) is much higher than the Western Coastal Zone tidal level (WCZ).

Table 2 Tidal Level in Three Points of Bangladesh

Point	Region	Latitude	Longitude	Datum	Trend
Hiron Point	Western	21º 48' N	89º 28' E	3.784 m.	4.0 mm/yr.
Char Changa	Central	22º 08' N	91º 06' E	4.996 m.	6.0 mm/yr.
Cox's Bazar	Eastern	21º 26' N	91º 59' E	4.836 m.	7.8 mm/yr.

Due to the rising sea level, salt water reaches Bangladesh's coastal regions (Seal & Baten, 2012). A study shows that the 88 cm increase in sea level affects the intrusion of 5 ppt of salt water into 40 km of the Tentulia freshwater river in the Meghna estuary (Shamsuddoha & Chowdhury, 2007).

2.2.3. Natural Hazard and Disaster

Bangladesh is vulnerable to natural hazards and disasters due to its geographic location. Among them, there are many catastrophes that have contributed to an increased intrusion of salt water into the river water. Some of the disasters that are responsible are cyclones, storm waves, tidal floods. Bangladesh has witnessed several destructive cyclones over the last few decades. The main examples are the Bhola Cyclone (1970) and the Bangladesh Cyclone (1991) (Ali 1996). Saline water invades agricultural land, wetlands, canals and rivers of the coastal zone that are still polluted by saline water during the Sidr (2007) and Aila (2009) cyclones. The people of the coastal zone continue to suffer from this problem (Mahmuduzzaman et al., 2014). Bangladesh's coastal zone is a very flat and low-lying area, less than 3 m above the mean sea level. Cyclone and storm surges are likely to be very frequent in the coastal Bangladesh due to the significant higher range astronomical tide and sea level rise (Seal & Baten, 2012). The frequency of tropical cyclones and storm surges in the Bangladesh coastal zone will increase with higher peak wind speeds and heavy precipitation due to climate change (Khan et al., 2010). Bangladesh faces two flood tides and two ebb tides in a day of six hours of successive time intervals. Due to the heavy rainfall and flood surges, urban areas of coastal Bangladesh face flooding due to water logging during the monsoon. Therefore, saline water spreads almost all over the coastal area due to the heavy rainfall and high tide during the monsoon (Mahmuduzzaman et al., 2014).

2.2.4. Back water effect

At the mouth of the river, the backwater effect is (transition zone). The backwater effect is a special form of movement of saline water from the sea into the river. It happens when the flow of tidewater is not sufficient for freshwater (Seal & Baten, 2012)

There are different explanations why the mouth of the river is responsible for the backwater effect.

The explanations are (Ali, 1999):

1. Monsoon Wind Southwest
2. Tides of Astronomics
3. Surge of Hurricanes

(Ali, 1999) also stated that the non-dynamic and long-term reason for the backwater effect is the rise in sea level.

2.2.5. Shrimp cultivation

Shrimp production plays a crucial role in salinity interference, among many anthropogenic factors. The farming of shrimp is causing significant alarm in the agricultural land of the coastal area of Bangladesh (Flaherty et al., 2000).

The cultivation of shrimp needs saline water which is carried in the Gher using external measures (pond). With the expansion of the shrimp cultivation practice in the fresh agricultural land, saline water intrusion is also growing day by day (Mahmuduzzaman et al., 2014).

Table 3 Land Use Changes in Shrimp Cultivation from 1975-76 to 2006-07

District	**Shrimp Cultivation (ha.)**	
	1975-76	**2006-07**
Cox's Bazar	7, 500	48, 105
Khulna	500	52, 950
Bagerhat	20	61, 960
Satkhira	5, 000	60, 000
Noakhali	500	2, 670
Barisal	250	542
Patuakhali	101	4,360

As a result of intensive shrimp farming, soil salinity is increasing and the supply of agricultural land is decreasing. Penaeus monodon is a brackish water shrimp with a significant international market demand. This shrimp farming has taken place in almost the entire coastal area of our nation due to the enormous demand on the international market (Mahmuduzzaman et al., 2014).

2.3. Impact of salinity in the rivers of coastal region of Bangladesh

In general, a common hazard to freshwater sources such as aquifers is salt water intrusion. The excessive content of salt and saline water minerals may also have a detrimental effect on animal species and on many forms of plant species (Thompson 2014).

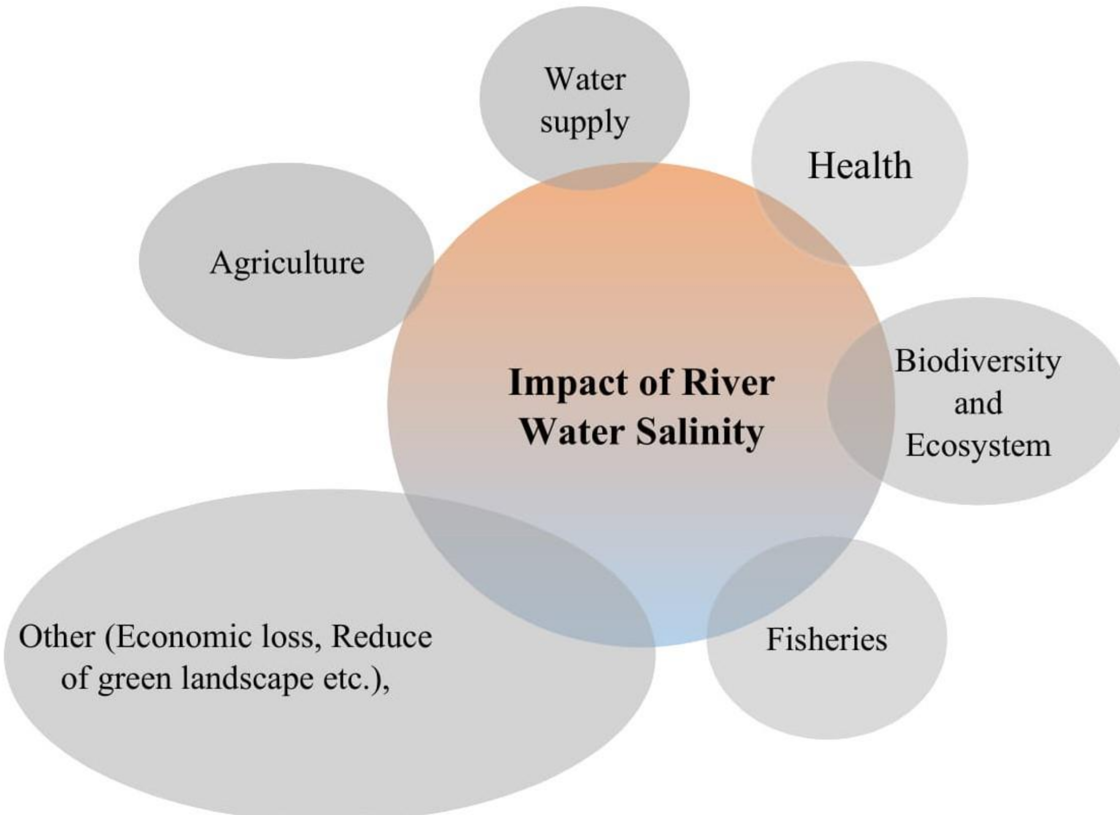

Photo 4 Flow Chart of Salinity Intrusion in the Rivers of Coastal BD

2.3.1. Water supply and Health

Communities have evolved near water throughout mankind's history. This fact is further justified by contemporary worlds with heavily populated coastal areas.

