Ichthyo diversity of Jamuna river, Sirajganj, Bangladesh

A thesis submitted in partial fulfillment of the requirements for Master of Philosophy (MPhil)

<u>Submitted By</u>

Exam Roll NO: 04

Reg. No: 113

Session: 2018-19

Department of Zoology

University of Dhaka, Bangladesh

DECLARATION

I hereby declare that this report entitled **"Ichthyo diversity of Jamuna river, Sirajganj, Bangladesh"** is a presentation of my original research work. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature review and acknowledgement of the collaborative research and discussion. The work was done under the supervision of Dr Gawsia W. Chowdhury, Professor, Department of Zoology, University of Dhaka, Bangladesh.

I further declare that this dissertation or any part of it has not been submitted elsewhere for any degree or diploma award.

Ashifa

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CERTIFICATE

This is to certify that the thesis entitled **"Ichthyo diversity of Jamuna river, Sirajganj, Bangladesh"** is an original research work conducted by Mst. Asifa Akter, bearing registration no: 113, MPhil (Thesis), Department of Zoology, University of Dhaka, Bangladesh. This thesis has been carried out under our supervision for the partial fulfillment of the requirements for the MPhil degree in Zoology of Shahjalal University of Science and Technology, Sylhet, Bangladesh.

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Dedicated

To

My Parents

and My

Family members

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Abstract

Millions of people depend on Bangladesh's river systems, which are among the most productive and biodiverse in the world. However, fish populations are under risk due to frequent environmental changes, which renders baseline research crucial for conservation. This study examined the seasonal variations of the fish species in the Jamuna River, Bangladesh, over a 12-month period of about 12-months from July 2022 to June 2023. The research aimed to understand how seasonal changes in this large and significant tropical river system affected fish diversity, abundance, and community composition. The Jamuna River, known for its dynamic hydrological conditions and diverse aquatic habitats, provides a unique environment to study the complex interactions between fish species and their environment. Understanding these seasonal patterns of the ichthyo diversity is crucial for maintaining the health and sustainability of fish populations, which are an important resource for local communities and ecosystems. Over the study period, a total of 79 distinct fish species, belonging to 10 orders and 27 families were identified and monitored to determine their abundance across different seasons. The study employed heat maps and diversity indices to analyze seasonal abundance patterns. Heat maps offered a visual representation of the distribution and concentration of species over time, while diversity indices quantified changes in species richness (number of different species), evenness (relative abundance of species), and overall diversity. These analytical tools provided a comprehensive overview of how fish communities varied in response to seasonal changes in the river's flow, temperature, and habitat conditions. The findings revealed clear and distinct seasonal trends in fish abundance. Several species, such as *Hyporhamphus limbatus* and *Xenentodon cancila*, were found to be more abundant during the rainy season, which corresponds to the monsoon period in Bangladesh. On the other hand, species such as *Setipinna phasa, Chanda nama, Gagata youssoufi* were observed to have higher abundances in the dry season, when water levels are lower. The findings from this study underscore the importance of understanding the natural seasonal variability of fish populations. Further research is needed to explore the specific ecological drivers behind these seasonal patterns and to evaluate the long-term impacts of environmental changes on fish communities in the Jamuna River and for developing management and conservation strategies.

Table of Contents

List of Figures

List of Table

Chapter 1 Introduction

Introduction

1.1 Background and Literature Review

The variety and variability of fish species within a specific ecosystem is referred to as ichthyo-diversity. It encompasses genetic diversity both within and between those species as well as species diversity, or the variety of species that are present (Magurran, 2003). Ecosystem resilience, or the ability of such ecosystems can endure shocks and continue to operate, is frequently linked to high ichthyo-diversity (Ashraf et al., 2023). On the other hand, environments with less fish diversity are more susceptible to alterations, which may result in the loss of significant ecosystem services and ecological imbalances (Arthington et al., 2016).

Freshwater systems including rivers, lakes, and wetlands are home to aquatic ecosystems, which are some of the planet's most important and productive settings (Bashar et al., 2020). They produce water, cycle nutrients, and serve as habitats for a diverse range of species, among other vital functions (Ramanujam et al., 2010). Fish hold a special place among these species, both in terms of ecology and commerce. A crucial source of protein for human populations, fish also help to maintain food webs and the cycling of nutrients. Maintaining these ecosystems' health and production depends on our ability to comprehend the diversity of fish species, or ichthyo-diversity (Hasan et al., 2015).Rivers are dynamic, complex systems that support a wide variety of biological groups. According to Dudgeon et al. (2006), fish diversity in rivers in particular is a key sign of the stability and health of the ecosystem. Fish diversity reductions can be an indicator of environmental deterioration, such as pollution or habitat loss, whereas high diversity levels are frequently indicative of healthy ecosystems (Allan et al., 2005). Studying ichthyo-diversity is therefore essential for maintaining the ecosystem services that rivers offer, especially in areas where human populations rely significantly on them, in addition to ecological reasons.

The pride of Bangladesh is its rivers, with one of the largest networks in the world and a total of about 700 rivers, including the Ganges- Brahmaputra River delta that acts as a reverent nature which is reflected in the life style, custom, economic and history of the people of Bangladesh (Islam & Gnauck, 2008). Due to its unique Geophysical location; Bangladesh is exceptionally characterized by its rich biological diversity (Latifa & Asaduzzaman, 2014; Minhas et al., 2023). A total of about 253 freshwater fish species are recorded from Bangladesh (Pandit et al., 2020). A study performed by Paul et al. (2021) in the Jamuna river of Sirajganj district revealed that among 55 fish species, 26 were the IUCN Red Listed species. The three dominant fish species observed in the freshwater ecosystem of Bangladesh are Cypriniformes, Siluriformes and Perciformes (Hossain, 2014; Mohsin et al., 2013; Rahman et al., 2012; Rahman, 2015). Another study conducted by Easmin et al. (2018) identified 77 fish species in the Jamuna river where 12% species were critically endangered according to IUCN Red Listed species. Galib et al. (2013) identified 63 species in the Jamuna River among which 41.27% were considered threatened in Bangladesh. While the number of fish species found in the Mahananda River was stated to be comparable to that of other Bangladeshi rivers(Bhuiyan et al., 2008; Rahman et al., 2012), the number of fish species recorded was significantly lower (Mohsin & Emdadul Haque, 2009).Each of these researchers came to the conclusion that the biodiversity in the rivers they had studied was gradually declining which also applies to River Choto Jamuna in that regard (Galib et al., 2013).The current threat posed by biodiversity loss is frightening, however solving the issue will need early and comprehensive management. Lakra (2010)asserts that maintaining the ecological, nutritional, and socioeconomic balance depends on the protection of fish diversity. Therefore, in-depth research work is much needed with updated list of fish species to take necessary management initiatives to conserve the biodiversity of the Jamuna River.

Fisheries sector plays a very important role in the national economy of country; about 60% of total animal protein comes from the fisheries sector (Shamsuzzaman et al., 2020). The Jamuna River is one of the three main rivers of Bangladesh. It is the lower stream of the Brahmaputra River, which originates in Tibet as yarlung Tsangpo, before flowing into India and then south west into Bangladesh. The Jamuna flows south and joins the Padma River, near Goalundo Ghat, before meeting the Meghna River near Chandpur. It then flows into the Bay of Bengal as the Meghna River (Rudra, 2022). The diverse aquatic habitats in Bangladesh compiled as 265 Species occurring in Bangladesh is the third freshwater fish producing in the world. About 3793 metric tons of fish are obtained from the Jamuna River during 2016-2017 (Easmin et al., 2018) .

Riverine environments have been severely impacted by human activities over the past century, leading to habitat loss and degradation. Therefore, many fish species have become extremely endangered, especially in rivers where there is a strong demand for freshwater (Fu et al., 2003). However, out of the 253 fish species that were evaluated, 64 species, or 25.3% of the total, have been classified as threatened by the IUCN (Keith et al., 2015). Among these are 30 species classified as endangered (EN), 25 species as vulnerable (VU), and 9 species classified as critically endangered (CR). Thirty-one species were classified as data deficient (DD), 122 species as least concern (LC), and a total of 27 species as near threatened (NT). There were no fish identified as extinct or locally extinct. However, the assessment of fish catch utilizes a variety of data that can provide substantial suggestions regarding the state of a fishery and the potential results of management activities. This covers certain aspects that are specific to resource abundance, such as whether the stock is depleted or approaching its maximum biomass, as well as other significant aspects of fish population dynamics, such as the present and predicted levels of mortality, the expected levels of future recruitment, or features that are relevant to the economy, such as probable changes in catch per unit effort.

In Bangladesh, the Jamuna River is an important waterway that is especially important to the Sirajganj area, where it is crucial to the local ecology and economy. Wide, braided channels and an abundance of sandbars and islands, referred to as chars locally, that are continually molded by the river's flow are the river's distinguishing features (Best et al., 2022). Fish are among the many aquatic species that are supported by the varied range of habitats created by this dynamic environment (Hossain et al., 2019).The Sirajganj district is located on the western bank of the Jamuna River. The livelihoods of the local inhabitants rely significantly on the river, with fishing serving as the principal source of income for man (Farhana & Naser, 2016). A vast range of species are captured, traded, and eaten locally in the area, which has thriving fish markets. Nevertheless, there haven't been many scientific research on this topic, despite the significance of the fish diversity of the Jamuna River to the area. The majority of previous studies have concentrated on the river's environmental and hydrological features, paying little attention to the biological richness of the waterway, especially with regard to fish species (Elosegi & Sabater, 2013).

