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Water Quality Plays An Important Role In The Socio-Economic Condition Of The Local Community: A Study On The Kushiara River

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ABSTRACT

In Bangladesh around 7.5% of the fish is harvested from the rivers, being one of the main sources of fish in the country. The water quality of the river must be within standard values to maintain aquatic biodiversity. In this study, water quality, available spaces for fish, and socio-economic status of fishermen were analyzed to find their relationships in Kushiara River, Fenchuganj, Sylhet. Samples of water quality and fish species were collected from August 2017 to September 2021. At the same time, fishermen were surveyed to find out their economic status. The water quality analysis showed all the parameters analyzed (pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Dissolved Solid (TDS)) are within the range of international and Bangladesh standards for surface water. The pH, DO, BOD, COD, TDS was respectively 7.1 - 7.99, 5.5 mg/l to 8.4 mg/l, 1 to 4.6 mg/l, 17 to 32 mg/l, 30 to 70 mg/l. Where the local standard is 6.5 - 8.5, more than 5 mg/l, less than 6 mg/l, 17 to 32 mg/l for pH, DO and BOD. The international standard is less than 34.2 mg/l. and 30 to 70 mg/l for COD and TDS in that order. A total of 40 species of fish are recorded in 2017 and 49 in 2021. The average income of a fisherman was 3 USD to 15 USD in the off pick season (December- February), and 7 USD to 30 USD in the peak season (September-November). The fish merchant's daily income was 4 USD to 20 USD in the off-peak season and 7 USD to 30 USD in the peak season. It is concluded that the water quality was adequate for fish diversity and to sustain the socioeconomic condition of the fishermen and fish traders in the Kushiara River
Keyword: Water Quality, Fish Diversity, Socio-economic

ABSTRAK

Di Bangladesh, sekitar 7,5% ikan dipanen dari sungai, yang merupakan salah satu sumber ikan utama di negara tersebut. Kualitas air sungai harus berada dalam batas standar untuk menjaga keanekaragaman hayati perairan. Dalam penelitian ini, kualitas air, ketersediaan ruang untuk ikan, dan status sosial ekonomi nelayan dianalisis untuk mengetahui hubungannya di Sungai Kushiara, Fenchuganj, Sylhet. Sampel kualitas air dan jenis ikan dikumpulkan pada Agustus 2017 hingga September 2021. Pada saat yang sama, nelayan juga disurvei untuk mengetahui status ekonominya. Analisis kualitas air menunjukkan seluruh parameter yang dianalisis (pH, Oksigen Terlarut (DO), Permintaan Oksigen Biokimia (BOD), Permintaan Oksigen Kimia (COD) dan Total Padatan Terlarut (TDS)) berada dalam kisaran standar permukaan internasional dan Bangladesh. air. PH, DO, BOD, COD, TDS masing-masing sebesar 7,1 – 7,99, 5,5 mg/l hingga 8,4 mg/l, 1 hingga 4,6 mg/l, 17 hingga 32 mg/l, 30 hingga 70 mg/l. Dimana standar lokalnya adalah 6,5 - 8,5, lebih dari 5 mg/l, kurang dari 6 mg/l, 17 hingga 32 mg/l untuk pH, DO dan BOD. Standar internasionalnya kurang dari 34,2 mg/l. dan 30 hingga 70 mg/l untuk COD dan TDS secara berurutan. Sebanyak 40 spesies ikan tercatat pada tahun 2017 dan 49 pada tahun 2021. Pendapatan rata-rata seorang nelayan adalah 3 USD hingga 15 USD pada musim off pick (Desember-Februari), dan 7 USD hingga 30 USD pada peak season (September-November). Pendapatan harian

pedagang ikan adalah 4 USD hingga 20 USD di luar musim sibuk dan 7 USD hingga 30 USD di musim puncak. Disimpulkan bahwa kualitas air cukup untuk keanekaragaman ikan dan menopang kondisi sosial ekonomi para nelayan dan pedagang ikan di Sungai Kushiara.
Keyword: Kualitas Air, Keanekaragaman Ikan, Sosial-ekonomi

1. Introduction

As Bangladesh is one of the largest freshwater fish producing countries in the world, there are large wetlands, rivers, lakes, ponds which are suitable for fish production. According to [1], Bangladesh becomes the 2nd largest freshwater fish producing country in the world. Fish production is a 3.61% contributor to the Bangladesh National GDP. The Kushiara River is one of the many distributary rivers between Bangladesh and India. It is created as a branch of the Barak River on the Bangladesh-India border where the Barak were divided into the Kushiara River and the Surma River. The Kushiara river water originate in the Nagaland state in India and pick up tributaries from different state of India like Asam, Miziram, and Monipur. Kushiara River is also one of the important fish sources in the Sylhet region of Bangladesh. Study shows that water quality is an essential part for fish production [2]–[4]. According to Bangladesh Environmental Rules 1997, the water pH level should be 6.5 to 8.5 for fish production. The other important river water quality parameters are BOD, COD, DO, and TDS [5]. A study from Davis, et al.,[6] asserted that freshwater fish require high-quality water to thrive. Water quality requirements for finely suspended particulates and pH values; water temperature; ammonia effect; phenolic wastes, dissolved oxygen; chlorine chemistry and toxicology; and zinc, copper, and cadmium toxicity are some of these features [7]. Standard surface water quality parameters is suitable for aquatic biodiversity by Sun, F. et al., [8]. So, surface water quality is very important for fish and fisheries industries. Some people are engaged for craft and gear selling to fisherman. The fisherman, fish traders, and craft traders' income is directly linked with fish production quantity in the river. Those people are earning money and maintain their family expenditure. They are contributing to the family and society development. Without fish production those people cannot earn money and they cannot contribute to their family and society. So, family will face trouble for arranging food, medical, education, and many other vital elements of life. It will affect the development of the local society. Some unethical activity include theft, smuggling, kidnap will be increased. Thus, fish production is very important for the society. According to a study conducted by Islam et el. [9] about fisheries in the Kushiara River, total 34 kind of fishes has been recorded. On the bank of the Kushiara River, there are many people lives who are engaged for fishing, fish trading and craft and gear making. In this study, we tried to identify the economic condition of people who are connected with fish related profession. On the same time, river water quality was measured for four years period and compared with local and international standard of surface water quality. We tried to find out a relation between river water quality and socio- economic condition of a local community. Without fish production, those people will lose their earning source, and it will create a negative impact on the local community.

Numerous studies have been done on issues such as water pollution, river water quality, fish species, and the social effects of fish production locally and globally. A study conducted by Islam et al. [10] found that the Kushiara river water quality metrics including dissolved oxygen, pH, temperature, turbidity, electrical conductivity, total dissolved solids, and sodium chloride are within the acceptable range for supporting aquatic life. Six phytoplankton groups of 19 genera, as well as three zooplankton groups (4 Rotifers genera, 3 Copepod genera, and 5 Cladoceras genera), are recorded in the current study. At the same perspective, this study also find pH, DO, BOD, COD, and TDS value are in acceptable range in the period of August 2017 to September 2021. While, fish species identified 40 and 49 numbers within study time. This suggests that the river water is in good ecological condition. Additionally, nine groups of benthos were discovered in the study, demonstrating a stable environment for benthos in the river [11]. Another study conducted by Shamsuzzaman [12] revealed the economic impact of Bangladesh's fisheries trade and production on the nation. Bangladesh's economy can grow by giving the fisheries sector greater attention.

River and lake provide freshwater, which is essential for human life, rivers serve as the cornerstone of human civilization. One of the key concerns in managing water resources is water quality. Physical, chemical, and biological are the three primary categories that can be used to categorize water quality, and each category has a number of parameters (Swamee and Tyagee, 2007). The water quality of a river, which is impacted by contaminants, determines the river's health. A variety of parameters that express the physical, chemical, and biological composition of water are typically used to evaluate the quality of water [13]. One of the most

pressing issues that humanity has been dealing with since the beginning of the industrial revolution is the degradation of river water quality [14]. Chemicals are among the most significant pollutants because of their detrimental effects on ecosystems and human health, which worry regulatory bodies, protection organizations, and the general public [14]. Various hazards effect to the peoples health and freshwater ecosystems contaminate numerous metals, metalloids, and solutes, such arsenic and sulfates [15]–[17]. Water temperature and pH are additional crucial physical factors since they serve as indications of the ecological health of rivers [18]. Development has been widely acknowledged as a significant factor in the decline of aquatic habitats and water quality in the Pacific Northwest [19]. It was observed that there was no study conducted to identify impact of Kushiara river water quality in the fisherman and fish trader community.