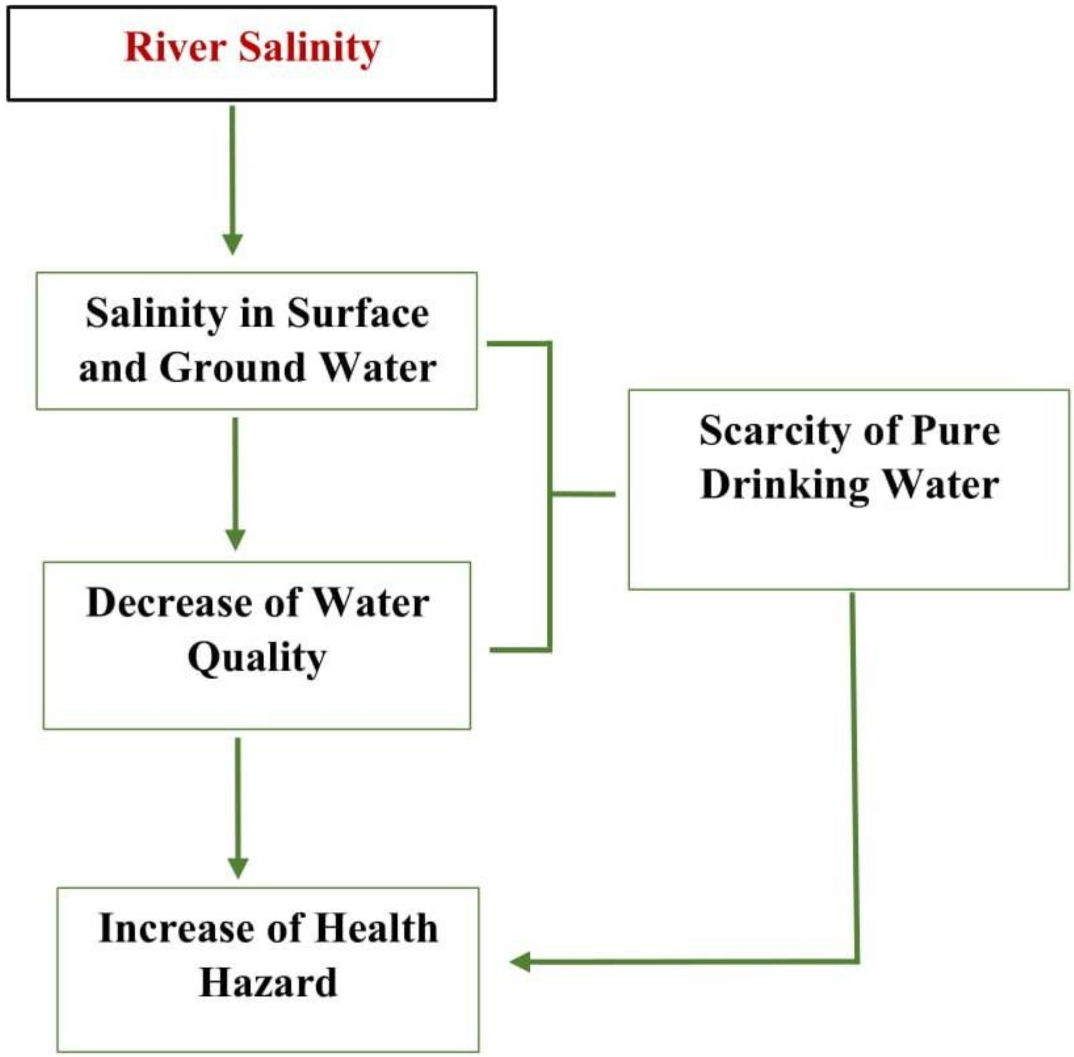

Photo 5 Impact of salinity on water supply and health

Since the Neolithic period, human beings have known the significance of the availability of steady water and the importance of constructing a society. For that reason people prefer to move to the coast. Integrated human activities with some hydrological problems (such as groundwater pollution by salt water intrusion) resolve the issue of day-to-day drinking water shortage in coastal regions (Duan, 2016). The increase in the salinity of water reduces drinking water supply and contaminates fresh water. People drink polluted water and become ill with water-borne diseases such as cholera, diarrhea, etc.) due to the lack of fresh water, the issue of malnutrition also increased due to the reduction in food output (Sarwar, 2005).

2.3.2 Agriculture

By reducing crop production, hampering industrial production, reducing floral species (as well as fauna) and forest products, saline water intrusion into river water causes massive economic losses. Increased salinity induces salt fixation at the root of plants, resulting in a nutrient imbalance, thus reducing output.

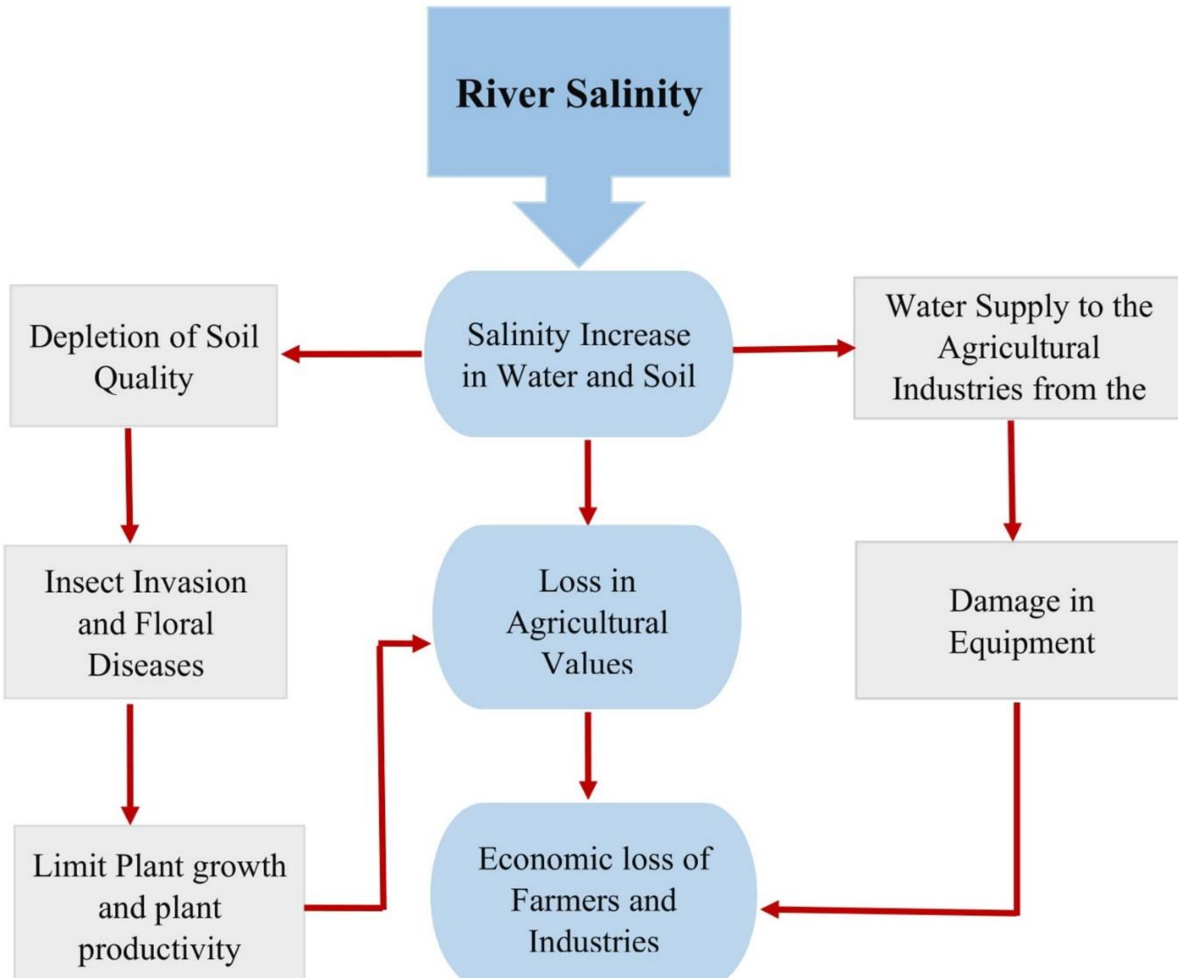

Photo 6 Impact of Salinity on Agriculture

Water from these rivers has been introduced by various industries to cool condensers or keep turbines going. Increased salinity restricts the use of river water and causes machinery to leak. This decreases productivity but raises the cost of production. For the entire process, that's a two-way loss. In 1993, Pakshi Paper Mill closed in north Khulna for the saltwater intrusion (Mirza, 1998). The rise in salinity also results in reduced growth of forest plants, causing soil quality to deteriorate. The whole thing has a detrimental effect on the wildlife and habitats around it (Seal & Baten, 2012). Simply put, the intrusion of saline water led to a shift in the condition of the soil or water that increases the floral disease and invasion of insects into the soil. These variables slow down the growth of the plant and reduce the diversity of plant species (Gain et al., 2014).