Numerous residents along the river rely on the river for their livelihood, either directly or indirectly. Nearly every fisherman owns a boat and net. Some fisherman share boats and nets with other six fishers (Scudder & Conelly, 1985). In addition to fishing, the fishers labor in the field. The sustainable catch of fish and the preservation of habitats are not on the minds of the fishers (Berkes, 1985). Fishing is most productive from July through September. During this season, a sizable number of fishing gears are used. From October onwards, the utilization of fishing gear gradually declines, with very few or no fishing gear being used from December through January. During this time, fishers take on additional jobs to supplement their income.

Nonetheless, numerous kinds of fishing equipment, crafts, and traps are utilized in our nation. Various fishing techniques have been employed throughout history, and now days, fishing techniques are constantly changing. In general, gears refer to the tools used in fishing operations. Depending on a number of variables, including the kind of water body, the specific region of operation, the depth of the water, and the presence of target species, the fishers choose their fishing equipment. In Bangladesh, traditional fishing gear, crafts, and traps are still used to catch fish and other aquatic wildlife (Sultana et al., 2016).

1.2 Rationale of the study

The varied biological groups that inhabit rivers are dynamic ecosystems that are essential to preserving ecological balance. The ecological stability and productivity of the Jamuna River, one of Bangladesh's principal rivers, are greatly enhanced by the abundance and diversity of fish species found there. Fish play a crucial role in the food chain of rivers, functioning as both predators and prey and contributing to the ecosystem's energy and nutrient cycles (Poletto et al., 2018). A river's ichthyo-diversity is a good indicator of its ecological health and resilience, showing that it can tolerate environmental shocks and still provide vital ecosystem services(Dudgeon et al., 2006).Fish diversity is known to be important for ecology, but little is known about the unique ichthyo-diversity of the Jamuna River, especially in the Sirajganj district. Our comprehension of the biological state of the river and its ability to sustain a wide variety of aquatic life is hampered by the absence of thorough baseline data on the species composition, distribution, and abundance of fish. In order to identify early indicators of ecological degradation and to direct conservation efforts, it is critical to evaluate the current level of ichthyo-diversity in rivers, which are increasingly endangered by human activities such as pollution, habitat change, and overfishing (Allan et al., 2005).

Furthermore, considering the area's reliance on the Jamuna River for fisheries and other ecosystem services, the study's focus on the Sirajganj district is especially pertinent. The study will shed light on the regional elements that affect ichthyo-diversity, such as fishing methods, habitat conditions, and seasonal fluctuations, by concentrating on this particular region. These discoveries will be helpful for larger regional and national initiatives targeted at safeguarding Bangladesh's freshwater biodiversity, as well as for local conservation and management initiatives. Through the documentation of the Jamuna River's ichthyo-diversity, this research will provide important data that can guide sustainable fishery management, assisting in the preservation of these resources for future generations to come.

1.3 Problem Statement

A wide variety of fish species that are essential to the local ecology, economics, and food security are supported by the Jamuna River in Sirajganj, Bangladesh. Even though this region faces rising challenges from pollution, habitat damage, and irresponsible fishing techniques, there is a shortage of detailed data on its ichthyo-diversity. This gap in understanding threatens the livelihoods of communities that depend on these fisheries as well as biodiversity by preventing sustainable management and effective conservation of the river's fish resources. Thus, in order to guide conservation efforts and guarantee the sustainable use of the river's fisheries resources, it is essential to evaluate and record the current level of ichthyo-diversity in the Jamuna River.

1.4 Objectives of the Study

The objectives of the present study are to find out the diversity, seasonal abundance, conservation status, catch composition in the Jamuna River. The findings of this study also intended to form a baseline for long term research and effective conservation management action plan for the threatened freshwater fish species which will ultimately help to take necessary solutions what are needed to reduce threats to fishes and riverine environment.The obhectives of the study are:

- To understand the community structure of the fish species in the Jamuna river
- To analyze the seasonal variations in fish diversity of the Jamuna River
- To qualitatively assess the diversity and abundance of fish species in the Jamuna River

Chapter 2 Materials and Methods

Materials and Methods

2.1 Study Area

The present study aimed to investigate the fish biodiversity in the Jamuna River, which is a crucial tributary of the Brahmaputra River, specifically within the Sirajganj district of Bangladesh (Figure 2.1). The Jamuna River is renowned for being one of the largest rivers in Bangladesh, both in terms of sediment load and water discharge. It is one of the three most significant rivers in the country, alongside the Padma and the Meghna. Given its importance, understanding the fish biodiversity in this river is essential for ecological management and conservation efforts. To effectively capture the biodiversity across different parts of the river, the study area was strategically divided into three sampling stations. The three points are (1) the Meghai Ghat (240 40’03.4” N to 890 38’ 49.0”E), Village - Meghai, Upazila - Kazipur, (2) The Moti Shaheber Ghat (240 28’ 46.7” N to 890 42’47.9”E), Village - Dhanbandhi, Upazila - Sirajganj Sadar,(3) The Betil Ghat (240 14’ 30” N to 890 42’ 30” E), Village - Betil, Upazila - Chauhali,. These coordinates cover a broad geographic area, allowing for a comprehensive assessment of the fish species present in the river. Data collection at these stations was conducted during the peak fishing seasons, specifically in November and January, when fish populations are most abundant and diverse. The study spanned from November 2018 to October 2019, covering both the wet season (November-April) and dry season (May-October), providing a full year of data to account for seasonal variations in fish biodiversity. This approach ensured that the study captured a holistic view of the river's biodiversity, taking into account the different species that may be present at various times of the year.

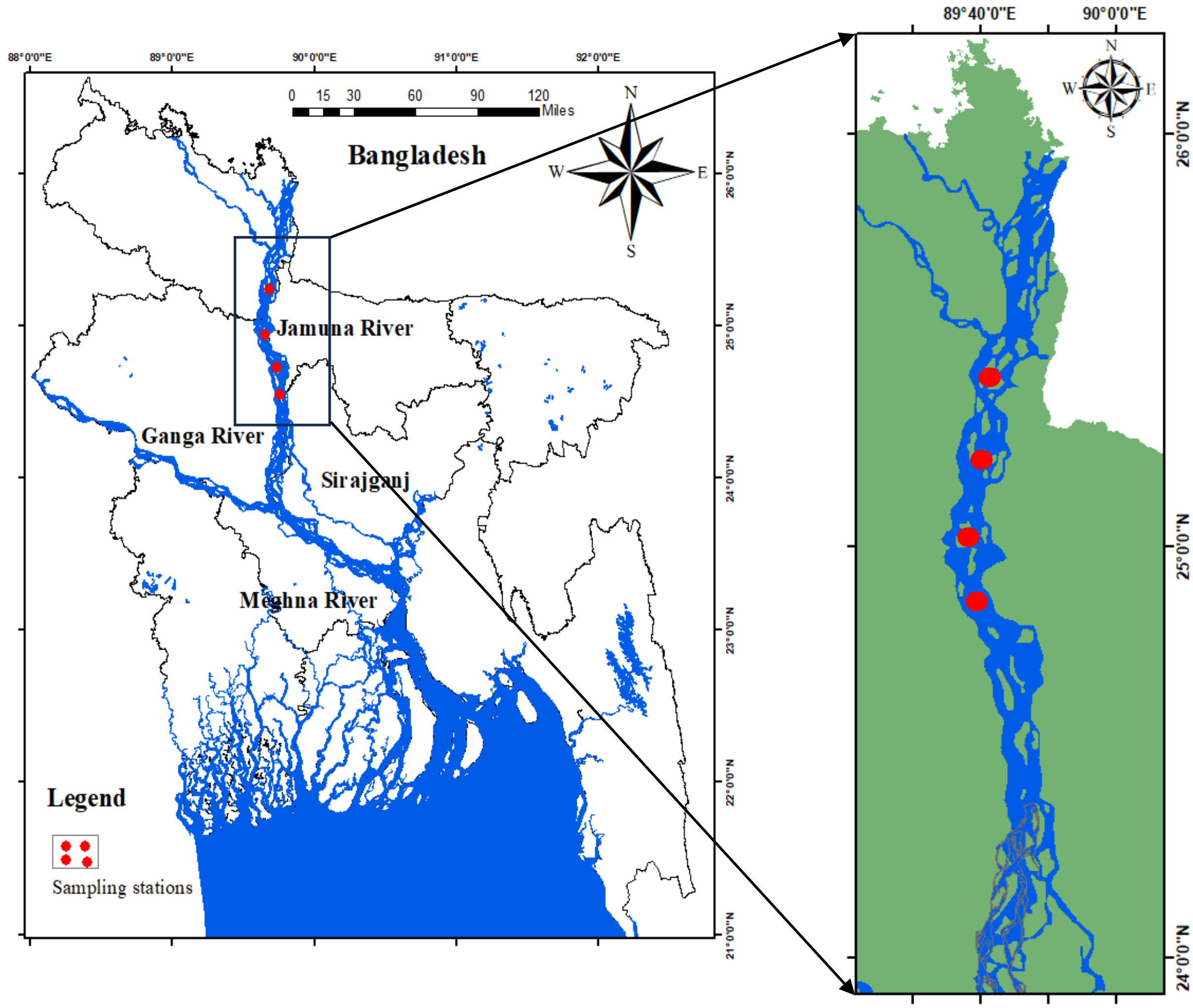


Figure 2. 1: Geographic Location of the study Area. The left side represents Bangladesh while the right side indicating the Jaumana River (The red dots indicating the sampling sites of the study area).