The key objective of this study is to observe impact of river water quality on socio-economic status of fishermen at the study area. To address the objectives of this study, we conducted the field study to access the presence of different types of fishes including critical habitats. River water quality for 4 years was analyzed and identification of the fish quantity and fish quality with seasonal variation in the study area was conducted. Also, available fish spaces in the study area and the socio-economic condition of fishermen, fish trader and craft seller in the dry and wet season were identified. Finally, we tried to find the link between water quality, fish species, and socio-economic impact in the local community.

2. Materials and Method

2.1. Study Area and Sampling Period

This study was conducted in the Kushiara River on Fenchuganj Upazila which is under Sylhet District of Bangladesh. The sampling point was nearby Shahajalal Fertilizer Factory jetty. The place is about 3.5 km from Sylhet-Moulvibazar Road to the west, about 28 km south-east of Sylhet and about 8 km road from Fenchuganj Upazila. The sampling location is geographically between 24°41'25.54"N; 91°55'7.80"E to 24°41'25.69"N; 91°55'6.72"E and 24°41'19.28"N; 91°55'6.80"E to 24°41'21.21"N. The study team carried out river water sampling, fish spaces survey, and fisherman survey during 2017 to 2021 and River water sample collected total 8 times from 2017 to 2021, conduct lab test to understand the season deviation effect in the river water quality ArcGIS Pro 2.9.0 was used to create the study map shown in Figure 1. where the yellow solid line indicated the sampling location.

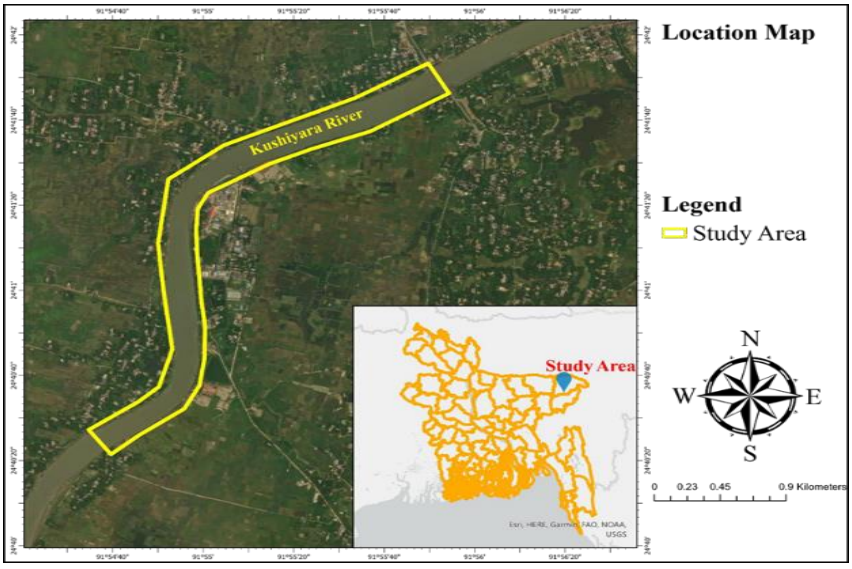


Figure 1. Location map of the study area

2.2. Sampling Procedure

2.2.1 River Water Sampling

New and clean disposable hand gloves were worn during sampling in all different sample points. The hand gloves didn't contact with media and proper cleanness was maintain at the sample collection time. Sample containers for samples suspected of containing high concentrations of contaminants always stored separately. All background or control samples were collected and placed in separate ice chests or shipping containers. A sampling team member collected samples, and the other sampling team member wrote down all the

information and took photographs of all sampling as evidence. During sampling time, procedure from American Public Health Association (APHA) was followed. The sampled river water samples were analyzed total 8 times from august 2017 to September 2021 shown in Table 1. It would be better if river water quality sample analysis could be done more frequently. But due to lack of funding, Covid-19 restrictions, and lack of resource it was not possible to conduct more examination. In future, we will try to conduct more rigorous research with sufficient resources.

Table 1. River water sampling date

S.L	Sampling Period	Sampling Date
01	August 2017	25-08-2017
02	November 2019	23-11-2019
03	June 2020	30-06-2020
04	October 2020	28-10-2020
05	December 2020	26-12-2020
06	March 2021	29-03-2021
07	June 2021	30-06-2021
08	September 2021	28-09-2021

2.2.2 Sample Handling and Preservation Requirements

Surface water samples are collected by directly filling the container from the surface water body. Then, we placed the sample into appropriate and labeled containers. We made sure that samples collected for VOC analysis did not have any headspace and they were preserved with HCl acid. All our sample containers had built in ullage allowance. We placed the samples in cooler with ice that needed to be kept in lower temperature.

a. pH

The balance between hydrogen ions (H+) and hydroxide ions (OH-) in water is represented by pH, which describes the acidity or alkalinity of water. The pH measured scale is within 0 to 14, where 0 is the lowest and 14 is the highest. pH level is less than 7 means Acidic solutions and contain more H+ than OH- ions in the solution. Basic, or alkaline solutions have pH greater than 7 and there are more OH- ions than H+ ions. pH of a solution is 7 means it is neutral, meaning it is neither acidic nor alkaline. It's important to know that the pH scale is logarithmic. Water with pH 5 means there are ten times of H+ ions and ten times more acidic with a pH of 6. Usually, water is used for the various purpose. Several national and international organizations set standard pH value according to purpose of use. Some standards are as follows. Recommended pH standards for drinking, fisheries, irrigation, or industrial cooling water is 6.5 to 8.5 mg/l. In the table 2, there are some national and international organizations mentioned standard pH value for surface water.

b. Dissolved Oxygen (DO)

For most aquatic species, dissolved oxygen (DO) is the most essential gas. Dissolved oxygen, or DO, is needed for respiration of aquatic animals. DO levels below 1 ppm are insufficient to sustain fish; most fish populations need levels of 5 to 6 ppm. The average DO level (6.5mg/l) indicates the river water's average consistency. Standard DO level is different according to purpose of using. Standard for dissolved oxygen for fisheries is mentioned in the following table 2.

c. Biochemical Oxygen Demand (BOD)

The Biochemical Oxygen Demand (BOD) provides an index for assessing the impact of discharged wastewater on the ecosystem so it is an important water quality metric in a water body. The higher the BOD number indicate there are more organic matter or food for oxygen-consuming bacteria to devour. When the amount of dissolved oxygen (DO) consumed by bacteria exceeds the amount of DO produce by aquatic plant photosynthesis or diffused from the air then an adverse situation arises in the aquatic environment. Surface waters with a BOD of 5 mg/l means there are unpolluted water, but rivers with a lower BOD have higher dissolved oxygen. If the source water has a lot of BOD, especially at high temperatures, microbial growth will be increased. This microbial development and the ensuing breakdown of organic matter would result in the absorption of oxygen. This can cause a lack of oxygen in the river, which can be fatal to fish. BOD has a direct

impact on the amount of dissolved oxygen present in rivers and streams. The faster the oxygen in the stream is drained, the higher the BOD. Unpolluted natural water typically has a BOD of 5 mg/l or less. As a result, higher types of aquatic life will have less oxygen available. As a result of high BOD, aquatic animals become stressed, suffocate, and perish. BOD can be found in leaves and woody debris, dead plants and livestock, animal wastes, effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food processing factories, failed septic systems, and urban storm water runoff. The higher the BOD, the faster the oxygen in the river gets depleted [20]. This means that higher stages of the aquatic lifecycle have less oxygen available to them. The consequences of a high BOD are the same as for a low dissolved oxygen level: aquatic creatures become stressed, quash, and die. Leaves and woody fragments, dead animals and plants, animal manure, effluents from paper mills or pulp mills, wastewater treatment plants, feedlots, food processing plants, malfunctioning septic systems, and urban storm water overspill are also sources of BOD.

d. Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) is a measure of water quality that indicate the amount of oxygen consumed by reactions in a measured solution. By COD value we can easily understand quantify of organics in specific water. Application of the COD value is most common in quantifying the amount of oxidizable pollutants found in surface water (e.g., lakes and rivers) or wastewater. The higher the COD value indicate there are more inorganic pollutant for oxygen-consuming bacteria. Surface waters with a COD of 20 mg/l means there are unpolluted water. Surface water for fisheries typically has a COD of 20 mg/l or less. As a result of high COD, aquatic animals become stressed, suffocate, and perish. COD value can be increase if inorganic materials rise in the water body. Most of the case, human waste, high level of decaying plant matter, and industrial wastewater is the main cause of COD increase [20]. The higher the COD value means the river water oxygen faster gets depleted. So, it is very important parameter for river water quality measurement.

e. TDS

The term "total dissolved solids," or "TDS" refers to the total concentration of dissolved materials in water. TDS is primarily composed of inorganic salts, with a trace quantity of organic material. Inorganic salts that are frequently found in water include the cations calcium, magnesium, potassium, and sodium as well as the anions carbonates, nitrates, bicarbonates, chlorides, and sulfates. Anions have a negative charge while cations have a positive charge. Higher TDS value indicate more concentration in the water. Changes in the number of dissolved solids can be harmful to the fish because the density of TDS determines the flow of water in and out of an organism's cell. Concentrations that are too high or low can affect the fish's growth or cause death. A level of 400ppm is recommended for most freshwater fish.