2.3.3. Fisheries

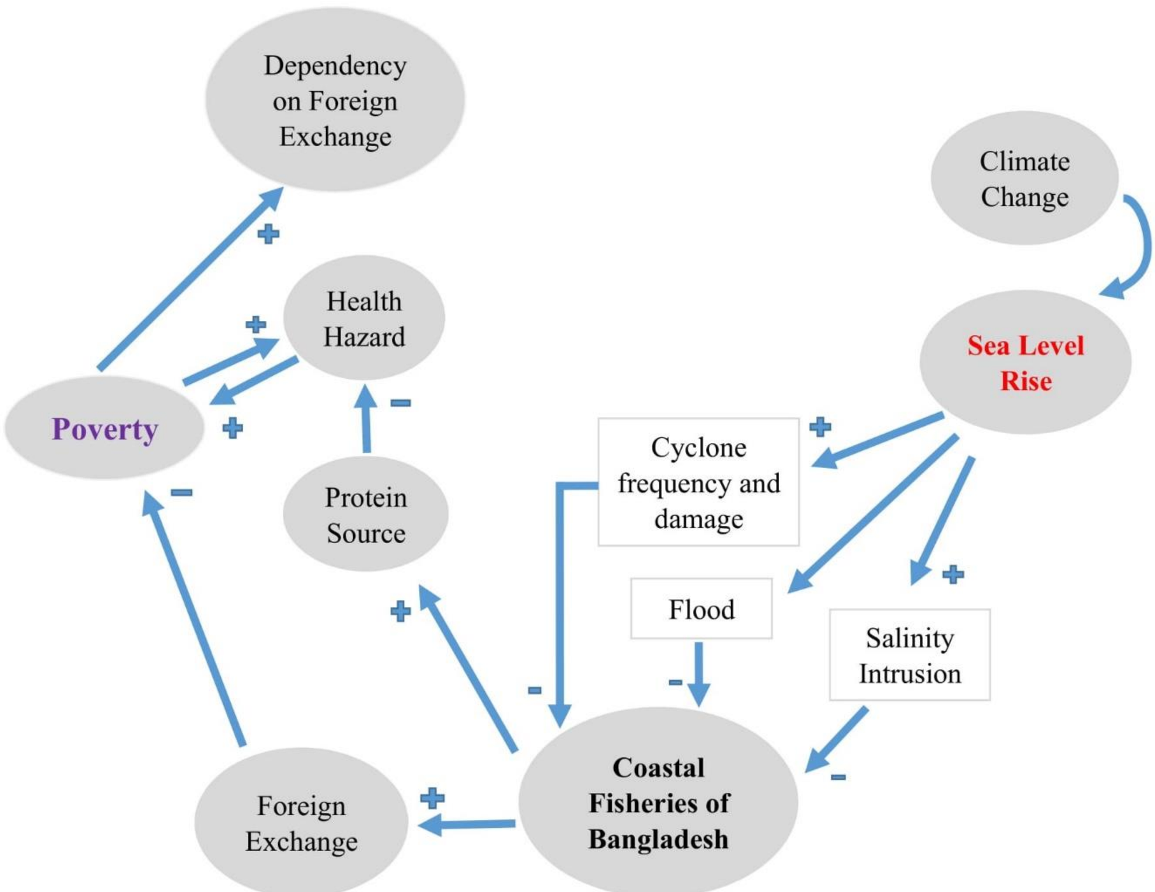

Photo 7 Impact of Salinity due to SLR on the Fisheries Resources of Coastal Bangladesh

According to CLD (Haraldson, 2004) - Casual Loop Diagram between sea level rise and Bangladesh's coastal fisheries (a model of effect relationship between two phenomena), the increase in sea level mainly affects coastal fisheries resources in three different ways (Sarwar, 2005). These are the ways:

1. Intrusion of saltwater
2. Flooding of coasts, and,
3. Growing the cyclone's severity

The decline in the fish population, which is the main source of subsistence for the people of this coastal area and their main source of protein, is responsible for these three phenomena. About 60-80% of the animal protein demand of the people of Bangladesh comes from fish consumption (Alam & Thomson, 2001). The increase in salinity and the reasons associated with climate change resulted in a decrease in fish production, thus showing a protein deficiency across the region. This is a tragedy for public health. Poverty in the coastal areas will rise due to the poor state of public health. The rise in poverty, on the other hand, would assign the risk to health (Sarwar, 2005). The Frozen Food industry is also tremendously harmed by the interference of salinity as one of Bangladesh's main Gross Domestic Product (GDP) earning sources. The decline in coastal fishing would reduce foreign exchange earnings. As a result, poverty will grow, forcing us to pursue international assistance (Sarwar, 2005).

2.3.4. Biodiversity and Eco-system

Ecosystems are widely recognised for their many significant ecological and environmental roles. A home for floral and faunal plants, such as nutrient cycling, etc (Fretwell et al., 1996).
Sudden changes in soil salinity have deadly consequences for the plant species involved. If an ecosystem's habitats are eroded, the biodiversity of that area may decrease immediately (Duan, 2016). Given the higher importance of our coastal Bangladesh's biodiversity, a few areas have been designated an Environmentally Protected Area (EPA) to conserve the species' natural habitat and save them from extinction (Islam 2004).

Table 4 Environmentally Protected Areas (EPA) of Coastal Bangladesh

EPA Type	Name	Area (ha.)	Location
Reserve Forest	-	885, 043	Bagerhat, Barguna, Bhola, Chottogram, Cox's Bazar, Feni, Khulna, Lakshmipur, Noakhali, Patuakhali, Satkhira
National Park	Himchari	1, 729	Cox's Bazar
	Nijhum Dweep	4, 232	Noakhali
Eco-park	Sitakunda	808	Chottogram
Wildlife Sanctuaries	Sundarban East	31, 227	Bagerhat
	Sundarbans South	36, 970	Khulna
	Sundarban West	71, 502	Satkhira
	Char Kukri Mukri	2, 017	Bhola
	Chunati	7, 761	Chottogram
Game Reserve	Teknaf	11, 615	Cox's Bazar
Ramsar Site	The Sundarban	601, 700	Bagerhat, Khulna, Satkhira
Environmentally Critical Areas (ECA)	Sonadia	4, 916	Cox's Bazar
	Teknaf beach	10, 465	Cox's Bazar
	St. Martin Island	590	Cox's Bazar
World Heritage Site	Sundarban Wildlife Sanctuaries	-	Bagerhat, Khulna, Satkhira
	Shaat Gombuz Mosque	0.16	Bagerhat
Marine	-	69, 800	Bay of Bengal
Fish Sanctuaries	-	15, 614	Barisal, Bagerhat, Bhola, Narail, Jessore, Khulna, Lakshmipur, Patuakhali, Feni

In these environmentally protected areas, many endangered animal species in our country live a healthy and sound life (EPA).

Table 5 Protected Species in the Environmentally Protected Areas (EPA)

Species Class	Species Number
Fish species	7 species
Amphibian species	2 species
Reptile species	7 species
Bird species	8 species
Mammal species	8 species

Chapter 3 – Methodology

3.1 Study area

Cox's Bazar is one of the most visited tourist destinations in the Chottogram division of Bangladesh. Cox's Bazar is a coastal district on the edge of the Bay of Bengal (BoB) with the largest sea beach in the world at 120 km. Cox's Bazar's geographic location is between 20o43 'and 21o56' north latitude and between 91o50' and 92o23 'east longitude. It is bordered on the north by the Chottogram district, on the east by the Bandarban district and Myanmar, on the south and west by the Bay of Bengal, and (BBS, 2011).

Bangladesh is a country with a river. There are four major rivers in Cox's Bazar district (The Matamuhuri, Bakkhali, Reju Khal and Naf) that went through the Bazar of Cox and dropped into the Bay of Bengal. The Masheshkhali and Kutubdia channels are the two main channels connected to the Bay of Bengal in Cox's Bazar district (BoB). The Bazar district of Cox is split into 8 Upazilas. Bazar Sadar of Cox, Chakoria, Maheshkhali, Teknaf, Ramu, Kutubdia, Ukhia, and Pekua are the Upazilas. The district of Cox's Bazar consists of a total area of 2, 491.85 sqkm (BBS, 2014).

One of the popular features of Cox's Bazar is the River Bakkhali. The river is formed in the south-western hills of Mizoram, India. Via Naikkhongchori, Bandorban, the waterline entered Bangladesh. This created the Bakkhali River that passed through Bazar Sadar Upazila of Ramu and Cox. Through the Maheshkhali Channel, it connects itself with BoB. The total length of the river is 69km, approximately 47km from the Ramu Upazila-Bandarban border to the Maheshkhali Channel. The Cox's Bazar Sadar Upazila is about 20km from his body. In the center of this length, an embankment is built around. From there the study area began up to the Maheshkhali River, which is about 11.10 km. The slope downwards from the dam is considered to be the Bakkhali River Downstream Region.

3.1.1 Sampling Location

During the analysis, a total of 11.10km of the downstream area was protected. A total of 7 randomly chosen sampling locations were used to collect data.

In Pata Sadar Para, the collection began and ended on the Maheshkhali Channel.

Table 6 Sampling Locations and their Distance from the Dam

No.	Sampling Location	Distance from the Dam to the Locations (km)
Downstream Zone (from Dam to Maheshkhali Channel, BoB)		
01	Chandu Para	1.12
02.	S M Para	2.28
03.	Gudar Para	4.59
04.	Khurushkul Bridge	5.69
05.	Kastura Ghat	7.08
06.	North Noniar Chara	9.04
07.	Maheshkhali Channel	11.05

Photo 8 Sampling Locations of Downstream Zone, Bakkhali River

3.2. Data Collection techniques of the study

The research concentrated mainly on the collection of primary data. Throughout the sampling process, however both qualitative and quantitative data are also combined. Primary data was derived from the review of different scientific research papers. The framework is as follows—
The secondary data provided an assessment of the current scenario and the consequences in the study region of increased salinity.