2.2 Data Collection and Taxonomic Identification

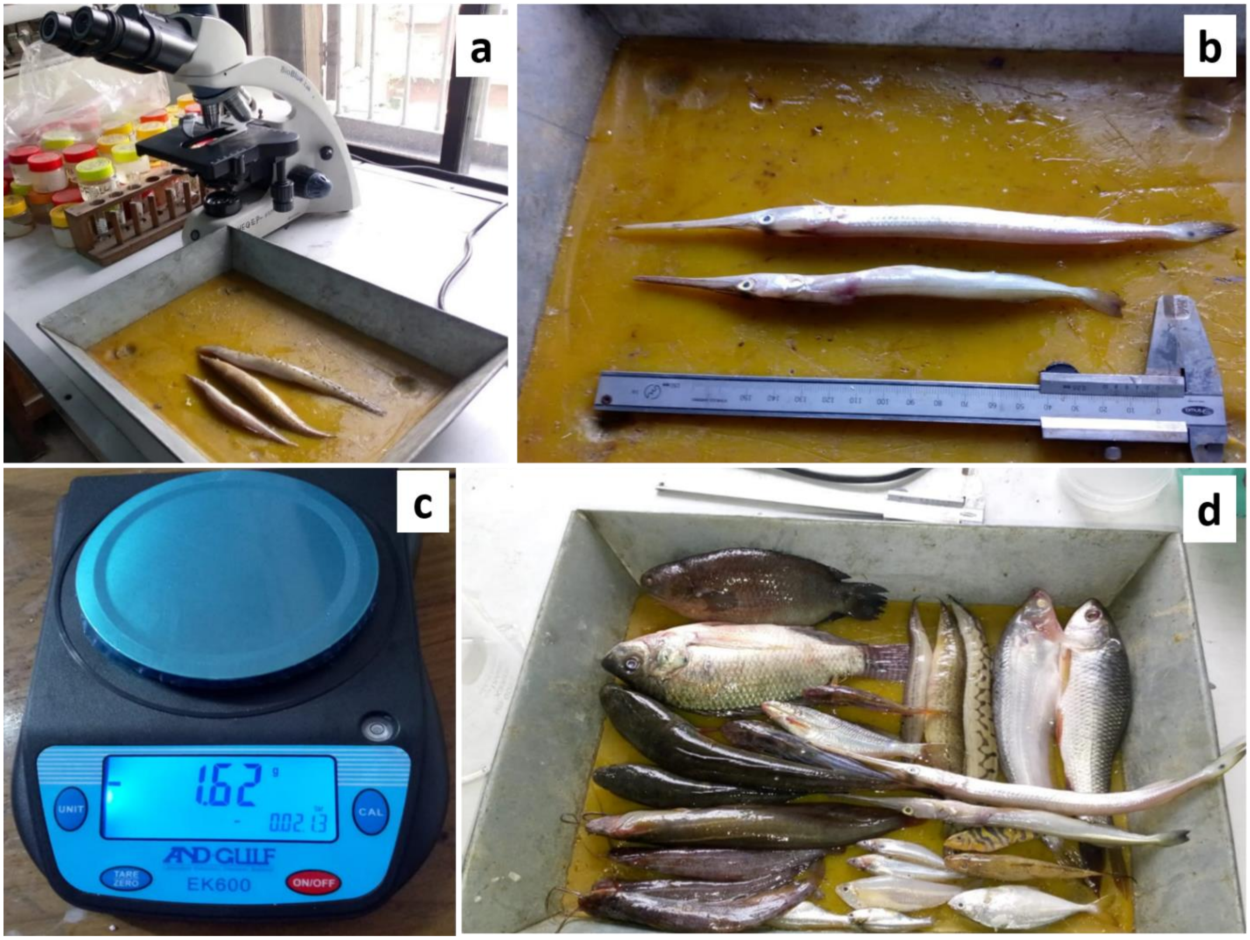


Figure 2.2 Lab analysis of the fish species collected from the Jamuna River (a) laboratory setup showing a stereomicroscope and preserved fish specimens prepared for examination; (b) measurement of fish specimens for recording morphometric parameters; (c) determination of fish body weight using a digital weighing balance; (d) assorted fish species collected during sampling and arranged for identification and further analysis.

The data collection process for this study was conducted since June 2022 and continues until June 2023. As new fish species were encountered, they were photographed and preserved in 8-10% formaldehyde for further analysis. Samples were systematically collected through monthly visits to fishing areas, landing centers, and adjacent fish markets in the selected study locations. All specimens were measured for total length (TL, in cm) and weighed (g) using a digital balance with 0.01g precision. A subsample of 10 individuals per species was measured when catches exceeded 50 individuals. Primary data were gathered by directly observing the fish catches of local fishers, complemented by structured questionnaire surveys, key informant interviews (KII), focused group discussions (FGD), and cross-checked interviews, as outlined by Ashrafuzzaman (2023). To ensure accuracy in species identification, some voucher specimens were collected for further clarification. Fishers, fish traders, and fish farmers were also consulted to gather additional information on the local fish biodiversity.

Specimen identification was conducted using taxonomic keys provided by Knebelsberger et al. (2014), Marceniuk et al. (2017) and (Misra, 1959). The identified species were recorded and archived in the museum of the Department of Zoology at the University of Dhaka. Monthly data collection takes place across different seasons, with field activities scheduled from 6:00 am to 6:00 pm. Fish catches are weighed using two portable balances with a precision of up to 0.01 grams to ensure accuracy. The total catch is recorded along with the time spent fishing, including the duration of time the fish are collected and the hours fished per day. Pre-tested survey forms are employed to systematically record catch data. This data is collected gear-wise on a daily basis, with records including the local name, common name, scientific name, and catch weight of each species (Rahman et al., 2010).

2.3Focused Group Discussion (FGD)

In order to obtain qualitative information about fish diversity, abundance, and seasonal variations, A total of 16 Focused Group Discussions (FGDs) were conducted. Local fishers, fisheries specialists, and community members with in-depth understanding of the aquatic environment were among the targeted participants. Around 15-16 people participated in each of the FGDs in average (ethical permission was taken from the fishers before FGDs). The selection of participants was based on their residency in the study region, fishing experience, and participation in fisheries management. In order to promote a thorough grasp of regional ecological trends, each FGD session contained organized conversations guided by a series of pre-formulated questions.

2.3.1 Questionnaire Design

In order to provide a quantitative foundation for comprehending the social aspects of fishing in the Jamuna River, the questionnaire was developed to support the biological data collection and FGD findings.

There were four primary sections of the questionnaire. Age, fishing experience, locality, and main source of income are examples of demographic data. Fishing practices include gear types, frequency of use, seasonal fluctuations, and trends in capture. Environmental observations include interactions with non-target species, bycatch observations, and perceived changes in fish diversity and abundance over time and Understanding local fishing laws, disposing of outdated equipment, and attitudes on conservation efforts. To ensure the relevancy and transparency of the questionnaire, it was pre-tested with a small group of fishers (n = 10) in a non-study location.
The full questionnaire is provided in Appendix 2.

2.4 Data Analysis

The data analysis for this study involves multiple steps, including data processing, tabulation, and statistical and mathematical analysis. To determine species composition, a specific formula is used to count small fish, which simplifies the process:

$$N = Wt \times Ns / Ws$$

Where:

- N = Estimated total number of small fish (Individuals with a total length of less than 10 cm was considered as 'small fish')
- Wt= Total weight of small fish found
- Ws= Weight of subsample
- Ns= Number of individual small fish in each subsample

The specimens are identified based on their morphometric and meristic characteristics, following the methodologies of Bhuiyan (1964), Rahman (2005), and Talwar and Jhingran (1991). After identification, the fish species are systematically arranged according to Nelson (2006). The threatened status of the species is evaluated in accordance with the IUCN Red List of Bangladesh (2015), considering three threat categories: Critically Endangered (CR), Endangered (EN), and Vulnerable (VU) (Macintosh et al., 2023; RANA, 2016; Sarwar, 2019).

To understand the seasonal diversity of fish, data are collected and preserved on a monthly basis. The diversity, richness, and evenness of fish species are estimated to assess the overall biodiversity in the Jamuna River. Shannon's diversity index (H) and Simpson's index (λ) are used as measures of diversity. Margalef's richness index (D) and Pielou's evenness index (E) are employed to investigate species richness and evenness. The following formulas are used:

- **Shannon-Weaver Diversity Index (H)**

$$H=-\sum (Pi \times \ln Pi)\ H$$

Where, Pi is the relative abundance of each species.

- **Simpson Index (λ)**

$$\lambda=\sum(Pi^2)$$

Where Pi is the proportion of each species in the sample.

- **Margalef's Richness Index (D)**

$$D= S-1/ \ln(N)$$

Where S is the total number of species, and N is the total number of individuals.

- **Pielou's Evenness Index (E)**

$$E= H/ \ln(S)$$

Where H is the Shannon-Weaver diversity index, and SSS is the total number of species.

The total catch of fish is estimated using data collected through catch assessment surveys. Gear-wise total catch (g/haul) is calculated using the formula:

$$CPUE= Sc\times Td/Sg\times Ts$$

Where:

- **CPUE** = Catch Per Unit Effort for gear
- **Sc** = Total sample catch (g)
- **Sg** = Number of sample gear
- **Ts** = Fishing time to catch the observed sample fish (hours)
- **Td** = Total fishing time in a day (hours)

These analyses allow for a comprehensive understanding of the fish biodiversity in the study area, facilitating effective conservation and management strategies.