2.2.3 Standard for pH, DO, BOD, COD and TDS for River Water Body

In the table, standard for pH, BOD, COD and TDS are mentioned

Table 1. Standard for pH, DO, BOD, COD and TDS

Parameter	Standard (mg/l)	Reference
pH	6.5 to 8.5	FAO, 1992
DO	Minimum 6 mg/l	FAO, 1992
BOD	10 mg/1	ECR 1997, DoE
COD	6 mg/l	ECR 1997, DoE
TDS	400ppm	(James, 2000)

2.2.4 Fish Species and Fisheries Status Sampling

Fish species sampling entailed collecting samples from various study locations with the assistance of locals, fishermen, and a trip to the fish market. Fishermen use traditional fishing methods and a variety of nets, including gill nets, cast nets, and dragnets. Locals were also able to buy fish

from the fishermen on the spot. The study team also visited local fish markets located on the banks of the river to monitor and look for the presence of any species which were not available during our experimental fishing. The study team using some questioner for various information collection. As the study objective is to identify the impact of river water quality among the fisherman and fish traders, the questioner was included how long they are involved in fishing, is they are professional or amateur, how much fish can catch in lean season and peak season, average income in lean season and peak season, family condition on fisherman and fish traders, etc. All questioners are included in the annexure 5.

3. Results

pH value in study area was observed 7.1 to 7.99 in between 2017 to 2021. Bangladesh standard river water quality for fisheries is 6.5-8.5. The study finds that pH value of Kushiara River is within Bangladesh standard and suitable for fish production. In Figure 2, pH values are given as different sampling time between the years of 2017 to 2021.

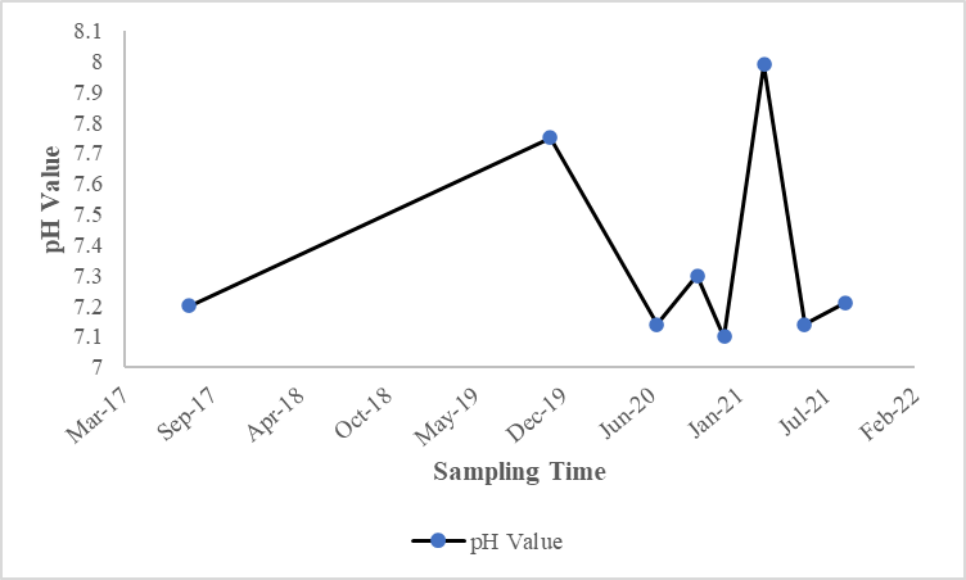


Figure 2. pH value of Kushiara River

Dissolved Oxygen (DO) value observed in the study area in between 5.5mg/l to 8.5 mg/l. River water quality Bangladesh standard for fisheries is 5mg/l or more. The study find that DO value of Kushiara River is within Bangladesh standard, and suitable for fish production (DoE, water quality standard for fisheries). In the Figure 3, DO values are given as different sampling time between the years of 2017 to 2021.

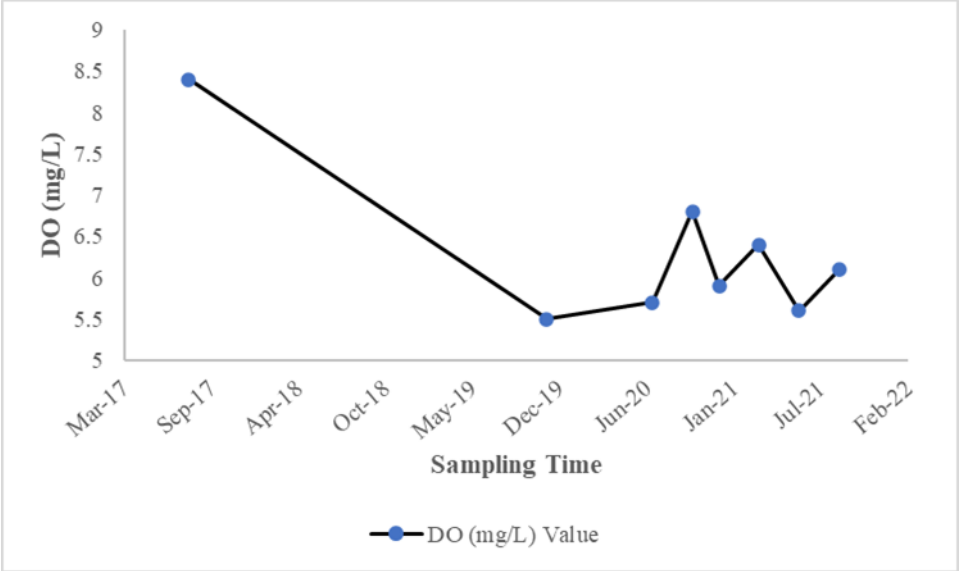


Figure 3. DO value of Kushiara River

Biological Oxygen Demand (BOD) value observed in the study area is 0.1 to 4.6. According to DoE, river water quality Bangladesh standard for fisheries is 6 or less. The study finds that BOD value of Kushiara River is within Bangladesh standard and suitable for fish production. In Figure 4, some BOD values has given as different sampling time between the years of 2017 to 2021.

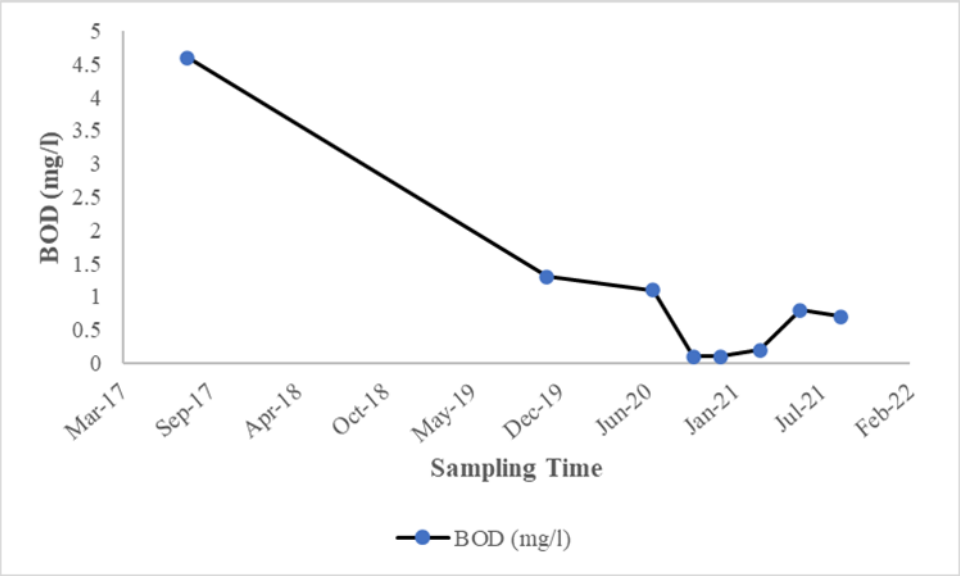


Figure 4. BOD value of Kushiara River

Chemical Oxygen Demand (COD) value observed in the study area is 17mg/l to 32mg/l. River water quality Bangladesh standard for fisheries is undefined. For surface water COD should be within 34.2 mg/l. So, COD value is within range of surface water quality and suitable for fish production. In Figure 5, some BOD values are given as different sampling time between the years of 2017 to 2021.