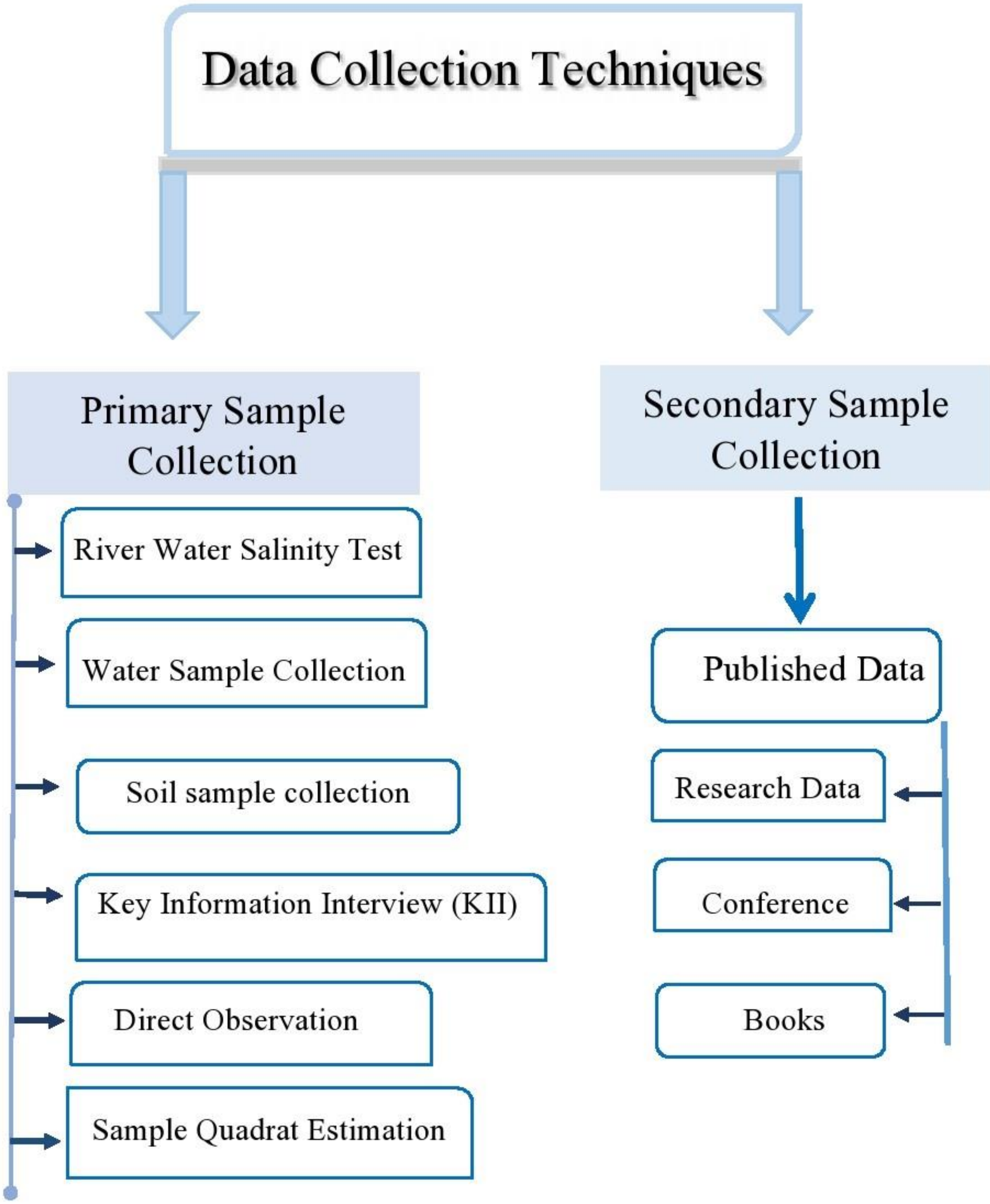

Photo 9 Data Collection Techniques of the Study

3.2.1 River Water Salinity test

We gather water from four separate river spots at a particular sampling site. We then used the portable salinity refractometer to combine these collected waters and determine the salinity of that water directly in that location. To test the water salinity of the Bakkhali river, we repeated the procedure at every 7 sampling locations.

3.2.2 Water sample collection

A total of 50 ml of water was collected from 4 points of the sampling site and then mixed into a 250 ml water collection bottle. In each sampling site, this process was repeated. The bottles were labeled with the name of the venue.

Further research was carried out at Daffodil International University's (DIU) Environmental Science and Disaster Management (ESDM) Laboratory.

3.2.3. Direct observation

To locate materials specific to the research, sampling sites and their surrounding areas were examined by naked eyes. These results allowed the analysis to use some in-depth knowledge of the pre-existing state of the field of study. For the observation section, a total distance of km was covered. Few of the local residents volunteered in an informal debate that helped obtain robust study results from the observation.

3.2.4. Sample Quadrat Estimation

Within 50m of the salinity test site, a 4 m2 plot was chosen at each sampling location. This plot is referred to as Quadrat (Odum 1969). Initially established plant species were identified within the square, accompanied by an estimation of the number of individuals within the plot for one plant species. For all 7 sampling sites, this procedure was then repeated.

Table 7 Sample Tabulation Sheet for Sample Quadrat Estimation

Sampling Quadrat ($10m^2$) Location 01: **Chandupara**	
Plant Species	**n (Number of Individuals)**
Vachellia nilotica	~~IIII~~ II (7)
Casuarina equisetifolia	~~IIII~~ III (8)
Swietenia mahagoni	~~IIII~~ IIII (9)
Acacia auriculiformis	III (3)
Areca catechu	~~IIII~~ ~~IIII~~ ~~IIII~~ II (17)
Samanea saman	IIII (4)

3.3. Data analysis

The data obtained has been evaluated according to the framework below.

The following steps introduced by (Taylor & Renner, 2003) have been used to evaluate and interpret qualitative data, namely:

1. Explore the interpretation of data
2. Concentrate on the interpretation of the data
3. Compilation and categorisation of data

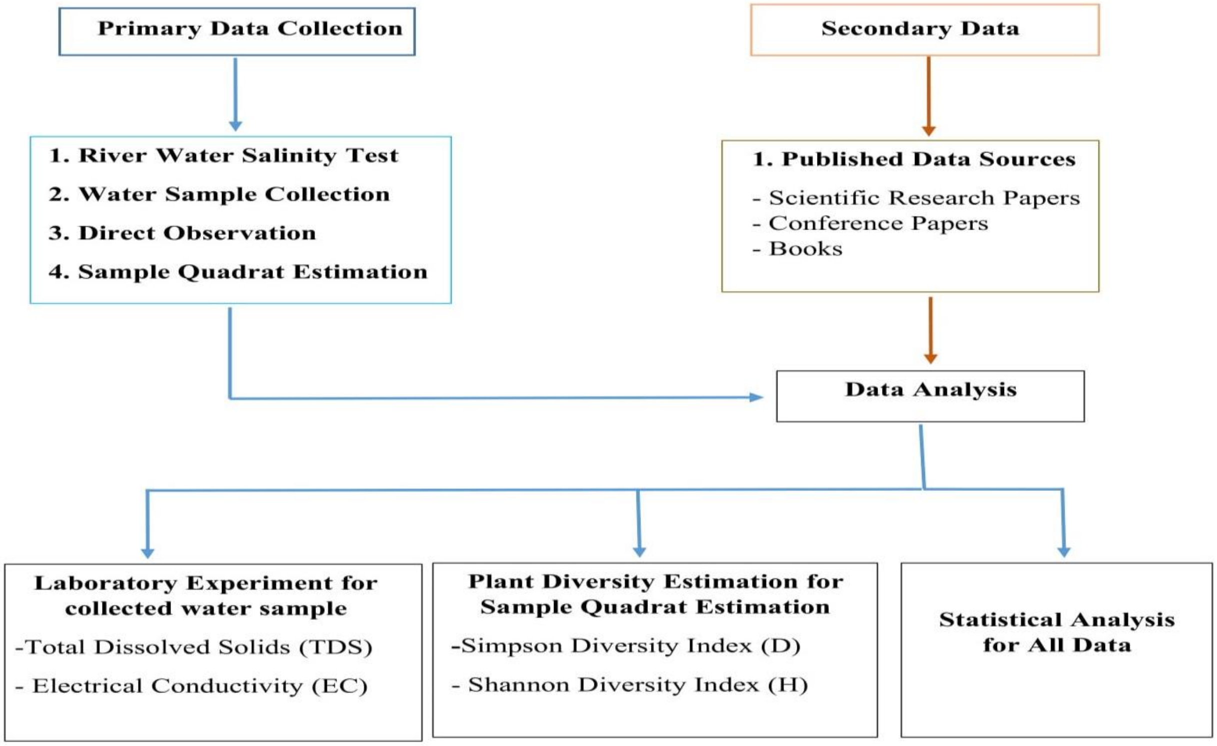

Photo 10 Structured Framework for Data Analysis

3.3.1. Laboratory Experiments

The Environmental Science and Disaster Management (ESDM) Laboratory of Daffodil International University (DIU), Ashulia, Savar, measured the Total Dissolved Solid (TDS) and Electrical Conductivity (EC) of the water samples collected from all 7 locations. The HANNA Ph/EC/TDS/Temperature Meter (HI9814) is used to separately measure the TDS of a 7-water sample. The HANNA EC tester (HI98304) was used to separately calculate the EC value of the 7-water sample. More than 50ppt salinity was not shown in any study. For the samples, no dilution was required.