2.5 Qualitative Data Analysis

Focused Group Discussions (FGDs) and interviews generated qualitative data which was translated and subjected to thematic analysis. Frequent factors brought up by fishers, such as seasonal fishing patterns, variations in fish diversity over time, gear usage and disposal, and awareness of fishing restrictions, were used to identify key themes. In order to reflect community agreement, general observations were descriptively recorded and, in cases where similar trends appeared across several discussions, these were reported using frequency indicators (such as "most fishers" or "the majority").

Chapter 3 Results

Results

3.1 Understand the Community Structure of the Fish species in the Jamuna River

The organization and diversity of species within an ecosystem, as well as their interactions and abundance, are referred to as community structure. It provides emphasis on the ecological roles of species, their interactions with one another, and the effects of the environment. Understanding the Jamuna River's community structure is crucial for evaluating the stability and health of the aquatic ecosystem. Through the examination of species diversity, dominance, and seasonal fluctuations, scientists can assess the effects of habitat degradation, fishing pressure, and environmental changes. Conservation and sustainable fisheries management depend on this information. Similar studies have been conducted in different river systems by researches including Hu et al. (2019), Jeppesen et al. (2010), Galib et al. (2016) and Das and Chakrabarty (2007). This study identified 79 fish species in the Jamuna River and also analyzed their seasonal variability throughout the year.

Table 1 Recorded Fish fauna of Jamuna River with their status during the study period

Sl. No	Order	Family	Scientific Name	Local Name	English Name	Local Status	Global Status
1	Anguiliformes	Ophichthidae	*Pisodonophis boro*	Kharu, Hizra	Rice Paddy Eel	LC	LC
2	Beloniformes	Belonidae	*Xenentodon cancila*	Kaika, Kakila	Freshwater Garfish	LC	NE
3		Hemiramphidae	*Hyporhamphus limbatus*	Ek Thuita, Ek Thota	Congaturi Halfbeak	LC	NE
4	Channiformes	Channidae	*Channa Punctata*	Taki	Spotted Snahehead	LC	LC
5			*Channa Striatus*	Shol	Snakehed Murrel	LC	LC

6			*Channa marulius*	Gajar	Great Snakehead	EN	LC
7	Clupeiformes	Clupeidae	*Corica soborna*	Kachki	Ganges River Spral	LC	LC
8			*Pellona ditchela*	Choukka	Indian Pellona	LC	LC
9			*Tenualosa ilisha*	llish	Hilsha Shad	LC	NE
10		Engraulidae	*Gudusia chapra*	chapila	Indian River Shad	VU	LC
11			*Setipinna phasa*	Phasa	Gangatic Hairfin Anchovy	LC	LC
12	Cypriformes	Cyprinidae	*Amblypharyngodon mola*	Mola, Moa	Mola Carplet	LC	LC
13			*Cabdio morar*	Morar, Morari	Aspidopara	VU	NE
14			*Barbonimus gonionotus*	Thai Sarpunti	Java Barb	Exotic	Exotic
15			*Gibelion catla*	Catla, Katal	Catla	LC	NE
16			*Cirrhinu cirrhosus*	Mrigal, Mirka	Mrigal Carp Reba	NT	VU
17			*Cirrhinus reba*	Bhangna Tatkini	Reba	NT	LC
18			*Cyprinus carpio var. nudus*	Carpu, Carphu	Common Carp	Exotic	Exotic
19			*Esomus danrica*	Darkina, Darka	Flying Barb	LC	LC

20			*Hypophthalmichthy smolitrix*	Silver Carp	Silver Carp	Exotic	Exotic
21			*Labeo bata*	Bata	Bata Labeo	LC	LC
22			*Labeo gonius*	Ghannya	Kuria Labeo	NT	LC
23			*Labeo calbasu*	Kalibaus	Orange Fin Labeo	LC	LC
24			*Labeo rohita*	Rui	Rohu Carp	LC	LC
25			*Osteobrama cotio*	Keti, Dhela	Cotia	NT	LC
26			*Puntius chola*	Chala Punti	Swamp Barb	LC	LC
27			*Pethia conchonius*	Kanchan Punti	Rosy Barb	LC	LC
28			*Puntius sophore*	Jat Punti	Spotfin Swamp Barb	LC	LC
29			*Systomus sarana*	Sar Punti	Olive Barb	NT	LC
30			*Pethia ticto*	Tit Punti	Two-spot Barb	VU	LC
31			*Puntius terio*	Teri Punti	One Spot Barb	LC	LC
32			*Rasbora daniconius*	Darkina	Common Rasbora	LC	LC
33			*Salmostoma bacaila*	Narkali	Large Razorbely Minnow	LC	LC

34			*Securicula gora*	Ghora-chela	Gora-chela	NT	LC
35		Balitoridae	*Acanthocobitis botia*	Balichata	Sand Loach	LC	LC
36		Cobitidae	*Botia dario*	Rani	Bengal loach	En	LC
37			*Botia lohachata*	Rani, Putul	Y-loach	En	NE
38			*Lepidochephalichth y sguntea*	Gutum, Puiya	Guntea Loach	LC	LC
39			*Neoeucirrhichthys maydelli*	Gutum, Puiya	Goalpara Loach	CR	LC
40	Osteoglossif ormes	Notopterida e	*Chitala Chitala*	Chital	Clown Knife Fish	EN	NT
41			*Notopterus notopterus*	Foli	Bronge Feather-back	VU	LC
42	Perciformes	Ambassidae	*Chanda nama*	Nama Chanda	Elongate Glass-perchlet	LC	LC
43			*Parambassis range*	Chanda, Ranga Chanda	Indian Glassy Fish	LC	LC
44			*Parambassis lala*	Lal Chanda	Highfin Glassy Fish	LC	NE
45		Sciaenidae	*Otolithoides pama*	poa	Pama Croaker	LC	NE
46		Nandidae	*Nandus nandus*	Bheda, Meni	Mottled Nandus	NT	LC

47		Mugilidae	*Rhinomugil corsula*	Khorsula	Corsula Mullet	LC	LC
48		Gobiidae	*Glossogobius giuris*	Bele, Bailla	Tank Goby	LC	LC
49		Anabantida e	*Anabas testudineus*	Koi, Koi	Climbing Perch	LC	DD
50		Osphronemi dae	*Trichogaster fasciata*	Khailsha, Kholla	Giant Gourami	LC	LC
51			*Trichogaster lalius*	Lal Khailsha	Dwarf Gourami	LC	LC
52		Mastacemb elidae	*Macrognathus aculeatus*	Tara Baim	Lesser Spiny Eel	NT	NE
53			*Macrognathus pancalus*	Guchi Baim	Barred Spiny Eel	LC	LC
54			*Mastacembelus armatus*	Baim, Salbaim	Zig-Zag Eel	EN	NE
55	Siluriformes	Pangasiidae	*Pangasiuspangasiu s*	Pangas	Yellowtail Catfish	LC	LC
56		Bagridae	*Mystus bleekeri*	Gulsha Tangra	Day's Mystus	LC	LC
57			*Mystus cavasius*	Kabashi Tengra	Gangetic Mystus	NT	LC
58			*Mystus tengara*	Bajari Tengra, Ghuitta Tengra	Stripped Dwarf Catfish	LC	LC
59			*Mystus vittatus*	Tengra	Asian Striped Catfish	LC	LC
60			*Rita rita*	Rita	Rita	EN	LC

61			*Sperata aor*	Ayre	Long-whiskered catfish	VU	LC
62			*Sperata seenghala*	Guijja, Guijja Ayre	Giant River-catfish	VU	LC
63		Siluridae	*Ompok bimaculatus*	Kani Pabda	Butter Catfish	EN	NT
64			*Ompok pabda*	Madhu Pabda	Pabdah Catfish	EN	NT
65			*Wallago attu*	Boal	Freshwater shark	VU	NT
66		Schilbeidae	*Ailia coila*	Kajuli, Bashpata	Gangetic Ailia	LC	NT
67			*Clupisoma garua*	Ghaura	Garua Bacha	EN	NE
68			*Eutropiichthys murius*	Muri Bacha	Murius Vacha	LC	LC
69			*Eutropiichthys vacha*	Bacha	Batchwa Vacha	LC	LC
70			*Pseudeutropius atherinoides*	Batasi	Indian Potasi	LC	LC
71		Sisoridae	*Bagarius yarrelli*	Baghayre	Giantdevil Catfish goonch	VU	VU
72			*Gagata cenia*	Cenia	Indian Gagata	LC	LC
73			*Gagata youssoufi*	Gang Tengra	Gangatic Gagata	LC	LC
74			*Nangra nangra*	Gang	Meghna	LC	LC

				Tengra	Nangra		
75		Clarridae	*Clarias gariepinus*	African Magur	North African Catfish	Exotic	Exotic
76			*Clarias batrachus*	Magur	Walking Catfish	LC	LC
77		Heteropneustidae	*Heteropneustes fossilis*	Shing	Stinging Catfish	LC	LC
78	Synbranchiformes	Synbranchidae	*Monopterus cuchia*	Kuchia	Gangatic mud eel	VU	VU
79	Tetraodontiformes	Tetraodontidae	*Leiodon cutcutia*	Tepa, Potka Kutkuitt	Ocellated Pufferfish	LC	LC

The heatmap illustrates the temporal variabilty of the fish species in Jamuna River from July, 2022 to June, 2023 (**Figure 3.1**). Around 79 fish species were observed and identifed during the study period in the river. The X-axis represents the 12 months while the Y-axis indicates different fish species identified throughout the study period. The color gradient scale shows the abundance of the species ranges from red (lower abundance) to blue (higher abundance). The visualization of the heatmap reveals the high abundance of *Chanda nama, Gagata youssoufi* and *Nangra nangra* throughout the entire study period. *Mystus tengara* and *Mystus vittatus*were observed higher during the month of August and September, 2022. *Osteobrama cotio*was found with a high abundance during December, 2022. Species, such as "*Acanthocobitis botia," "Ailia coila," "Barbonymus gonionotus*," and "*Channa Punctata*," were observed lower in abundance (darker red) throughout all months.Some species like "*Gudusia chapra*" and "*Clarias gariepinus*" showed sharp abundance peaks in single months only. Moreover, many species showed low abundance in a consistent manner throughout the study period.