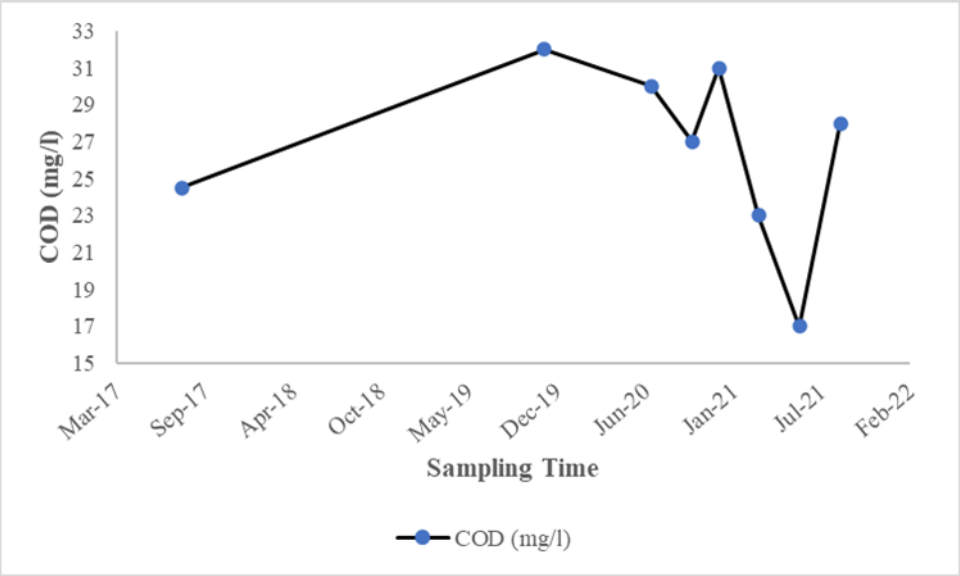


Figure 5. COD value of Kushiara River

Total Dissolved Solid (TDS) value observed in the study area is 30 to 70. River water quality Bangladesh standard for fisheries is not yet started. The standard value is 165 mg/l. The study finds that TDS value of Kushiara River is within Bangladesh standard and suitable for fish production. In Figure 6, some TDS values are given as different sampling time between the years of 2017 to 2021.

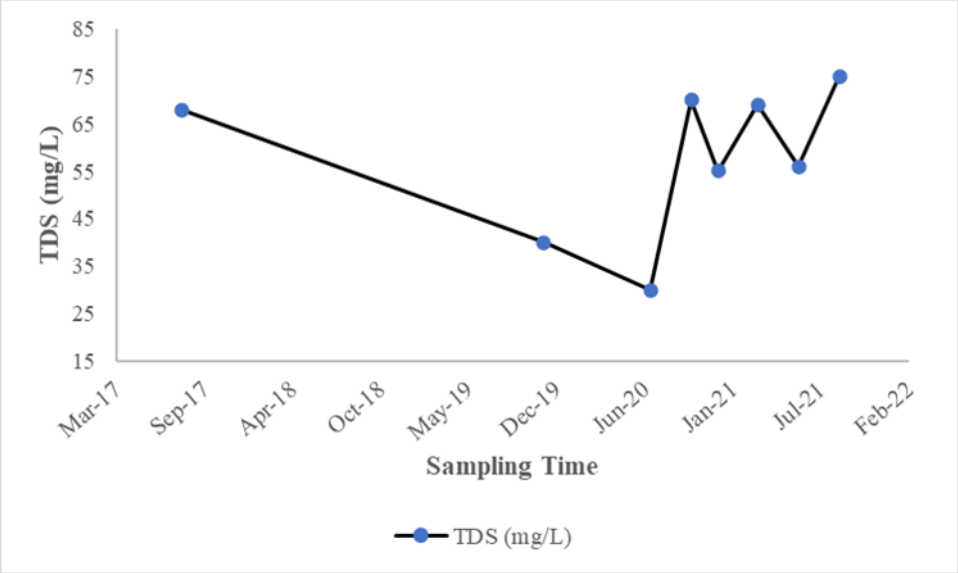


Figure 6. TDS value of Kushiara River

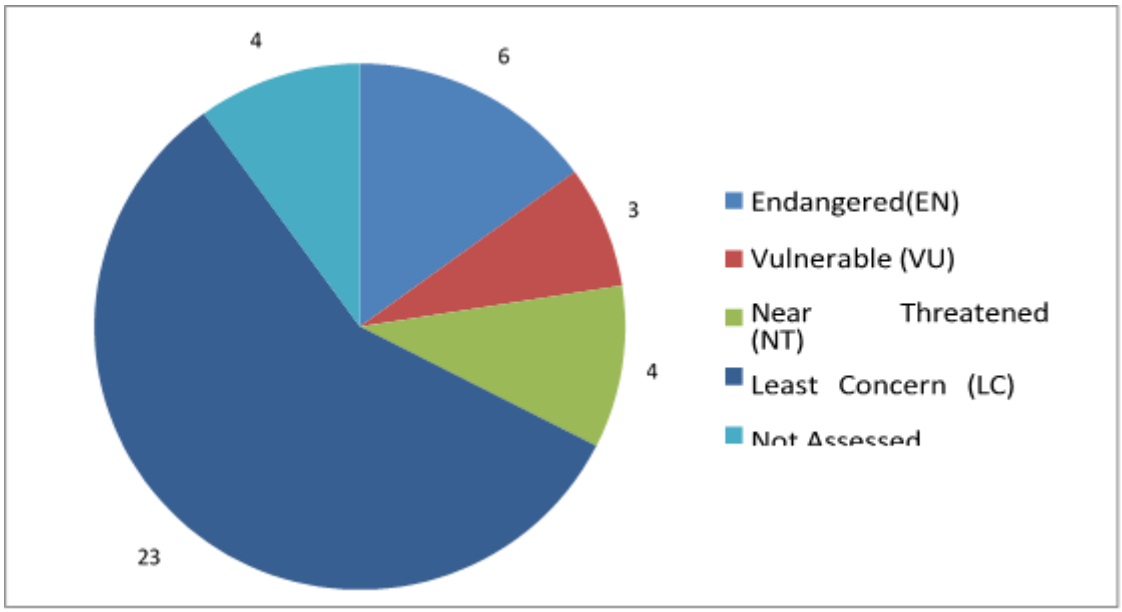


Figure 7. IUCN Fish Species Available in 2017

4.1. Status and Diversity of Fish at the Study Area 2021

During the field visit, a total 49 species of fishes were recorded from the Kushiara River which are shown in annexure 02. The common fish species found were Chapila (Gudisia chapra), Tengra (Mystus tengra), Kalbaosh (Labeo kalbasu), Rui (Labeo rohita), Mrigel (Cirrhinus cirrhosis), Ayre (Sperata aor) etc. The highest catches of species were Poa (Panna microdon), Kavashi Tengra (Mystus cavasius), and Bacha (Eutropiichthys vacha). The catches have been calculated through boat-to-boat survey, FGDs and with relevant respondents.