3.3.2 Plant diversity estimation

This is a statistical calculation that estimates a given area's species diversity. The greater the number of animals, the more diverse the population is. There are usually two types of diversity indexing (Odum, 1969). They are as follows –

3.3.2.1. Simpson Diversity Index (D)

In more common animals, this is a dominance index as it weights. The key feature of this index system is that the general diversity of a region would not be influenced by a few rare species with a few individuals (Simpson, 1949). So, the equation is -

$$\mathrm{D} = 1/\sum_{i=1}^{s} p_i^2$$

Where, D = Simpson Diversity; Pi = Proportion of (n/N); n = Individuals of one species; N = Total number of all species individuals; Σ = Sum of the calculations.

3.3.2.2. Shannon Diversity Index (H)

The Shannon Diversity Index is a commonly used statistical knowledge index that represents all species in a sample and selects samples randomly (Shannon & Weaver, 1963). The equation is –

$$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$$

Where, H = Shannon Diversity; Pi = Proportion of (n/N); n = Individuals of one species; N = Total number of all species individuals; ln = Natural log; Σ = Sum of the calculations.

3.3.2.3. Estimation Procedure

A 10m2 plot quadrat was taken within 50m of the salinity test spot. For all 7 sampling sites, the same thing was replicated. Current plant species were described after that. Later, for a single species, the number of individuals was described. Then, using both the Simpson Diversity Index

(D) and the Shanon Diversity Index (H) through the following process, the diversity for a particular quadrat plot was measured.

Table 8 Diversity Estimation Procedure by Using both Simpson and Shannon Diversity Index

Sampling Location – Chandupara					
Plant Species	**n**	**n/N = P_i**	**P_i^2**	**ln P_i**	**$P_i \times \ln P_i$**
Vachellia nilotica	7	0.145833	0.021267	-1.9252909	-0.28077
Casuarina equisetifolia	8	0.166667	0.027778	-1.7917595	-0.29863
Swietenia mahagoni	9	0.1875	0.035156	-1.6739764	-0.31387
Acacia auriculiformis	3	0.0625	0.003906	-2.7725887	-0.17329
Areca catechu	17	0.354167	0.125434	-1.0379877	-0.36762
Samanea saman	4	0.083333	0.006944	-2.4849066	-0.20708
N = 48		$\Sigma Pi^2 = 0.220486$		$\Sigma Pi \times \ln Pi = -1.64125$	
$D = 1/\sum_{i=1}^{s} p_i^2$		D = 1/0.220486		4.535433071	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$		H= -(-1.636)		1.641251725	

3.3.3. Statistical Analysis

Using Microsoft Excel, all the data was compiled. The correlation coefficient and regression between the variables were analyzed using Microsoft Excel. In addition to all that, the T-test was also performed to prove the hypothesis of the supposed analysis.

3.4. Instrumental Technique

For Salinity, Gross Dissolved Solid and Electrical Conductivity measurements, three different instruments were used. For statistical analysis and visualization, a lot of other software was used. The instruments are as follows –

Table 9 Used Instruments, Tool, and Software's to Conduct the Study

Category	Parameters	Name or Model
Instruments	Water Salinity	Portable Salinity Refractometer
	TDS	*HANNA* Ph/EC/TDS/Temperature Meter (HI9814)
	EC	*HANNA* EC Tester (HI98304)
Tool	Navigation	Garmin eTrex® 10 (GPS Navigation Device)
Software's	Mapping	ArcGIS 10.2.1
		Google Earth Pro
	Statistics	Microsoft Excel 2016

Table 10 Major Characteristics of the Instruments

Instruments	Characteristics Category	
	Range	**Resolution**
HANNA pH/EC/TDS/Temperature Meter (HI9814)	0 to 3999 ppm	10 ppm
HANNA EC Tester (HI98304)	0.00 to 20.00 mS/cm	0.01 mS/cm
Portable Salinity Refractometer	0 to 100 %	20 %

Chapter 4 – Result and Discussion

This chapter presents the findings and results of the analysis through different forms and parameters. The research goals are also answered by evaluating the data and outcomes obtained. The entire chapter is split into 5 parts.

4.1. Study Findings

The study results are discussed here. The current state and status of the salinity, calculated TDS and EC of the water obtained from the Bakkhali River sampling locations are shown here. The estimates of the plant diversity of the downstream zone of the study region are also in this segment.

The location of the analysis begins with a river dam, for which the topographical location goes downwards. The study area is thus known as the Downstream Region. The sampling locations were chosen according to the descending distance from the Rabar Dam to the Bay of Bengal Moheshkhali River. On the location, the salinity level was calculated. Via laboratory experiment, EC and TDS were observed. Using both the Simpson (D) and Sharon (H) Diversity Index, plant diversity was estimated.

4.1.1. Salinity

River water salinity increases in the downstream zone as the distance from the Rabar dam to the Maheshkhali Channel of the Bay of Bengal rises downward (Gain et al., 2014; Petersen & Shireen, 2001).

Table 11 Measured Salinity at the Sampling Locations (SL) of the Study Area

Downstream Zone			
Sl.	***Downward Distance of SL from Dam to the BoB (km)***	***Location Name***	***Salinity (ppt)***
1	1.12	Chandu Para	0%
2	2.28	S M Para	0%
3	4.59	Gudar Para	3%
4	5.69	Khurushkul Bridge	5%
5	7.08	Kastura Ghat	8%
6	9.04	North Noniar Chara	11%
7	11.05	Moheshkhali Channel	24%

The first two sample positions showed salinity at 0 percent. As the sampling positions changed outwards to BoB, the salinity increased. At the Moheshkhali Channel sampling site, the highest measured salinity was 240ppt.

Overall, the water salinity status in the downward zone of the Bakkhali River is-
A The maximum salinity is 240ppt and 0ppt is the lowest. As sampling locations shifted down from Rabar Dam to BoB, salinity increased.
(b) Low salinity in the downstream section also means a much lower risk of finding salinity in the upstream portion.

4.1.2. Total Dissolved Solid (TDS)

Some of the samples were diluted 5 times during the laboratory experiments to get the TDS value within the range (0-3999) of the used TDS meter (HANNA Ph/EC/TDS/Temperature meter-H19814) (Corwin & Yemoto, 2017). More than 50ppt of salinity was seen in the samples that were diluted. The locations are BoB's Moheshkhali Channel, Kastura Ghat and North Noniar Chora.

Table 12 Measured TDS at the Sampling Locations (SL) of the Study Area

Downstream Zone			
Sl.	***Downward Distance of SL from Dam to the BoB (km)***	***Location Name***	***TDS (ppm)***
1	1.12	Chandu Para	90
2	2.28	S M Para	110
3	4.59	Gudar Para	860
4	5.69	Khurushkul Bridge	350
5	7.08	Kastura Ghat	5700
6	9.04	North Noniar Chara	11450
7	11.05	Moheshkhali Channel	14000

As the downward distance from the Rabar Dam to BoB increased, the TDS showed an improvement. The Moheshkhali Channel had the highest TDS value of 14000ppm and the Chandu Para sampling position had the lowest value of 90ppm. As the sampling positions went downward, the TDS count was greater, much like salinity.

4.1.3. Electrical Conductivity (EC)

To get the value inside the EC range (0.00 to 20mS/cm) of the used EC tester (HANNA EC tester-H198304), three samples from the sampling locations that showed more than 50ppt salinity were diluted 5 times (Corwin and Yemoto, 2017). BoB's Moheshkhali Channel, North Nonier Chora and Kastura Ghat are the sampling locations.

Table 13 Measured EC at the Sampling Locations (SL) of the Study Area

Downstream Zone			
Sl	***Downward Distance of SL from Dam to the BoB (km)***	***Location Name***	***EC (µS/cm)***
1	1.12	Chandu Para	0.08
2	2.28	S M Para	0.11
3	4.59	Gudar Para	0.98
4	5.69	Khurushkul Bridge	0.39
5	7.08	Kastura Ghat	1.30
6	9.04	North Noniar Chara	2.57
7	11.05	Moheshkhali Channel	3.18

The EC count is also higher as the sampling positions moved downward from Rabar Dam to BoB. This relates to the rise in downward positions of TDS and Salinity, respectively.

4.1.4. Plant Diversity

The estimation of plant diversity was performed according to the downward sampling positions respectively. The estimate started at the Rabar dam and ends at the Moheshkhali Channel BoB sampling site. Using both the Simpson and Shannon Diversity Index, diversity was estimated.