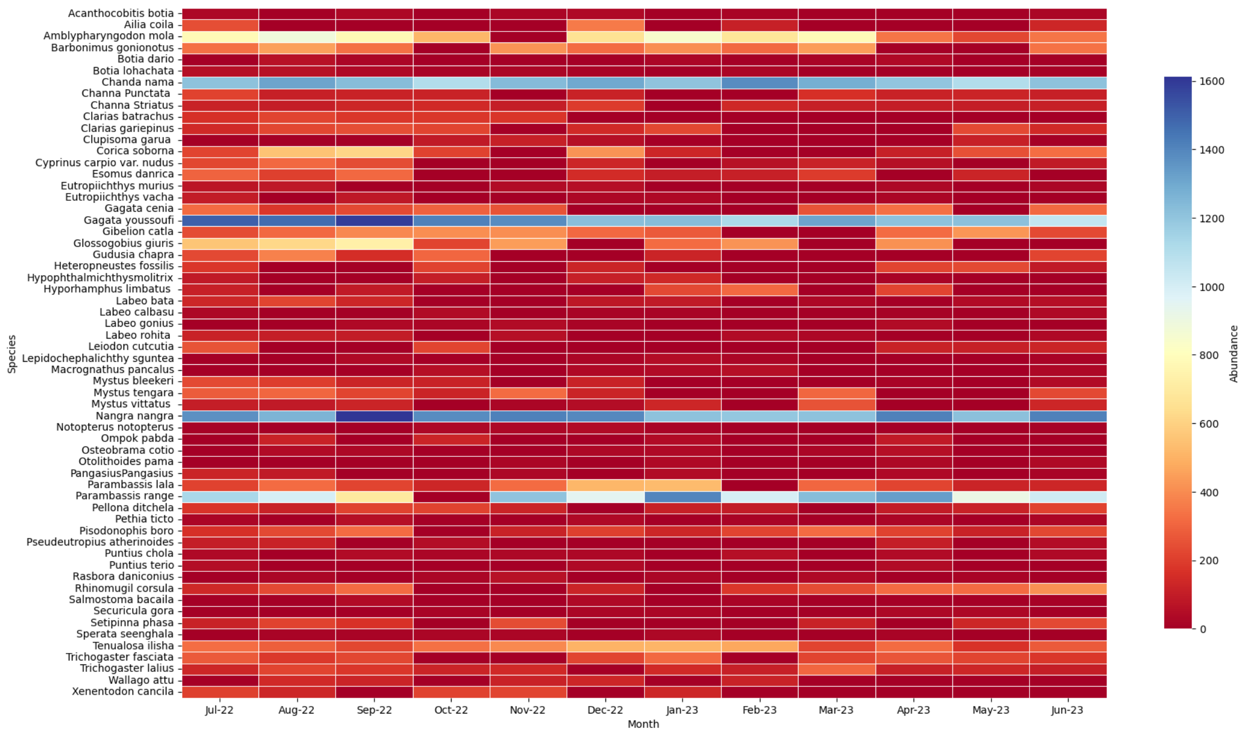


Figure 3. 1: Diversity of fish species identified in the Jamuna River

Figure 3. 2: Collected fish species from the Jamuna River (Some examples of the diversity of fish species collected from the river)

Table 2: *Identified fish species from the Jamuna River*

		
Pisodonophis boro	*Xenentodon cancila*	*Hyporhamphus limbatus*

		
Channa Punctata	*Channa Striatus*	*Channa marulius*

		
Corica soborna	*Pellona ditchela*	*Tenualosa ilisha*

		
Gudusia chapra	*Setipinna phasa*	*Amblypharyngodon mola*

		
Cabdio morar	*Barbonimus gonionotus*	*Gibelion catla*

		
Cirrhinu cirrhosus	*Cirrhinus reba*	*Cyprinus carpio var. nudus*

		
Esomus danrica	*Hypophthalmichthysmolitrix*	*Labeo bata*

		
Labeo gonius	*Labeo calbasu*	*Labeo rohita*

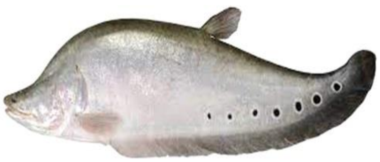
		
Osteobrama cotio	*Puntius chola*	*Pethia conchonius*

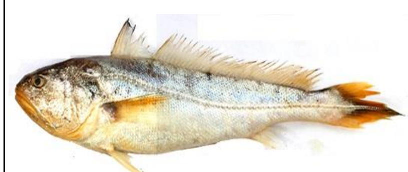
		
Puntius sophore	*Systomus sarana*	*Pethia ticto*

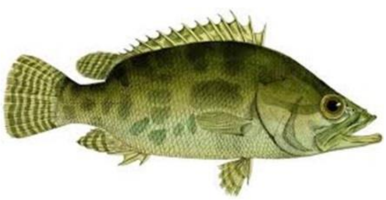
		
Puntius terio	*Rasbora daniconius*	*Salmostoma bacaila*

		
Securicula gora	*Acanthocobitis botia*	*Botia dario*

		
Botia lohachata	*Lepidochephalichthy sguntea*	*Neoeucirrhichthys maydelli*

		
Chitala Chitala	*Notopterus notopterus*	*Chanda nama*

		
Parambassis range	*Parambassis lala*	*Otolithoides pama*

		
Nandus nandus	*Rhinomugil corsula*	*Glossogobius giuris*

		
Anabas testudineus	*Trichogaster fasciata*	*Trichogaster lalius*

		
Macrognathus aculeatus	*Macrognathus pancalus*	*Mastacembelus armatus*

		
Pangasiuspangasius	*Mystus bleekeri*	*Mystus cavasius*

		
Mystus tengara	*Mystus vittatus*	*Rita rita*

		
Sperata aor	*Sperata seenghala*	*Ompok bimaculatus*

		
Ompok pabda	*Wallago attu*	*Ailia coila*

		
Clupisoma garua	*Eutropiichthys murius*	*Eutropiichthys vacha*

		
Pseudeutropius atherinoides	*Bagarius yarrelli*	*Gagata cenia*

		
Gagata youssoufi	*Nangra nangra*	*Clarias gariepinus*

		
Clarias batrachus	*Heteropneustes fossilis*	*Monopterus cuchia*


Leiodon cutcutia

Photo Credit: FishBase (fishbase.org)

3.1.1 Ichthyo-diversity according to fish orders in the Jamuna River

The donat chart represents the orders of fish species identified during the study period (**Figure 3.3**). In total, six orders of fish were found. The different colors in the plot represents different fish order with the percentage which indicates their relative presence in the dataset. The percentage labels indicate the contribution of each order to the total diversity.

From the chart, it can be observed that, Siluriformes was the most abundant order among others, with a significant percentage of 39.6%. After Siluriformes, Percifomes was the second most abundant fish order at 33.1%. The chart shows that Siluriformes and Perciformestogether make up nearly 75% of the total diversity which indicates that these two orders dominate the fish community in the study area which can be due to the suitability of these water conditions for these two particular fish orders. On the other hand, Anguiliformes was the lowest observed fish order in the Jamuna river with the least percentage of 2%. Cypriniformes consists approximately 11.3% of the total diversity. After Cypriniformes, Clupeiformes represents 9.6% of the fish diversity while Others" accounts for the remaining 2.5% of the dataset, consisting of less common orders.