Kalo Pabda (Ompok pabo) and Baga Ayre (Bagarius bagarius) recorded during market survey are Considered as Critically Endangered species whereas Pabda (Ompok pabda), Gozar (Channa marulius), Shal Baim (Mastacembelus armatus), Bengal Loach (Botia Dario), Chital (Chitala chitala) and Rita (Rita rita) are considered as Endangered species Bangladesh (IUCN Red List of Bangladesh 2015). Chapila (Gudusia chapra), Boal (Wallago attu), Ayre (Sperata aor), Guttum (Lepidocephalus annandalei), Foli (Notopterus notopterus) and Bamosh (Anguilla bengalensis) are considered as Vulnerable species. Deshi Sharpunti (Puntius sarana), Gangetic Leaffish (Nandus nandus), Tara Baim (Macrognathus aculeatus), Mrigal (Cirrhinus cirrhosis), Gang Tengra (Gagata youssoufi) and Gonia

(Labeo gonius) are considered as Near Threatened according to IUCN Red List of Bangladesh (2015). As per the following Figure 8, the maximum diversity (21) is included as Least Concern (LC), 11 are Near Threatened (NT), 6 Species are Vulnerable, 7 species are Endangered, 2 species are Critically Endangered (CR), 2 species were Data deficient (DD) following the IUCN Red List of Bangladesh (2015).

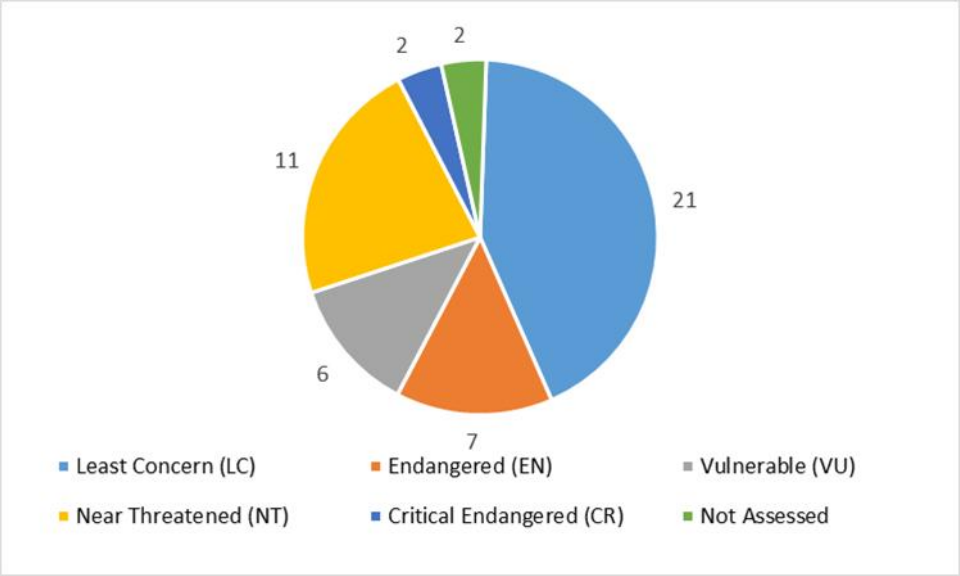
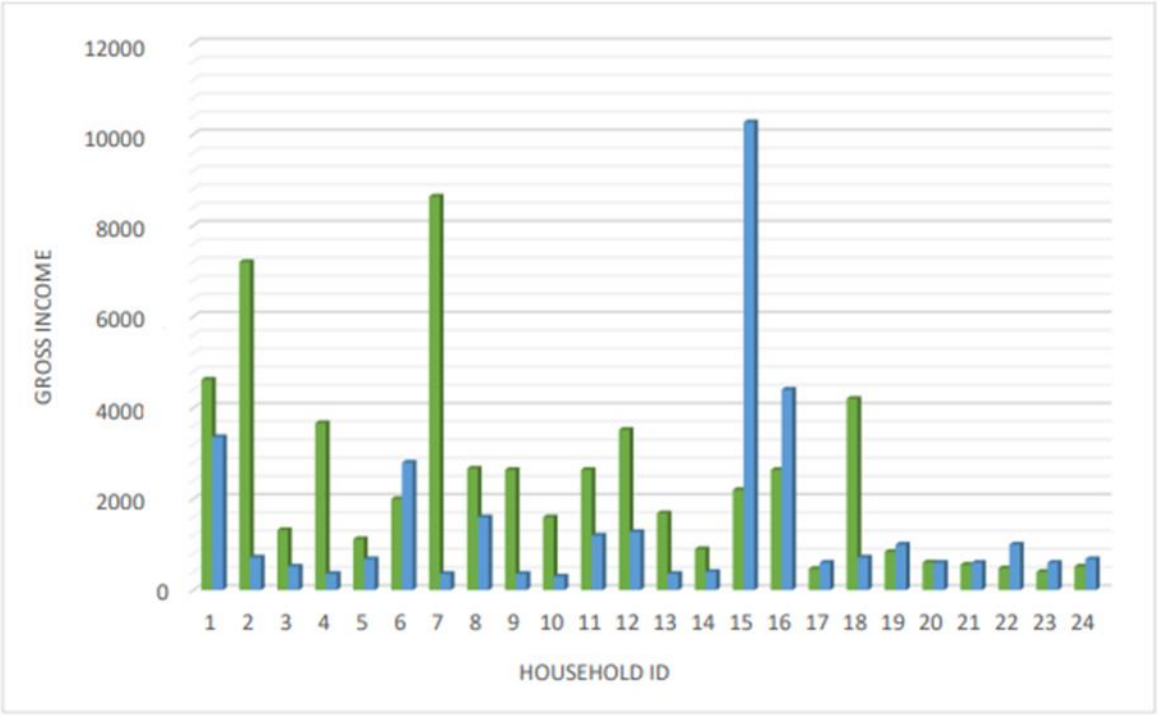


Figure 8. IUCN Fish Species Available in 2021

After comparison of fish species available during the two surveys in 2017 and 2021 it is identifying that nu`1mber if fish species increase from 40 to 49.

4.2. Socio-economic Condition

September-November (Ashwin-Kartik) is the peak season for fishing while winter (December- February) is the lean season for fishing in the study area. Fishing intensity for Regular fishermen varies for peak season and off- peak/lean season.



The study has completed of the field study covering both peak and lean season. From interviews, consultation, and focus group discussion, group discussion with the fishermen the study team found that fish catch for

regular fishermen ranges from highest of 9 kg to lowest of 3 kg during the peak season resulting an average fish catch of 5 kg at the study area. Associated daily earning during the peak season ranges from 3 USD to 27 USD depending on the type and size of fish. During the lean-season fish catch from the river ranges in between 1 kg to 5 kg with an average catch of 2 kg. Daily earning during the lean- season ranges from 100 to 15 USD. Almost all the regular fishermen have their own fishing gears e.g., fishing boat, fishing net. Total investment on fishing gears ranges from 25000 to 300 USD. The timing for fish catch starts usually from 3:00-4:00 am till 12:00 pm for majority of the fisherman. Gross income for fishermen during peak season ranges from 400 USD to 864000 with an average of 2380 USD, whereas in lean season that ranges from 300 USD to 1000 USD with an average of 1440 USD. The net income of the fishermen surveyed during the peak-season ranges from 160 USD to 8400 USD, whereas in lean-season that ranges from 148 USD to 1000 USD.

Almost all the fish traders surveyed are full-time fish trader. The mean years of engagement into the fish trading is 14 years among the surveyed fish traders. Out of nine fish traders, six of them (67%) engaged into the fish trading more than 10 years. Usually, the fish traders collect fish from the fishermen or fishermen sell their fish to fish-traders. The nearest fish market is the Fenchuganj Purba-Bazar which is located approx. 2 km upstream from the study area. There is a designated fish selling point in the Fenchuganj Bazar near the MSC Ghat where primarily buying and selling of cultured fishes occur. For buying and selling of fishes caught from the Kushiara River there is no permanent fish trading spot. The traders customarily sit beside the road near the Fenchuganj Purba Bazar and there by sell their fishes. Trading volume varies from peak season to off-peak/lean season. Peak-season identified/reported by fish traders is Ashwin- Kartik in Bengali Calendar which is equivalent as the time period of June to Mid-October in Georgian Calendar. The off-peak/lean season reported by fish traders is Falgun-Chaitra in Bengali Calendar which is equivalent as the time period of March to May in Georgian Calendar. Trading volume deviates from peak-season to lean-season. While in peak- season trade volume reaches maximum close to twenty (20) kg whereas off-peak season's maximum trade volume reaches a maximum of thirteen (13) kg. Trade price for fish does not vary dramatically from peak-season to lean-season. However, for some fish traders, trading price in peak season reaches a maximum of 7-8 USD/kg whereas in lean-season maximum trading price becomes 4-500 USD/kg.