4.1.4.1. Simpson Diveristy Index

With the rise in the downward distance of sampling locations from the dam to the Maheshkhali River, the diversity decreases (Gain et al., 2014). The highest plant diversity occurs in the downstream zone in North Noniar Chara, the 6th sampling location from Rabar dam to BoB. However as the sampling locations changed downwards from Rabar dam to BoB, other sampling locations showed a steady decrease. A significant cause of the loss of diversity in the downward zone is greater salinity. The diversity in North Noniar Chara, however, has shown a significant change. Thanks to the pandemic, less tourist footprints, monsoon rain, decreased pollution and social forestry have played a key role in rising the diversity of the entire study region.

Table 14 Estimated Plant Diversity using Simpson Diversity Index (D) at the Sampling Locations (SL) of the Study Area

Downstream Zone			
Sl.	***Downward Distance of SL from Dam to the BoB (km)***	***Location Name***	***Diversity (D)***
1	1.12	Chandu Para	4.535433071
2	2.28	S M Para	5.01980198
3	4.59	Gudar Para	4.918128655
4	5.69	Khurushkul Bridge	6.84045584
5	7.08	Kastura Ghat	6.755351682
6	9.04	North Noniar Chara	11.95364238
7	11.05	Moheshkhali Channel	2.734177215

Under the Simpsons Diversity Index (D)-

A) In the downstream region, 11.95364238 is the highest plant diversity value and 2.734177215 is the lowest. The variety of plants remains close to the importance of all sampling locations.

(b) Increased diversity of Northern Noniar Chara plants indicates lower human footprint and independent development in floral species.

4.1.4.2. Shannon Diversity Index

The Shannon Diversity Index was measured downwards from the Rabar Dam to the BoB Moheshkhali Channel respectively. At North Noniar Chara, the highest value was found. The diversity remains closer to other sampling locations in terms of importance.

Table 15 Estimated Plant Diversity using the Shannon Diversity Index (H) at the Sampling Locations (SL) of the Study Area

Downstream Zone			
Sl.	***Downward Distance of SL from Dam to the BoB (km)***	***Location Name***	***Diversity (H)***
1	1.12	Chandu Para	1.641251725
2	2.28	S M Para	1.77127
3	4.59	Gudar Para	1.8417
4	5.69	Khurushkul Bridge	2.05774
5	7.08	Kastura Ghat	2.09097
6	9.04	North Noniar Chara	2.60798
7	11.05	Moheshkhali Channel	1.05082

Under the Shannon Diversity Index (H) –

1. The highest value found was in North Noniar Chara at 2.60798 indicating a more suitable pre-existing condition for the plant species to thrive.

2. All the other areas of diversity estimation remain similar to each other, apart from the highest defined result field.

From the two results it can be said that, according to both Simpson and Shannon Diversity –

1. Plant diversity is comparatively lower in the downstream region of the Bakkhali River. Also with the rise in the downward distance of sampling locations from the dam to the Bay of Bengal, plant diversity decreases.

2. The values of plant diversity at sampling sites are close to each other and comparatively similar.

4.2 Water Salinity (Distance vs Salinity Level)

Salinity increases steadily in the downstream zone as the downward distance of sampling locations from the dam to the BoB's Maheshkhali Channel increases.

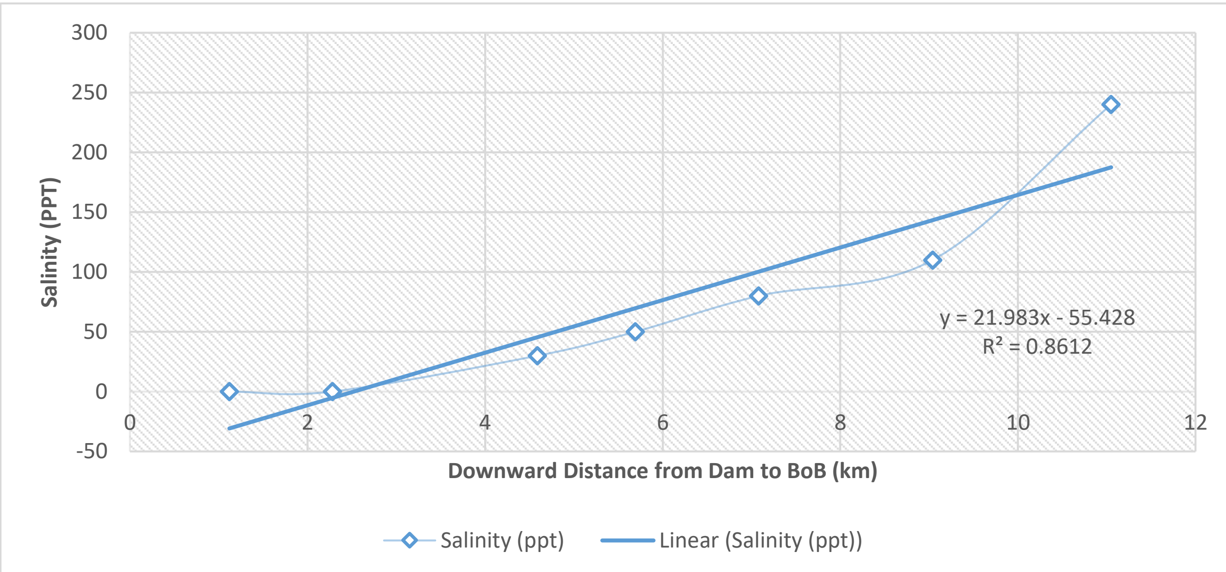

Photo 11 The relation between Salinity and Distance

The figure shows a weak positive correlation between downward distance from Dam to BoB and Salinity level. In the figure the linear trendline represents the correlation coefficient between those two variable. The value (r) is 0.92 which means it shows almost perfect positive relationship between these two variable. The salinity continues to rise as the downward gap rises from the dam to the BoB. The figure indicates that it is a very strong relationship in terms of the frequency of the relationship, where the data points firmly embrace the linear trendline. It is an amorphous, very strongly correlated glob.

4.3. Plant Diversity

In the downstream zone and the upstream zone of the Bakkhali river, we have shown the difference of plant diversity here. In both the Simpson Diversity Index (D) and the Shannon

Diversity Index (H), we estimated the plant diversity for each single sampling position or each 7 sample quadrat.

4.3.1. Simpson Diversity Index (D)

The figure shows the relationship between the diversity (D) and the downward distance from the dam to the Bay of Bengal from the sampling locations. The correlation coefficient between the salinity and downward distance was represented in the figure by the linear trendline. The value of the coefficient of correlation (r) here is 0.23. That implies that it is portrayed as a poor positive link between diversity (D) and downward distance. The diversity (D) continues to steadily decrease as downward distance increases. With regard to the strength of the relationship, the figure reveals that it is a poor positive relationship where the linear trendline is not embraced by

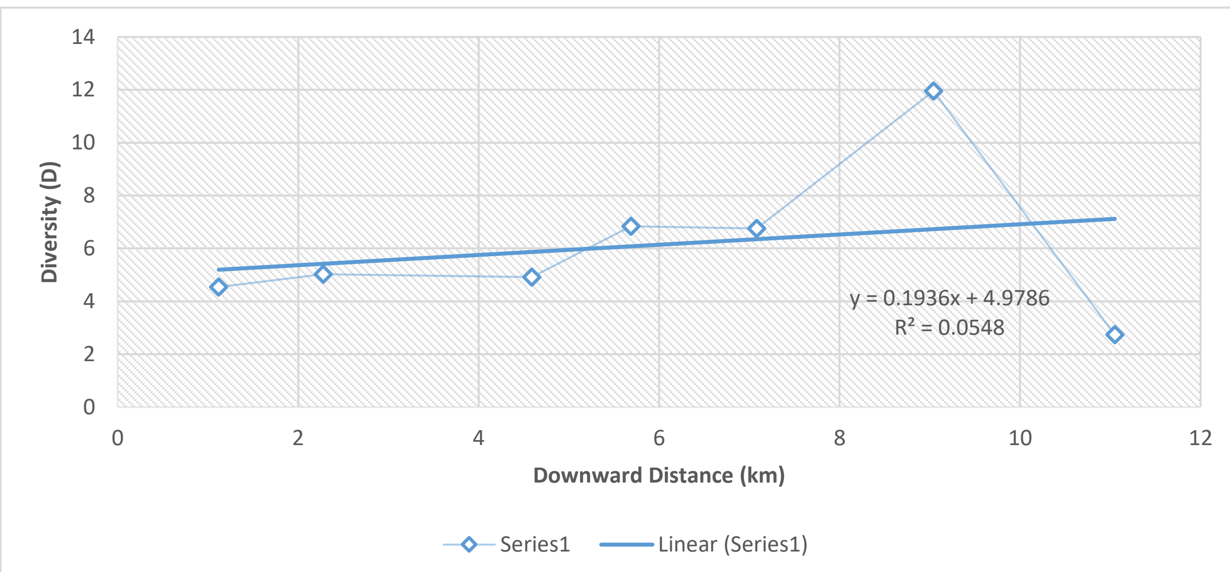

Photo 12 The relation between Diversity (D) and Distance

the data points. It's an amorphous blob with a connection that is quite fair.