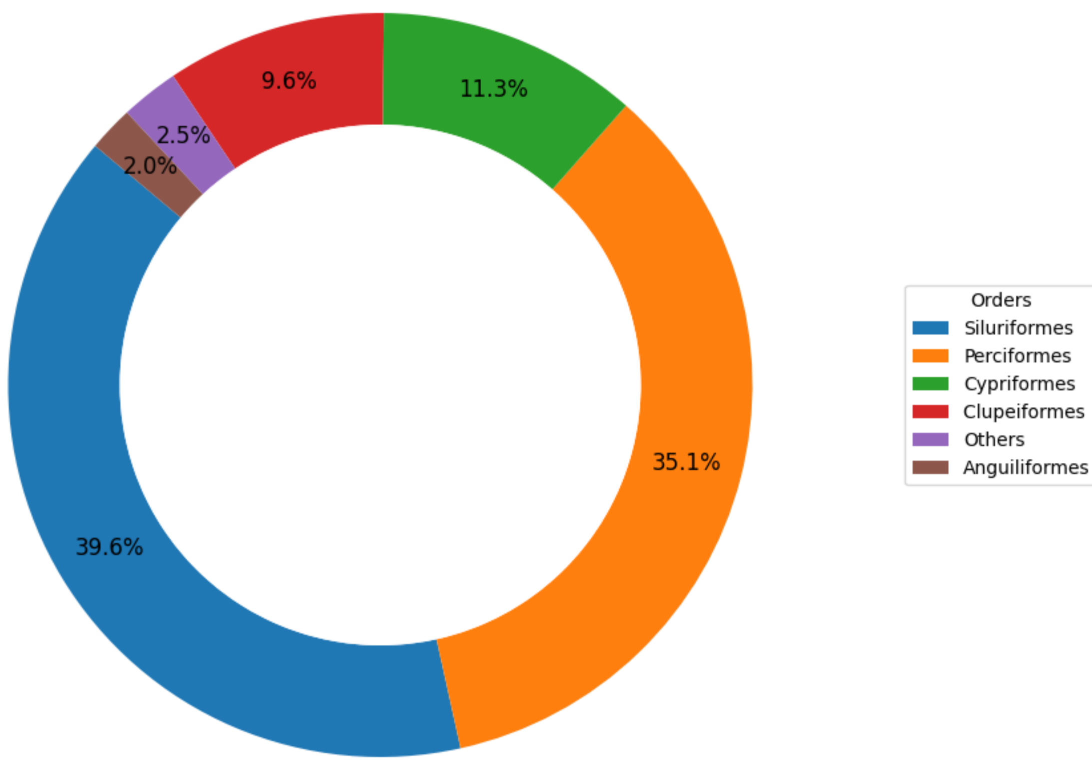


Figure 3. 3: Diversity of Fish Orders identified in the Jamuna River

3.1.2 Ichthyo-diversity according to fish families identified in the Jamuna River

This chart (**Figure 3.4**) offers a detailed look at the different families of fish present, their relative abundanceto broadly understand the composition and diversity of fish families in the ecosystem.. Each segment in this plot represents a family while the percentage shows their share of the total fish diversity. A total of 18 families were identified. Observations from the donut chart reveals that, Ambassidae was the most dominant family accounting for around 34.3% of the total fish diversity.

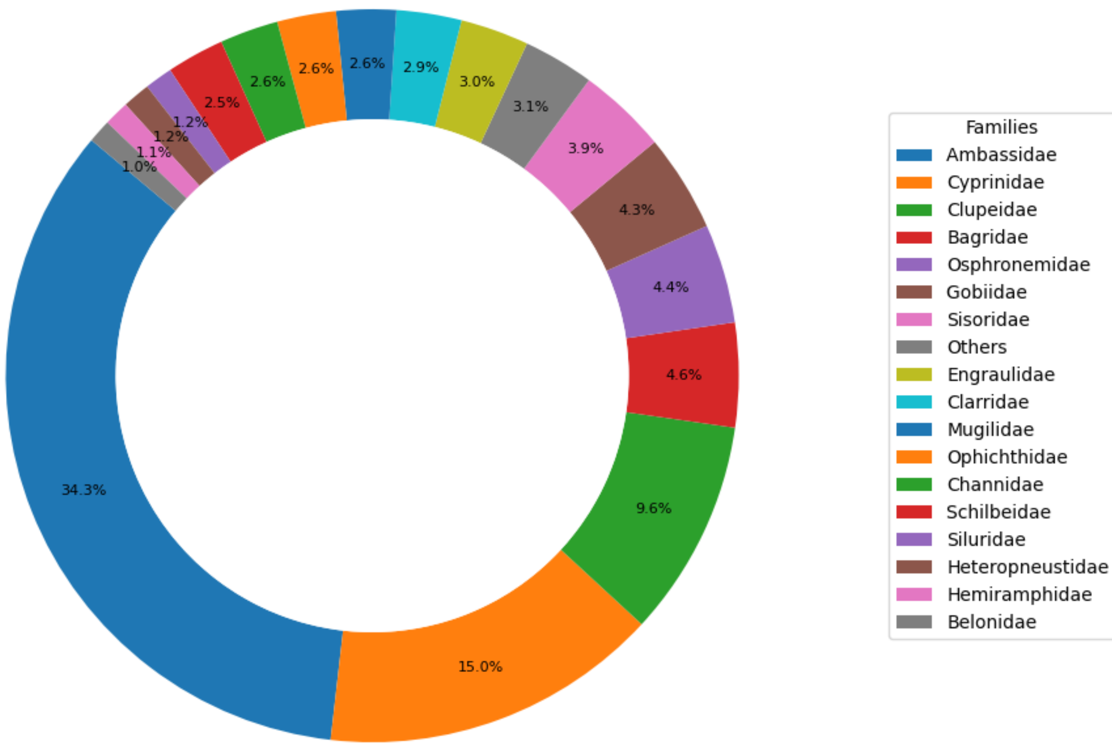


Figure 3.4: Diversity of Fish Families identified in the Jamuna River

The second-largest family in the dataset was Cyprinidae atapproximately 15%.Clupeidaerepresents 9.6% of the fish diversity.This family,Bagridae comprises 4.6% of the diversity. Besides, Families like Clupeidae, Osphronemidae, Gobiidae, and Sisoridae show moderate diversity with relative percentage of around 9.6%, 4.4%, 4.3% and 3.9% respectively. Species such as Clariidae, Engraulidae, Mugilidae, Ophichthidae contributes between 2.5% to 3%. Families like Schilbeidae (1.2%), Siluridae (1.2%), Heteropneustidae (1.1%), Hemiramphidae (1.0%), and Belonidae (1.0%) contribute relatively small proportions to the overall diversity.

3.2 Seasonal Variations in Fish Diversity of the Jamuna River

The seasonal variability of the fish diversity was analyzed during dry and wet season. All the 79 fish species identified were divided into four batches to show the seasonal variabilty of each species found during the study period.

Figure 3.5: Seasonal variability of fish species in the Jamuna River (20 species in each batch). Batch 1: Species 1–20; Batch 2: Species 21–40

The seasonal abundance of several fish species during the dry and wet seasons was shown in the first plot (**Fig 3.5**). Certain species, like *Hyporhamphus limbatus*, *Xenetodon cancila*, and

Pisodonophis boro, exhibit greater abundance during the wet season, suggesting that these species may flourish or be more readily available during this time. Some species, such as *Channa punctata* and *Channa marulius*, On the other hand, exhibit low or relatively constant abundance during both seasons, indicating that seasonal fluctuation has little effect on their populations.

Certain species, such as *Setipinna phasa*, are more abundant during the dry season, whereas species like *Cirrhina reba* show a discernible rise in abundance during the wet season. Furthermore, certain species exhibit significant seasonal changes, such as *Amblypharyngodon mola* and *Cyprinus carpiovar. nudus*, indicating a complex interaction of ecological factors that affect their abundance across seasons.

The seasonal trends of abundance for a different group of fish species are displayed in the second plot (**Fig 3.5**). Certain species, such as *Labeo rohita* and bata, show greater abundance in the dry season and a drop in population during the wet season, indicating that they may be more suited to the conditions of the dry season. Conversely, species with less seasonal sensitivity, such *Securicula gora* and *Rasbora daniconius*, show rather consistent abundances during both seasons.

While some species, such *Pethia conchonius* and *Puntius sophore*, remain at low levels year-round, others, like *Botia darlo* and *Lepidocephalichthys guntea*, exhibit a moderate rise in abundance during the wet season. Overall, this plot illustrates a variety of species' seasonal reactions, from those with noticeable changes to others with more consistent population levels.

The seasonal abundance of an additional group of fish species is depicted in the third plot (**Fig 3.6**). While some species, including *Trichogaster fasciata* and Parambassis *lala*, are more plentiful in the rainy season, some others, such *Chanda nama* and *Glossogobius giuris*, exhibit a notable rise in abundance during the dry season. This suggests that certain species are more resilient or have a differential tolerance to seasonal fluctuations than others. While some species, like *Nandus nandus* and *Mastacembelus armatus*, have low but somewhat changeable populations, others, like *Mystus cavasius* and *Macrognathus pancalus*, show very steady abundance across both seasons. Notably, several species, like *Rita rita* and *Pangasius pangasius*, consistently exhibit low abundance in both wet and dry seasons, indicating that their populations may not be severely affected.

Figure 3. 6: Seasonal variability of fish species in the Jamuna River (species 41-60 in the 3rd batch and species 61-79 in the 4th batch)

The fourth batch (**Fig 3.6**) showed seasonal abundance of another 19 fish species during the wet and dry seasons. In the wet season, the quantity of *Sperata aor* and *Sperata seenghala*was greatly reduced; in the dry season, *Ompok bimaculatus* and *Ompok pabda*were similarly significantly more numerous, although with some variability and outliers. *Ailia coila*showed greater variability during this season, while *Wallago attu* and *Ailia coila* exhibit the opposite pattern, with increased abundance during the wet season. *Clupisoma garua* and *Eutropiichthys murius* were more abundant during the dry season; during the wet season, *Clupisoma garua*was especially scarce. While *Bagarius yarrelli* likewise showed a higher dry season abundance with some fluctuation, *Eutropiichthys vacha* and *Pseudeutropius atherinoides* both showed severe decreases in the rainy season. While *Nangra nangra* and *Clarias gariepinus* remain relatively constant in numbers across the seasons, with *Clarias gariepinus* showing a minor rise in the wet season, *Gagata cenia* and *Gagata youssoufi* exhibit significant abundances in the dry season, with a marked drop in the rainy season. While *Monopterus cuchia* and *Lelodon cutcutia* showed very low numbers with little variation between seasons, *Clarias batrachus* and *Heteropneustes fossilis* demonstrate steady abundances across both seasons. Overall, the trend points to a number of species that were more abundant during the dry season, with a few, such as *Wallago attu* and *Ailia coila*, thriving during the wet season.