The maximum difference found in gross income from peak-season to lean-season for fish traders is USD 1540 whereas the minimum difference is USD 60. On an average yearly gross income of fish traders is around USD 2540. Therefore, on an average the yearly net income of surveyed fish traders is USD 2300. Seasonal variation in net income from peak-season to lean-season follows the similar pattern of gross income as shown in the following table 10.

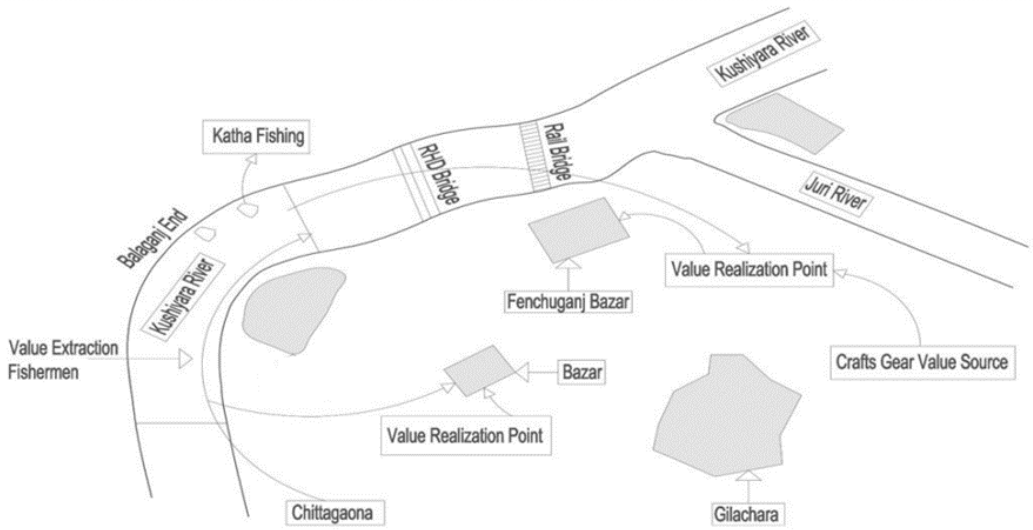


Figure 10. Kushiara River Fish Chain

Table 3. Income and Expenditure Associated with Fishing Craft and Gear Making/Trading

Sl. No	Average Monthly Income	Yearly Income	Yearly Expenditure	Yearly Net Income
1	250	3000	428	2571
2	178	2142	142	2000
3	157	1885	357	1528
4	64	771	71	700
5	178	2142	357	1785
6	178	2142	285	1857
7	571	6857	2285	4571
Average	225	2706	561	2144
Maximum	571	6857	2285	4571
Minimum	64	771	71	700

As reported by the fish traders, they don't have any loan outstanding and except the part-time fish trader no other fish trader have secondary occupation.

4. Discussion

The study shows that the water quality of Kushiara River is within suitable for fisheries [2]. pH found in the river water was within 7.1mg/l to 7.75mg/l. Where Bangladesh standard is 6.5mg/l to 8.5mg/l (According to DoE). DO was found 5.5mg/l to 8.4mg/l. According to DoE Bangladesh standard for fisheries, DO label in water is minimum 5mg/l. BOD was found 0.1mg/l to 4.6mg/l. According to DoE Bangladesh standard for fisheries, BOD label is required 6mg/l or less. The COD value of Kushiara River is found 24.5 mg/l to 32mg/l, though Bangladesh standard of COD value is not yet started. The TDS value of Kushiara River is found 30 to 68. Bangladesh standard of TDS value is not yet started. River water quality is directly associated to fish production in a water body ((Keskin and Unsal, 1998). Fish species found 40 in the year of 2017 and 49 species found the year of 2020. The study represents river water and aquatic environment is suitable for fisheries (Faruk, A.R., Sultana, N. and Kabir, M.B., 2005). There are various types of species as Least Concern (LC), Near Threatened (NT), Vulnerable, Endangered, Critically Endangered (CR), Data deficient (DD) following the IUCN Red List of Bangladesh (2015). In can be noted that another study was conducted in the Kushiara river in the year 2015 to 2016 (Hossen M et al, 2018). The study also found a total of 74 fish species in the Kushiara River. Local people are engaged for professional fishing and amateur fishing both. Some people are professional fisherman, and they earn money from the river by catching fish. Their yearly income is around 1372 USD to 2268 USD. Fish trader also related to fish from Kushiara River. Their monthly income is 138 USD to 952 USD. The craft and gear manufacturer and trader also related to the fish production [21]. Their average income is monthly 65 USD. The fish from Kushiara River have a great impact in the local economy. Many people are involved in fishing which is a very important in their daily life. Not only that many people are involved in the fish trading at the local market.

Along with these, some people are engaged for craft selling, boat making and repairing. People involved in all these works, earning money for their daily needs and they can maintain their family expense. There are a great impact in the local community and socio economic condition [22]. All of those activity is directly related to fish production as well as river water quality. Fish production sector is a contributor in the economy growth in Bangladesh [10].

5. Conclusion

Fresh water fish is an important contributor as protein source in Bangladesh. The Fish is not only an element in our daily protein intake but also economically important part of our society. The study found that there are 40 to 49 fish species are found in the river so many people are involved in fish catching, fish treading and craft and gear selling. By the fish catching and selling fish they are contributing to their family expenditure average 138 USD to 952 USD depends on peak and off peak season and by selling crafts and gear they are contributing to their family expenditure average 2145 USD yearly and there has an impact in the society. Without good water quality, aquatic fish cannot survive in a water body. Then people are related to fish catching and trading cannot earn money. It will create an economical problem in the local community. So, we can see that river water quality is directly related to economic and social condition. To keep river water quality as good, we must avoid any pollution in the river and its surrounding area. We must monitor all kind of industrial pollution, wastewater discharge in the water, household waste, and boat waste in river water. Then the river water can be in suitable condition, and it can keep a role in our food intake and socio-economic condition. The concern government authority, media, researcher, environmentalist should focus on this and should keep our aquatic environment is suitable for fish and flora and fauna.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to their containing information that could compromise the privacy of research participants.

Conflict of Interest

The authors whose names are listed certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Annexure 02

SL #	Scientific Name	Local name	Fish base name	Availability status	IUCN Bangladesh 2015. Red List of Bangladesh Volume 5: Freshwater Fishes.
1.	Labeo rohita	Rui	-	Abundant	Least Concern (LC) ver 3.1
2.	Catla catla	Katal	-	Abundant	Least Concern (LC) ver 3.1
3.	Lepidocephalus guntea	Gutum	Guntea loach	Common	Least Concern (LC) ver 3.1
4.	Puntius sophore	Punti	Punti	Common	Least Concern (LC) ver 3.1
5.	Clarias batrachus	Walkig catfish	Magur	Abundant	Least Concern (LC) ver 3.1
6.	Wallago attu	Boal	Wallago	Rare	Vulnerable (VU) A2cd ver 3.1
7.	Silonia silondia	Shillong	Silond catfish	Rare	Least Concern (LC) ver 3.1
8.	Pangasius	Yellowtail catfish	Pangas	Abundant	Endangered (EN) A2bcd ver 3.1
9.	Eutropiichth	Bacha	-	Common	Least Concern (LC) ver 3.1
10.	Clupisoma	Garu bacha	Gharua	Rare	Endangered (EN) A2bcd ver
11.	Rita rita	Rita	Rita	Rare	Endangered (EN) A2bcd ver
12.	Sperata aor	Ayre	Long Whiskered	Common	Least Concern (LC) ver 3.1
13.	Mystus cavasius	Kabashi tengra	Gangetic mystus	Common	Near Threatened (NT) ver 3.1
14.	Chitala chitala	Chital	Clown knife	Rare	Endangered (EN) A2bcd ver
15.	Corica soborna	Kachki	Ganges river spral	Abundant	Least Concern (LC) ver 3.1
16.	Mastacembelus armatus	Baim	Zigzag eel	Abundant	Endangered (EN) A2bcd ver 3.1
17.	Rhinomugil corsula	Halla	-	Common	Least Concern (LC) ver 3.1
18.	Trichogastes fasciata	Khalisha	Banded gourami	Common	Least Concern (LC) ver 3.1
19.	Anabas testudineu	Koi	Climbing perch	Common	Least Concern (LC) ver 3.1
20.	Monopterus cuchia	Cuchia	Kunche	Rare	Vulnerable (VU) A2cd ver 3.1
21.	Xenentodon cancila	Kaikka	-	Rare	Least Concern (LC) ver 3.1
22.	Channa striatus	Shol	Snakehead murrel	Abundant	Least Concern (LC) ver 3.1
23.	Channa punctatu	Lata, Taki	Spotted snakehead	Abundant	Least Concern (LC) ver 3.1