4.3.2 Shannon Diversity Index

The relationship between diversity (H) and the downward distance from the dam to the Bay of Bengal is illustrated in this figure. The correlation coefficient between the salinity and downward distance was represented in the figure by the linear trendline. The value of the coefficient of correlation (r) here is 0.02. That implies that the relationship between the diversity (H) and the downward distance was very weak or positive. As for the strength of the relationship, the figure reveals that it is a very poor positive relationship or no relationship where the data points do not at all embrace the linear trendline. It's an amorphous blob with a connection that is quite fair.

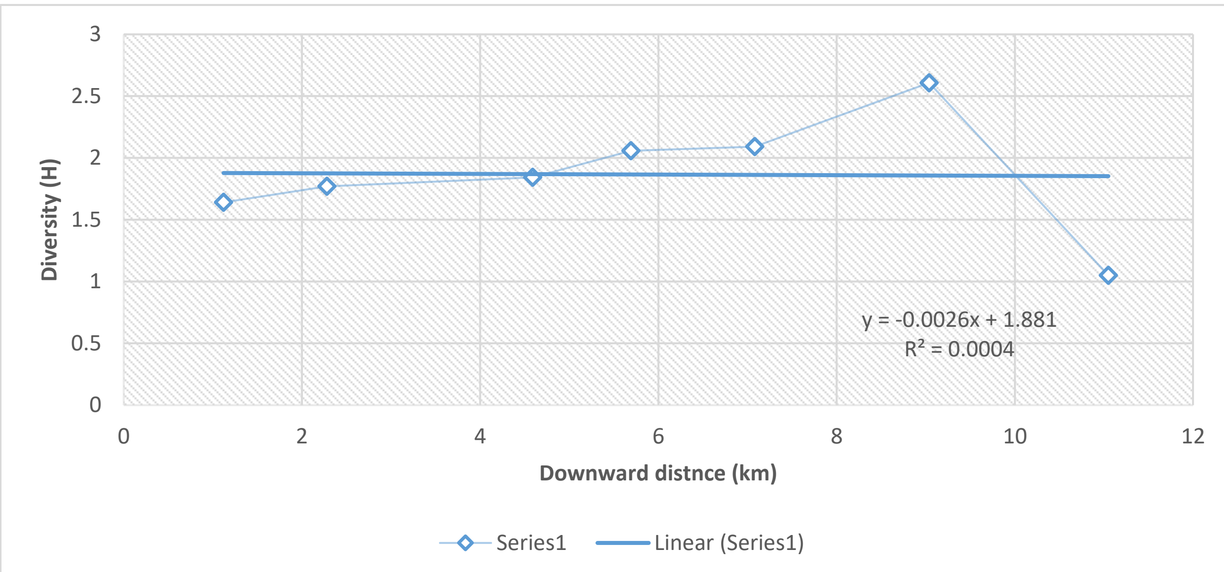

Photo 13 The relation between Diversity (H) and Distance

4.4. Impact of water Salinity on Plant diversity

Here in the downstream and upstream areas of the Bakkhali River, we tried to investigate the effect of water salinity on plant diversity. We used both the Diversity Index of Simpson (D) and Shannon (H). In Microsoft Excel, we investigated the effect using the correlation regression formula (Gain et al., 2014; Briggs & Taws, 2003).

If we look at the figure, the relationship between salinity and plant diversity in both the Simpson (D) and Shannon (H) diversity index can easily be understood, as the salinity increases in the downstream region, plant diversity does not really decrease. Both figures indicate that the downstream zone has almost no interaction between salinity and plant diversity. The two linear trendlines are almost identical and show a very poor positive association between plant diversity and salinity. Thus the correlation coefficient (r) value is 0.02 for Simpson (D) and 0.36 for the diversity index of Shannon (H). That means that both trendlines show a poor positive (fairly) relationship in the downstream region, where diversity remains almost the same as the salinity rises from the Dam towards the Bay of Bengal (BoB).

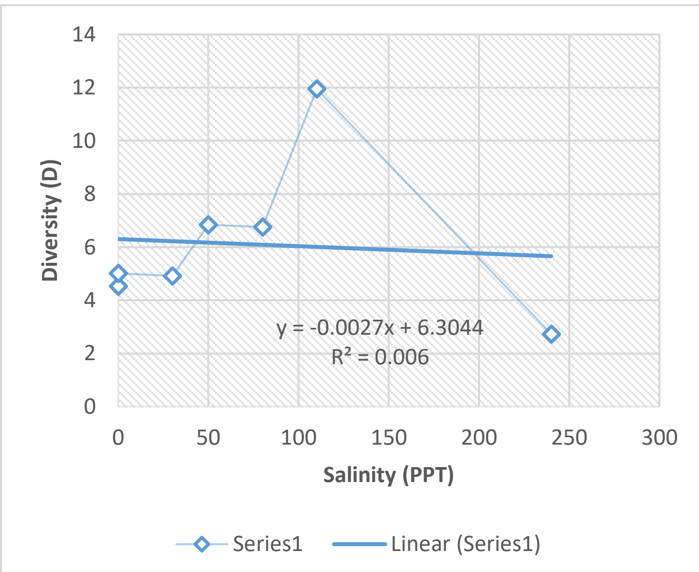

Photo 14 Impact of Salinity in Plant Diversity (D) of the Bakkhali River

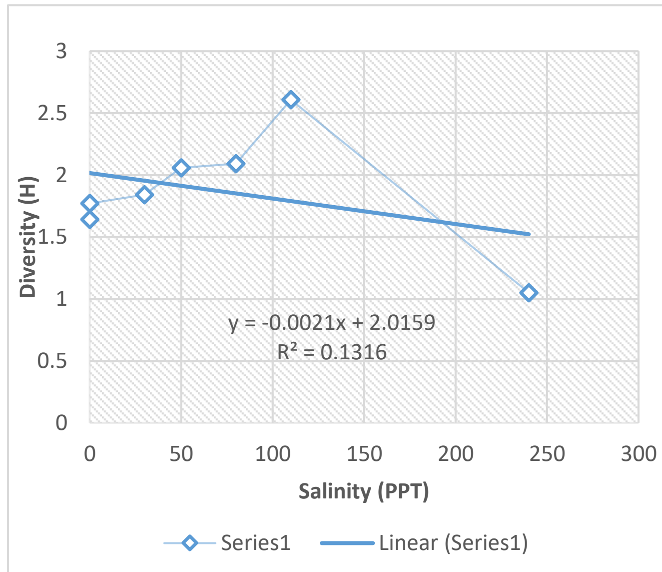

Photo 15 Impact of Salinity in Plant Diversity (H) of the Bakkhali River

Chapter 5 – Conclusion and Recommendation.

All research points from the literature review, data collection, data analysis, outcome, and discussions are given in this final chapter of the study. Here we have tried to explain the assembled aims of the research. In order to better understand the future analysis, guidelines for the researchers are also given. This chapter was split into two parts.

5.1 Recommendations

This part was divided into two parts for better understanding of the reader.

a. Study Limitations

1. Often there can be a major difference between the riverside waters. So you need to be conscious and mindful of the correct calculation or set of water parameters from both sides of a river.

2. Wherever you like, you will not get sufficient water transport facilities. So you've got to be mindful of that.

3. Cox's Bazar's local language is very difficult to understand in every way unless you are a local resident. On this subject, you always have to be careful.

4. Access is very complicated in many regions. Because of certain national or government institutions nearby, it is very difficult to use a drone for aerial observation.

b. Study outcomes or understandings

1. The most valuable estuarine zone in our country could be the Maheshkhali Channel and the transition point between the Bakkhali River and the Bay of Bengal (BoB). The government should have to think about it in order to do that.

2. By planting salt-tolerant mangrove plants in the far downstream region of the Bakkhali River, the government can easily expand the range of mangrove forests in our country.

3. Local faunal species are migrating or dying due to the enormous salinity rise in the downstream zone of the Bakkhali river. They're simply going extinct day by day.

c. For future study –

1. Often aim to prioritize the knowledge and understanding of the surrounding world by the very local people.
2. Further research work on the management of salinity in the downstream zone of the river Bakkhali and the effects on the fishery resources of the river Bakkhali could be carried out.

So from the beginning to the end of the report, these are the key points of this study's recommendations.

5.2 Conclusion

Salinity increases steadily in the downstream zone as the downward distance of the sampling locations from the Rabar Dam to the Maheshkhali River of the Bay of Bengal increases (BoB). With the rise in water salinity, plant diversity steadily decreases in the downstream zone of the Bakkhali river. As a result, the plant diversity pattern is not well distributed in the downstream region. With the rise in salinity towards the Maheshkhali Channel of the Bay of Bengal (BoB) from the Rabar Dam, plant diversity is decreasing in the downstream zone of the Bakkhali River.