3.2.1 Diversity, Richness and Evenness Indices

The monthly variation in species diversity over a one-year period is displayed in the graph titled Diversity (H). The diversity index (**Fig 3.7a**) indicated a general downward trend, peaking at roughly 3.3 in July and decreasing to a low of approximately 2.8 in February. Later, diversity started to rise again, varying from 3.0 to 3.1 in March through May and then rising strongly to approximately 3.1 in June. This suggests that species variety declines significantly from late fall to winter and then starts to increase again in the summer.

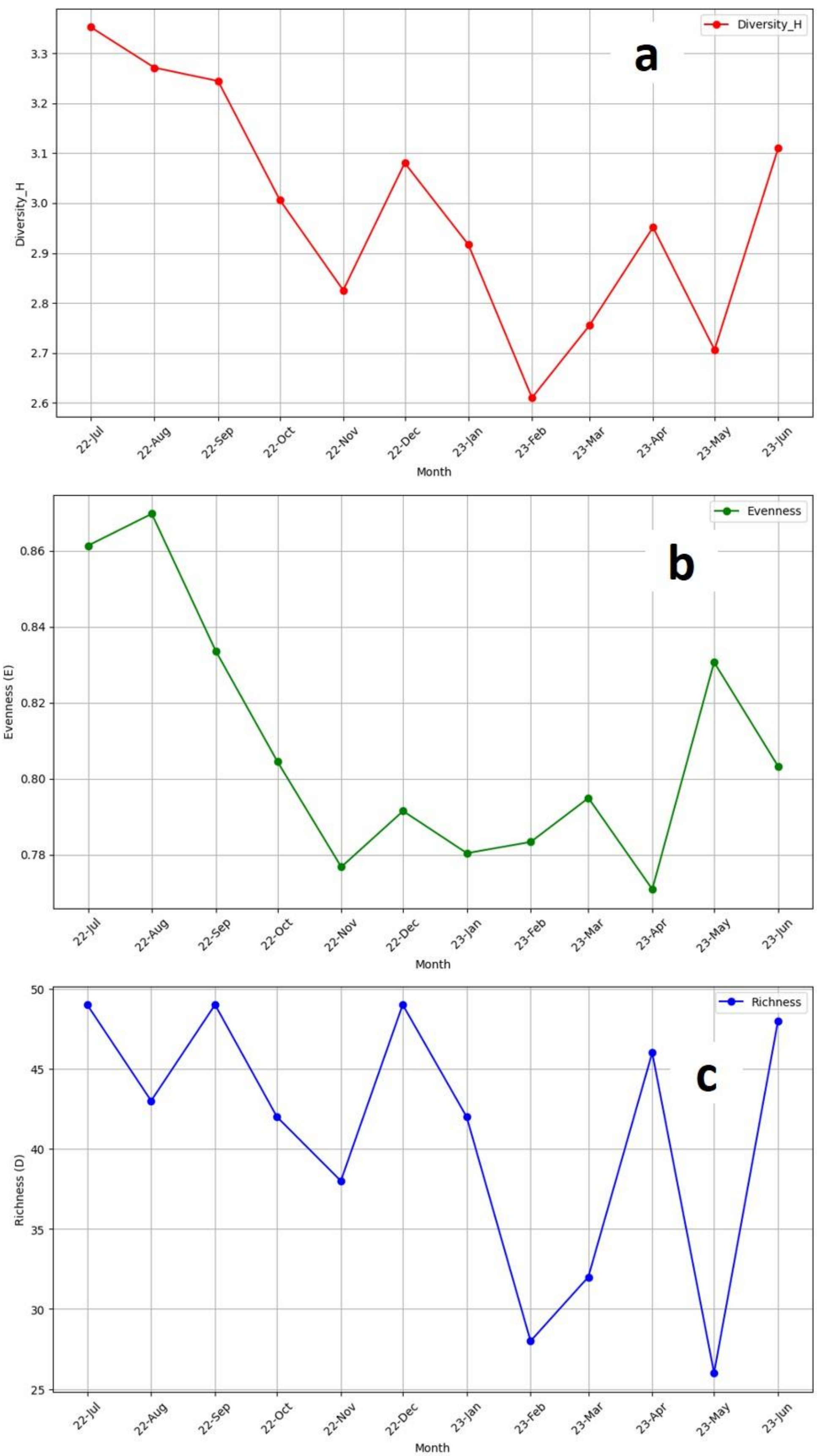

Diversity_H
a
3.3
3.2
3.1
3.0
2.9
2.8
2.7
2.6
22-Jul
22-Aug
22-Sep
22-Oct
22-Nov
22-Dec
23-Jan
23-Feb
23-Mar
23-Apr
23-May
23-Jun
Month
Evenness
b
Evenness (E)
0.86
0.84
0.82
0.80
0.78
Richness
c
Richness (D)
50
45
40
35
30
25

Figure 3. 7: (a) Monthly variation in species diversity from July 2022 to June 2023. The Shannon–Wiener diversity index (H′) shows fluctuations in species diversity across the study period. Peaks in diversity are observed in late 2022 and early 2023, with the highest value recorded in February 2023 (H′ = 3.1). **(b)** Monthly variation in species evenness from July 2022 to June 2023. Pielou's evenness index (J′) reflects the relative abundance distribution among species within the community**. (c)** Monthly variation in species richness from July 2022 to June 2023. Species richness (S), measured as the total number of species recorded each month, shows modest fluctuations over time. Values range from approximately 22 to 24 species per month, with a slight increasing trend from late 2022 to mid-2023

The monthly fluctuation in species evenness over the same period was shown in the plot entitled Evenness (E) (**Fig 3.7b**). The peak level of evenness, at roughly 0.86 in July, is followed by a sharp decrease through October, with the lowest point of roughly 0.78 in November. With a few minimal variations, it remained comparatively low and steady from November through March. After that, the evenness peaked in May at 0.84 and then started to decline a little bit further in June. This implies that species distribution exhibits a more balanced distribution in the summer and decreases even in the fall and winter.

Richness (D) (**Fig 3.7c**), the plot that represents the number of distinct species present throughout the year, is used to show the monthly fluctuations in species richness. Richness varied from 40 to 50 species until November, when it decreased to about 40. Species Richness started at about 50 species in July, dropped somewhat in August, then steadily increased in September. When compared to other months, February showed the lowest richness, with a quick decline to 25 species, and a subsequent steadily rising high in June. Seasonal variations in species richness were evident in this pattern, which indicates that the number of species present is largest during the summer and lowest during the winter.

Table 3 Total species and specimens recorded and studied with values of Shannon-Weaver diversity (H), richness(D) and evenness (E) indices in each sampling month

Month	Number_of_Species	Number_of_Individuals	Diversity_H	Richness_D	Evenness_E
22-Aug	43	13231	3.27116	43	0.869712

22-Dec	49	10617	3.080322	49	0.791486
22-Jul	49	13175	3.352186	49	0.861341
22-Nov	38	9654	2.825562	38	0.776768
22-Oct	42	8985	3.006988	42	0.804509
22-Sep	49	12908	3.244474	49	0.833665
23-Apr	46	9766	2.95152	46	0.770905
23-Feb	28	8279	2.610332	28	0.783365
23-Jan	42	10377	2.916872	42	0.780399
23-Jun	48	9904	3.109868	48	0.803334
23-Mar	32	9584	2.754953	32	0.794911
23-May	26	7792	2.706367	26	0.830659

3.3 Qualitative assessment of the fish diversity in the Jamuna River

This study explored the fish diversity of the Jamuna River in the Sirajganj district through a qualitative assessment involving local fishers. Focus Group Discussions (FGDs) were conducted with 116 fishers, who provided insights into the changes in fish diversity and fishing practices over time. These discussions took place at six different sampling sites along the river, including Ranigram, Tarakandi, Ekdala Punorbashon Noukaghat, Charmalsha, Borobajar, and Boroitoli. The majority of participants were over the age of 30, allowing them to draw on decades of personal experience and observations regarding the river's fish populations.

The fishers described a rich and diverse fish population in the Jamuna River, highlighting the presence of numerous species over the last 50 years. Species frequently mentioned included bele (*Glossogobius giuris*), piyali (*Sperata aor*), kalagachi (*Labeo calbasu*), baghair (*Bagarius bagarius*), baluchata (*Xenentodon cancila*), pangas (*Pangasius pangasius*), mrigel (*Cirrhinus cirrhosus*), rui (*Labeo rohita*), golosha (*Mystus cavasius*), ayr (*Sperata seenghala*), hilsha (*Tenualosa ilisha*), puti (*Puntius sophore*), kaiyakata (*Xenentodon cancila*, noted to sometimes be used interchangeably with baluchata), shei (*Channa striatus*), rita (*Rita rita*), and chela

(*Salmostoma bacaila*).. The fishers noted that fish populations and species composition varied with the seasons. During the rainy season, tengra, taki, bele, and bowal were most commonly caught, while the dry season saw a wider range of species being caught. Throughout the year, species like baila, ghaura (*Clupisoma garua*), and shrimp (*Macrobrachium rosenbergii*) were particularly abundant. However, the fishers expressed serious concerns about a significant decline in fish populations over the past 50 years, a trend observed consistently across all six sites. They attributed this decline to a range of factors, including overfishing, environmental changes, and the impact of modern fishing methods. One specific challenge noted was the use of certain types of nets, which they said made it harder to catch fish in some areas. The fishers also mentioned various difficulties they face, such as conflicts over fishing areas, competition for dwindling resources, and challenges in selling their catch at fair prices in local markets.