SL #	Scientific Name	Local name	Fish base name	Availability status	IUCN Bangladesh 2015. Red List of Bangladesh Volume 5: Freshwater Fishes.
24.	Psilorhynchus sucatio	Titari	River stone	Common	Near Threatened (NT) ver 3.1
25.	Salmosto ma	Katari	Large	Rare	Least Concern (LC) ver 3.1
26.	Esomus danricus	Darka	Flying barb	Common	Least Concern (LC) ver 3.1
27.	Chela laubuca	Chela	Indian glassbarb	Rare	Least Concern (LC) ver 3.1
28.	Megarasbora elanga	Along	Bengala barb	Common	Least Concern (LC) ver 3.1
29.	Danio rerio	Anju	-	Abundant	Near Threatened (NT) ver 3.1
30.	Chagunius	Utti	Chaguni	Rare	Vulnerable (VU) A2cd ver 3.1
31.	Labeo gonius	Ghainna	Karia labeo	Rare	Near Threatened (NT) ver 3.1
32.	Labeo calbasu	Kalibaus	Orange fin labeo	Common	Least Concern (LC) ver 3.1
33.	Labeo angra	Kharsa	-	Common	Least Concern (LC) ver 3.1
34.	Botia dario	Bou mach	-	Rare	Endangered (EN) ver 3.1
35.	Heteropneustes fossilis	Shing	-	Common	Least Concern (LC) ver 3.1
36.	Macrobrachiumsp.	Chingri	-	Abundant	Least Concern (LC) ver 3.1
37.	Oreochromis niloticus	Tillapia	Tillapia	Abundant	Not Assessed
38.	Barbonem us	Sarpunti	-	Common	Not Assessed
39.	Hypophthalmic hthys molitrix	Silver carp	Common carp	Abundant	Not Assessed
40.	Ctenopharyngo donidellus	Grass carp	Grass carp	Common	Not Assessed

Annexure 03

S.N.	Family	Common Name	English Name	Scientific Name	IUCN Red List Status**
1.	Clupeidae	Chapila	Indian River Shad	*Gudusia chapra*	VU
2.	Clupeidae	Mola	Mola Carplet	*Amblypharyngodon mola*	LC
3.	Siluridae	Kalo Pabda	Pabo Catfish	*Ompok pabo*	CR
4.	Siluridae	Modhu Pabda	Pabdah Catfish	*Ompok pabda*	EN
5.	Cyprinidae	Jat Punti	Pool Barb	*Puntius sophore*	LC
6.	Clupeidae	Ganges river sprat		*Corica soborna*	LC
7.	Cyprinidae	Deshi Shar Punti	Kachki Olive Barb	*Puntius sarana*	NT
8.	Bagridae	Menoda catfish	Ghagla, Gang Tengra	*Hemibagrus menoda*	NT
9.	Channidae	Taki	Spotted Snakehead	*Channa punctata*	LC
10.	Channidae	Shoal	Striped Snaked	*Channa striata*	LC
11.	Channidae	Gozar	Great Snakehead	*Channa marulius*	EN
12.	Nandidae	Meni/Veda	Gangetic Leaffish	*Nandus nandus*	NT
13.	Bagridae	Tengra	Tengara Mystus	*Mystus tengara*	LC
14.	Centropomidae	Chanda	Elongate Glass-perchlet	*Chanda nama*	LC
15.	Bagridae	Bagha Air	Long- Whiskered	*Bagarius*	CR
16.	Cyprinidae	Kalbaosh	Orange Fin	*Labeo calbasu*	LC
17.	Mugilidae	Bhangan Bata	Flathead Mullet	*Mugil cephalus*	LC
18.	Mastacembelidae	Tara Baim	Lesser Spiny Eel	*Macrognathus aculeatus*	NT
19.	Cyprinidae	Cotio	Dhela	*Osteobrama cotio*	NT
20.	Mastacembelidae	Shal Baim	Zi-Zag Eel	*Mastacembelus armatus*	EN
21.	Mastacembelidae	Guchi Baim	Barred Spinyeel	*Macrognathus pancalus*	LC
22.	Sciaenidae	Coitor Poa	Panna Croaker	*Johnius coitor*	LC
23.	Cyprinidae	Kalabans	Kursha	*Bangana dero*	DD
24.	Cobitidae	Bou	Bengal Loach	*Botia dario*	EN
25.	Cobitidae	Rani	Gangetic Loach	*Botia rostrata*	DD
26.	Schilbeidae	Vacha	Garua Bachcha	*Clupisoma garua*	EN
27.	Schilbeidae	Muri bacha	Indus Garua	*Eutropiichthys murius*	LC
28.	Schilbeidae	Batchwa vacha	Bacha	*Eutropiichthys vacha*	LC
29.	Cyprinidae	Rui	Rohu Carp	*Labeo rohita*	LC
30.	Cyprinidae	Katol	Catla	*Catla catla*	LC

S.N.	Family	Common Name	English Name	Scientific Name	IUCN Red List Status**
31.	Cyprinidae	Mrigel	Mrigal	*Cirrhinus cirrhosus*	NT
32.	Siluridae	Boal	Freshwater Shark	*Wallago attu*	VU
33.	Notopteridae	Chital	Clown Knifefish	*Chiatal chitala*	EN

Annexure 04

Figure 12. Study Area-Kushira River

Figure 13. Fishing Activity during the Peak-season within the Study Area

Figure 14. Fish Observed in the Local Market

Annexure 05

Focus Group Discussion Participants

Sl.	Name of Participant	Age	Occupation	Phone Number
1	Abdul Jalil	38	Fishing Craft & Gear Maker	8801706996143
2	Imran Ahmed	28	Fisherman	8801742492945
3	Md. Fayez Uddin	60	Fish Trader	8801735521953
4	Chomok Ali	60	Fisherman	8801763502319
5	Asman Mia	65	Fishing Craft & Gear Maker	8801743333541
6	Dulu Mia	52	Fish Trader	8801762455052
7	Md. Janu Mia	46	Fisherman	8801312673804
8	Md. Ziaur Rahman	32	Fisherman	8801759718313

Annecure 06

Introductory Note: Good morning/afternoon. We are conducting a socio-economic study to assess the fishing related livelihood under the project titled as **"**WATER QUALITY PLAYS AN IMPORTANT ROLE IN THE SOCIO-ECONOMIC CONDITION OF THE LOCAL COMMUNITY: A STUDY ON THE KUSHIARA RIVER**"** Based on the outcome of this study, we will be able to assess the impact of the river water quality on the Fisheries and associated livelihood activities. We only seek your responses and opinions regarding some of the issues. We assure that your personal details will be kept confidential. The interview could take no more than 10-15 minutes. We seek your cooperation in this regard.
May we proceed? …….. Thank you

Enumerator Details		**Survey Date (DD/MM/YY)**		
Name			**Signature**	
Section-A [Basic Information]				
A-1	**Respondent's Name**		Religion (tick the appropriate one)	□ Buddhism □ Christian □ Hindu □ Muslim □ Others
Respondent's ID		CL	_FS_SEC_	
Mobile No.			01	
Name of Household Head		Wife of/Son of/Others		
Household Structure (tick the appropriate one)			□ Nuclear □ Joint/Extended	
Category of the Respondent (tick the appropriate one)			□ Fisherman □ Fish Trader □ Middleman (Hoarder/Aratdar/Wholesaler) □ Craft and Gear Maker □ Craft and Gear Trader	

Codes to be followed for Module A-2			
Gender	**Marital Status**	**Educational Status**	**Last Level of Education**
1. Female 2. Male 3. Others	1. Married 2. Single/Unmarried 3. Separated 4. Divorced 5. Widowed 6. Abandoned	1. Currently Studying 2. Not School Going 3. Age Completed 4. Currently not studying/discontinuing	1. Primary/Ebtedaye 2. Secondary/Dakhil 3. Higher Secondary/Aalim 4. Graduation/Degree/Hon Fazil 5. Post graduation/Master's/Kaamil 6. Vocational Training 7. Never been informal EIs