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APPENDIX – I

Diversity estimation tables for both Simpson (H) and Shannon Diveristy (D) Index –

Sampling Location (01) – Chandupara					
Plant Species	**n**	**n/N = Pi**	**Pi²**	**ln Pi**	**Pi × ln Pi**
Vachellia nilotica	7	0.145833	0.021267	-1.9252909	-0.28077
Casuarina equisetifolia	8	0.166667	0.027778	-1.7917595	-0.29863
Swietenia mahagoni	9	0.1875	0.035156	-1.6739764	-0.31387
Acacia auriculiformis	3	0.0625	0.003906	-2.7725887	-0.17329
Areca catechu	17	0.354167	0.125434	-1.0379877	-0.36762
Samanea saman	4	0.083333	0.006944	-2.4849066	-0.20708
N = 48		$\Sigma Pi^2 = 0.220486$		$\Sigma Pi \times \ln Pi = -1.64125$	
$D = 1/\sum_{i=1}^{s} p_i^2$		D = 1/0.220486		4.535433071	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$		H= -(-1.636)		1.641251725	

Sampling Location (02) – S M Para					
Plant Species	**n**	**n/N = Pi**	**Pi²**	**ln Pi**	**Pi × ln Pi**
Ziziphus mauritiana	2	0.051282	0.00263	-2.9704145	-0.15233
Acacia auriculiformis	8	0.205128	0.042078	-1.5841201	-0.32495
Swietenia mahagoni	5	0.128205	0.016437	-2.0541237	-0.26335
Samanea saman	4	0.102564	0.010519	-2.2772673	-0.23357
Cocos nucifera	13	0.333333	0.111111	-1.0986123	-0.3662
Mimusops elengi	4	0.102564	0.010519	-2.2772673	-0.23357
Albizia lebbeck	3	0.076923	0.005917	-2.5649494	-0.1973
N = 39		$\Sigma Pi^2 = 0.199211$		$\Sigma Pi \times \ln Pi = -1.77127$	
$D = 1/\sum_{i=1}^{s} p_i^2$		D = 1/0.199211		5.01980198	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$		H= -(-1.77127)		1.77127	

Sampling Location (03) – Gudarpara					
Plant Species	**n**	**n/N = Pi**	**Pi^2**	**ln Pi**	**Pi × ln Pi**
Acacia auriculiformis	3	0.103448	0.010702	-2.2686835	-0.23469
Dalbergia sissoo	3	0.103448	0.010702	-2.2686835	-0.23469
Swietenia mahagoni	11	0.37931	0.143876	-0.9694006	-0.3677
Bombax ceiba	2	0.068966	0.004756	-2.6741486	-0.18442
Artocarpus heterophyllus	3	0.103448	0.010702	-2.2686835	-0.23469
Populus balsamifera	1	0.034483	0.001189	-3.3672958	-0.11611
Ziziphus mauritiana	3	0.103448	0.010702	-2.2686835	-0.23469
Acacia auriculiformis	3	0.103448	0.010702	-2.2686835	-0.23469
N = 29		Σ Pi^2 = 0.203329		Σ Pi × ln Pi = -1.8417	
$D = 1/\sum_{i=1}^{s} p_i^2$		D = 1/0.203329		4.918128655	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$		H= -(-1.8417)		1.8417	

Sampling Location (04) – Khurushkul Bridge					
Plant Species	**n**	**n/N = Pi**	**Pi^2**	**ln Pi**	**Pi × ln Pi**
Swietenia mahagoni	13	0.265306	0.070387	-1.3268709	-0.35203
Casuarina equisetifolia	6	0.122449	0.014994	-2.1000608	-0.25715
Cocos nucifera	3	0.061224	0.003748	-2.793208	-0.17101
Terminalia arjuna	3	0.061224	0.003748	-2.793208	-0.17101
Azadirachta indica	6	0.122449	0.014994	-2.1000608	-0.25715
Acacia auriculiformis	6	0.122449	0.014994	-2.1000608	-0.25715
Ficus religiosa	2	0.040816	0.001666	-3.1986731	-0.13056
Albizia lebbeck	6	0.122449	0.014994	-2.1000608	-0.25715
Samanea saman	4	0.081633	0.006664	-2.5055259	-0.20453
N = 49		Σ Pi^2 = 0.146189		Σ Pi × ln Pi = -2.05774	
$D = 1/\sum_{i=1}^{s} p_i^2$		D = 1/0.146189		6.84045584	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$		H= -(-2.05774)		2.05774	

Sampling Location (05) – Kastura Ghat					
Plant Species	**n**	**n/N = Pi**	**Pi²**	**ln Pi**	**Pi × ln Pi**
Ziziphus mauritiana	4	0.085106	0.007243	-2.4638532	-0.20969
Averrhoa carambola	3	0.06383	0.004074	-2.7515353	-0.17563
Samanea saman	2	0.042553	0.001811	-3.1570004	-0.13434
Swietenia mahagoni	8	0.170213	0.028972	-1.7707061	-0.3014
Cocos nucifera	12	0.255319	0.065188	-1.365241	-0.34857
Mangifera indica	8	0.170213	0.028972	-1.7707061	-0.3014
Bombax ceiba	3	0.06383	0.004074	-2.7515353	-0.17563
Acacia auriculiformis	3	0.06383	0.004074	-2.7515353	-0.17563
Vachellia nilotica	2	0.042553	0.001811	-3.1570004	-0.13434
Azadirachta indica	2	0.042553	0.001811	-3.1570004	-0.13434
N = 47		$\Sigma Pi^2 = 0.148031$		$\Sigma Pi \times \ln Pi = -2.09097$	
$D = 1/\sum_{i=1}^{s} p_i^2$		D = 1/0.148031		6.755351682	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$		H= -(-2.09097)		2.09097	

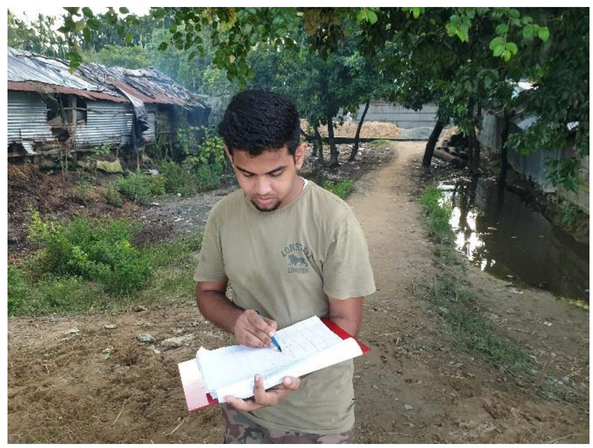
Sampling Location (06) – North Noniar Chara					
Plant Species	**n**	**n/N = Pi**	**Pi²**	**ln Pi**	**Pi × ln Pi**
Ziziphus mauritiana	5	0.052632	0.00277	-2.944439	-0.15497
Averrhoa carambola	4	0.042105	0.001773	-3.1675825	-0.13337
Azadirachta indica	3	0.031579	0.000997	-3.4552646	-0.10911
Samanea saman	10	0.105263	0.01108	-2.2512918	-0.23698
Swietenia mahagoni	10	0.105263	0.01108	-2.2512918	-0.23698
Tectona grandis	2	0.021053	0.000443	-3.8607297	-0.08128
Cocos nucifera	13	0.136842	0.018726	-1.9889275	-0.27217
Mangifera indica	9	0.094737	0.008975	-2.3566523	-0.22326
Bombax ceiba	4	0.042105	0.001773	-3.1675825	-0.13337
Acacia auriculiformis	4	0.042105	0.001773	-3.1675825	-0.13337
Vachellia nilotica	3	0.031579	0.000997	-3.4552646	-0.10911

Spondias pinnata	4	0.042105	0.001773	-3.1675825	-0.13337
Casuarina equisetifolia	10	0.105263	0.01108	-2.2512918	-0.23698
Calotropis gigantea	2	0.021053	0.000443	-3.8607297	-0.08128
Aegle marmelos L.	3	0.031579	0.000997	-3.4552646	-0.10911
Areca catechu	9	0.094737	0.008975	-2.3566523	-0.22326
N = 95		Σ Pi^2 = 0.083657		Σ Pi × ln Pi = -2.60798	
$D = 1/\sum_{i=1}^{s} p_i^2$		D = 1/0.083657		11.95364238	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$		H= -(-2.60798)		2.60798	

Sampling Location (07) – Moheshkhali channel					
Plant Species	**n**	**n/N = Pi**	**Pi^2**	**ln Pi**	**Pi × ln Pi**
Sonneratia apetala	17	0.472222	0.222994	-0.7503056	-0.35431
Avicennia officinalis	11	0.305556	0.093364	-1.1856237	-0.36227
Avicennia alba	8	0.222222	0.049383	-1.5040774	-0.33424
N = 36		Σ Pi^2 = 0.365741		Σ Pi × ln Pi = -1.05082	
$D = 1/\sum_{i=1}^{s} p_i^2$		D = 1/0.365741		2.734177215	
$H = \sum_{i=1}^{s} -(P_i \times \ln P_i)$		H= -(-1.05082)		1.05082	

Appendix – II
Photograph

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