Primary & Secondary Occupation	**Skill Set**	**Disability**
1. Fishing 2. Fish Trading 3. Fishing Gear & Craft Making/Trading 4. Farming/Crop Cultivation 5. Livestock Rearing/Trading 6. Foreign Employment 7. Agricultural Labor 8. Wage Labor (Non-agriculture) 9. Construction Worker 10. Business/Trade/Shopkeeper 11. Electrician 12. Mechanic 13. Driving 14. Heavy Machinery Operator 15. Professional 16. Private Job 17. Government Job 18. Traditional Medicine 19. Housewife 20. Teaching 21. Rent Collection 22. No Occupation	1. Agro-based Training 2. Cattle Rearing 3. Carpenter 4. Driving 5. Plumbing 6. Electrician 7. Welding 8. Masonry 9. Mechanic 10. Cooking 11. Tailoring/Stitching/Sewing 12. Baking 13. Artisan/Handicrafts 14. None _____	1. No 2. Eye Sight 3. Mobility 4. Speech 5. Mental Disability 6. Hearing specify_____

A-2 Household Members' Detail											
Sl.	**Name**	**Gender [use code]**	**Age**	**rital Status [use code]**	**Educational Status [use code]**	**Current/last Level of Education [use Code]**	**rimary Occupation [use code]**	**Secondary Occupation [use code]**	**kill Set/Training [use code]**	**her ship**	**Disability [use code]**
01											
02											
03											
04											
05											
06											
07											
08											
09											
10											

Section-B [Livelihood Information]		
B-1 [Applicable for Fisherman Only]		
B-1A	Type of Fisherman [use code*]	
B-1B	Fishing as Primary Income Source (tick the appropriate one)	□ Yes □ No
B-1C	Fishing as Secondary Income Source (tick the appropriate one)	□ Yes □ No
B-1D Years engaged in fishing		
B-1E What is the Peak Season for Fishing?		
B-1F What is the Off/Lean Season for Fishing?		

B1-G Seasonal Variation			
Peak Season		**Off/Lean Season**	
Fishing Frequency [use code*]		Fishing Frequency [use code*]	
Fishing Intensity [use code*]		Fishing Intensity [use code*]	
Available Species		Available Species	
Catch (in Kg)		Catch (in Kg)	
Income (in BDT)		Income (in BDT)	

Historical Variation (one/two years before)			
Peak Season		**Off/Lean Season**	
Fishing Frequency [use code*]		Fishing Frequency [use code*]	
Fishing Intensity [use code*]		Fishing Intensity [use code*]	
Available Species		Available Species	
Catch (in Kg)		Catch (in Kg)	
Income (in BDT)		Income (in BDT)	
B1-H What is your yearly gross income from fishing?			
B1-I Fishing Related Expenditures			

Name of the Item	**Amount (BDT)**
B1-J Are you and any other member(s) from your household member of any formal fishermen association (tick the appropriate one)?	Yes No
B1-K Do you have any outstanding loan (tick the appropriate one)?	Yes No
If yes in **B1-K**, then	Bank Debt NGO Debt Cooperative Debt Samity Family/Friends Informal Money Lenders
If there is a current loan, please explain the reason?	Illness Home construction/ improvements Health and treatment Marriage/Rituals/Cultural/Festiva l Death Ceremonies/Funerals Acquisition of property (including vehicles) Economic activity Migration Studies Other, specify
B1-L Do you have any livestock (tick the appropriate one)?	Yes No

B1-L Details of Livestock				
Type	**Quantity**	**Usage**	**Product**	**Total Income**
Cow				
Buffalo				
Goat				
Chicken/Poultry				
Duck				
Others (specify)--				

B1-M Do you observe any changes in fishing activities in recent times?	☐ Yes ☐ No

If yes in **B1-M**, then provide some details

B1-N Do you observe any impact of the water pollution in your locality (in general)?

Positive Impacts	**Negative Impacts**

B1-O Do you observe any impact of the water pollution in your locality (specific to fishing activities)?

Positive Impacts	**Negative Impacts**

***Codes**

B-1A Fisherman Type	**B-1F** Fishing Frequency	**B-1F** Fishing Intensity	**B-1J** Usage
1. Full Time 2. Part time/Casual 3. Amateur	1. Daily 2. Alternate Day	1. Once 2. Twice 3. Thrice	1. Self- consumption 2. Sale 3. Both

	3. Weekly 4. Monthly	4. More than thrice	

B-2 [Applicable for Fish Trader Only]			
B-2A	Type of Fish Trader [use code**]		
B-2B	Fish Trading as Primary Income Source (tick the appropriate one)		□ Yes □ No
B-2C	Fish Trading as Secondary Income Source (tick the appropriate one)		□ Yes □ No
B-2D Years engaged in Fish Trading			
B-2E What is the Peak Season for Fish Trading?			
B-2F What is the Off/Lean Season for Fish Trading?			
B-2G Seasonal Variation			
Peak Season		**Off/Lean Season**	
Trading Frequency [use code**]		Trading Frequency [use code**]	
Available Species		Available Species	
Sell Volume (in Kg)		Sell Volume (in Kg)	
Income (in BDT)		Income (in BDT)	
Historical Variation (one/two years before)			
Peak Season		**Off/Lean Season**	
Trading Frequency [use code**]		Trading Frequency [use code**]	
Available Species		Available Species	
Sell Volume (in Kg)		Sell Volume (in Kg)	
Income (in BDT)		Income (in BDT)	
B-2H What is your yearly gross income from fish trading?			
B-2I What is your yearly gross expenditure related to fish trading?			

B-2J Are you and any other member(s) from your household member of any formal fish trading association (tick the appropriate one)?	□ Yes □ No
B-2K Do you have any outstanding loan (tick the appropriate one)?	□ Yes □ No
If yes in **B-2K**, then	□ Bank Debt □ NGO Debt □ Cooperative Debt □ Family/Friends □ Informal Money Lenders
If there is a current loan, please explain the reason?	□ Illness □ Home construction □ Health and treatment
	□ Marriage/Rituals/Cultural/Festival □ Death Ceremonies/Funerals □ Home improvements □ Acquisition of property □ Acquisition of vehicle □ Economic activity □ Family Function □ Migration □ Studies □ Other, specify _____
B-2L Do you observe any changes in fish trading activities in recent times?	□ Yes □ No
If yes in **B-2L**, then provide some details	

B-2M Do you observe any impact of the river water pollution in your locality (in general)?

Positive Impacts	**Negative Impacts**

B-2N Do you observe any impact of the river water pollution in your locality (specific to fish trading)?

Positive Impacts	**Negative Impacts**

****Codes**	
B-2A Fish Trader Type 1. Full Time 2. Part-time/Casual	**B-2G** Trading Frequency 1. Daily 2. Alternate Day 3. Weekly 4. Monthly

B-3 [Applicable for Fishing Gear & Craft Makers Only]		
B-3A	Type of Fishing Gear & Craft Maker [use code***]	
B-3B	Fishing Gears & Crafts Making as Primary Income Source (tick the appropriate one)	☐ Yes ☐ No
B-3C	Fishing Gears & Crafts Making as Secondary Income Source (tick the appropriate one)	☐ Yes ☐ No
B-3D Years engaged in Fishing Gears & Crafts Making		
B-3E What is your yearly gross income from fishing gears & crafts making?		
B-3F What is your yearly gross expenditure related to fishing gears & crafts making?		
B-3G Are you and any other member(s) from your household member of any formal fishing gears & crafts making association (tick the appropriate one)?		☐ Yes ☐ No
B-3H Do you have any outstanding loan (tick the appropriate one)?		☐ Yes ☐ No
If yes in **B-3H**, then		☐ Bank Debt ☐ NGO Debt ☐ Cooperative Debt ☐ Family/Friends ☐ Informal Money Lenders
If there is a current loan, please explain the reason?		☐ Illness ☐ Home construction ☐ Health and treatment ☐ Marriage/Rituals/Cultural/Festival ☐ Death Ceremonies/Funerals ☐ Home improvements ☐ Acquisition of property ☐ Acquisition of vehicle ☐ Economic activity ☐ Family Function ☐ Migration ☐ Studies ☐ Other, specify _____
B-3I Do you observe any changes in fishing activities in recent times?		☐ Yes ☐ No
If yes in **B-3I**, then provide some details		