The discussions provided a detailed overview of the fishing practices and techniques used by the local community. Fishers in the Jamuna River region rely on a variety of gear, such as nets, hooks, and traps, which they use depending on the season, the type of fish they aim to catch, and the specific conditions of the river at different times of the year. For most fishers, these practices are not only a source of income but also a way of life, deeply intertwined with their cultural and social identity. They emphasized that fishing is their primary livelihood, and they are highly dependent on the river's resources to sustain their families. The fishers also discussed their practices regarding fish at different life stages, particularly the capture of fish in their larval or juvenile stages. Most reported that they release these fish back into the river if they are still alive, recognizing the importance of allowing young fish to mature and reproduce to maintain healthy fish populations. They expressed a similar approach to bycatch—fish that are unintentionally caught and are not the target species—where they often release the bycatch if it is alive. This reflects a level of awareness and concern for sustainable fishing practices among the community.

A significant issue raised was the disposal of damaged or broken fishing equipment. Many fishers admitted to throwing these materials directly into the river, contributing to pollution and potentially harming the aquatic environment. This practice is partly due to a lack of awareness or alternatives for proper disposal. Nonetheless, the discussions also revealed that many fishers are aware of local fishing laws and regulations, and they try to adhere to these rules to the best of their ability, understanding the long-term benefits of sustainable fishing practices for their livelihoods. Overall, the qualitative assessment revealed a complex picture of fish diversity and fishing practices in the Jamuna River. While there is still a diverse range of fish species present, there is a clear concern among local fishers about the declining fish populations and the challenges they face in their daily activities. Their experiences underscore the importance of developing effective management and conservation strategies to sustain the river's fish resources. The insights gained from the fishers highlight the need for community-based approaches that incorporate local knowledge, promote sustainable fishing practices, and address the socio-economic challenges faced by fishing communities in the region.

Chapter 4 Discussion

Discussion

The study conducted on fish species in the Jamuna River from July 2022 to June 2023 recorded observations of 79 species, indicating notable seasonal and temporal fluctuations in variety and abundance. Based on a heatmap analysis, species like *Chanda nama*, *Gagata youssoufi*, and *Nangra nangra* consistently had high abundance throughout the year, while species like *Acanthocobitis botia* and *Channa punctata* consistently displayed lower abundance. Two orders of fish, the Siluriformes (39.6%) and Perciformes (33.1%), accounted for about 75% of the total diversity, while the Anguiliformes was the least represented. Seasonal patterns of abundance revealed that some species, like *Labeo rohita*, were more common in the dry season, while others, including *Hyporhamphus limbatus* and *Pisodonophis boro*, thrived during the wet season. Richness and diversity trends showed a decrease from the end of September to winter, with diversity peaking in the summer and evenness reaching its maximum point in July and lowest point in November, indicating a more balanced distribution of species in the summer. Overall, the results show how intricate ecological interactions affect fish variety and abundance in the Jamuna River ecosystem throughout the year.

4.1 Community structure of the fish species in the Jamuna River

The heatmap analysis showed that while some species, including *Acanthocobitis botia* and *Channa punctata*, were constantly low in abundance during the study period, others, such as *Chanda nama*, *Gagata youssoufi*, and *Nangra nangra*, were consistently plentiful. Due to their food preferences, reproductive techniques, or resistance to changing water quality parameters, some species may have adapted to the environmental circumstances of the Jamuna River, as indicated by their persistent abundance (Zona et al., 2022). These species' dominance might also be an indication of their resistance to human stresses, such pollution and overfishing, which are frequent in the Jamuna River (Nemichand, 2024).Certain species, such as *Osteobrama cotio*, *Mystus tengara*, and *Mystus vittatus*, demonstrated highest abundance during particular months, suggesting potential spawning events or seasonal movement patterns. Galib (2022) revealed that spawning is frequently timed in accordance with monsoonal rainfall patterns in South Asia, where a large number of freshwater fish have seasonally driven reproductive cycles. The post-monsoon period corresponds with the peaks in abundance of these species, which are found in August, September, and December. This suggests a relationship with seasonal hydrological changes that improve spawning conditions by increasing water levels and nutrient availability (Bhuyan et al., 2020). It's possible that some species, including *Acanthocobitis botia* and *Channa punctata*, have low and stable abundances because of their specific habitat requirements and ecological specialization. Given the wide range of climatic variables found in the Jamuna River, for example, species with particular preferences for sediment or flow may be less able to adapt (Reise, 2002). Moreover, as proposed by Hossain and Wahab (2010), species-specific reactions to temporary environmental changes, like water temperature or dissolved oxygen levels, may be indicated by the strong abundance peaks for species like *Gudusia chapra* and *Clarias gariepinus* in particular months.

The biological significance of the Siluriformes and Perciformes orders in the Jamuna River is highlighted by their dominance, which accounts for around 75% of the entire diversity. The family Siluriformes, which includes fish species like catfishes, is known for its high fertility, ability to adapt to a variety of habitats, and extensive range of eating habits (Gomes et al., 2015). Although there are significant differences based on local habitat and hydrological conditions, the dominance of Siluriformes (39.6%) and Perciformes (33.1%) in the Jamuna River is consistent with observations from other significant river systems in Bangladesh. Cypriniformes is often reported as the most abundant order in many Bangladeshi rivers, such as the Choto Jamuna (Galib et al., 2013), the Mahananda (Mohsin & Haque, 2009), the Tista (Hossain, 2013), and the Padma (Rahman et al., 2012). In contrast, the Jamuna River showed a stronger representation of Siluriformes, which may reflect the river’s deeper channels and sandy substrates that favor catfish species. Interestingly, in the Halda River, an important spawning ground for major carps. Cypriniformes dominates, followed by Perciformes, with Siluriformes ranking third. Their predominance in the research region might be explained by their ability to take advantage of a variety of food sources and their resistance to the Jamuna River's fluctuating water quality (Hossain & Wahab, 2010).Observations from other aquatic systems, where these species bloom in both lentic and lotic habitats, are consistent with the high abundance of Perciformes, especially when it comes to taxa like Ambassidae (Máiz-Tomé et al., 2018). According to Haque et al. (2024), the relatively small number of orders such as Anguiliformes implies that these species are either less suited to the Jamuna River's environmental conditions or have unique ecological requirements that are not fulfilled in most of the studied region.

Fish activity and migration tend to increase during the monsoon season, which is consistent with the seasonal fluctuations in fish quantity that have been recorded. Species including *Hyporhamphus limbatus*, *Xenetodon cancila*, and *Pisodonophis boro* are more abundant during the rainy season (Chowdhury et al., 2017). The rainy season usually offers the best circumstances for growth, spawning, and foraging because of its enhanced water flow and habitat connectivity (Pusey et al., 2020). Mondal and Bhat (2020) suggested that particular species, such as *Labeo rohita* and bata, which exhibit greater abundance during the dry season, would prefer stable water conditions and lower flow rates. This could encourage certain feeding techniques and reduce competition. *Securicula gora* and *Rasbora daniconius*, for example, have low seasonal sensitivity, which indicates that their populations remain stable throughout the year. This could be because of their broad tolerance to environmental fluctuations or their opportunistic feeding habits (Peck et al., 2006). According to Fraser et al. (2018), species that exhibit comparatively constant abundance in both wet and dry seasons, such as *Securicula gora* and *Rasbora daniconius*, may have adaptable life-history strategies or broad ecological tolerances that allow them to survive in a variety of environmental conditions. The Jamuna River is one of those extremely changeable settings where such stability is beneficial because monsoonal impacts can cause fast changes in hydrological conditions (Jha, 2006).

To safeguard the varied fish communities in the Jamuna River, certain conservation measures are required, as indicated by the study's findings. A large variety of species depend on diverse habitats, and the dominance of a few taxa raises the possibility that the fish community may be less adaptable to changes in the environment (Halpern & Floeter, 2008). As per Miranda et al. (2020), safeguarding vital habitats like floodplains and backwaters, which offer crucial resources for various phases of fish life, need to be a top priority for management.

4.2 Seasonal Variability of the fish species in the Jamuna River

The complex relationship of hydrological, environmental, and biological elements can be observed in the seasonal variations in fish species diversity and abundance that has been recorded in the Jamuna River. In monsoon-driven regions such as South Asia, where hydrological conditions strongly influence aquatic biodiversity, an understanding of these patterns is crucial to understanding the biological fluctuations in riverine systems (Wang et al., 2014).

Some species, including *Pisodonophis boro*, *Xenetodon cancila*, and *Hyporhamphus limbatus*, were more abundant during the rainy season, suggesting that they prefer environments that involve floods and rising water levels (Ray et al., 2022). According to studies (Barletta et al., 2010; Junk et al., 2007; Mosepele, 2008), this trend is consistent with the idea that a large number of aquatic fish species in tropical and subtropical areas depend on floodplain flooding to gain access to a variety of habitats and improved food supplies. These fish species feed on the phytoplankton, zooplankton, and detritus that are created in the temporary aquatic conditions created during the wet season by the extension of the river's riverbank and overflow of surrounding regions (Asaeda et al., 2009; Hamerlynck et al., 2008; Ruddle, 1993). Conversely, species like *Channa punctata* and *Channa marulius* displayed comparatively consistent populations during both seasons. Their vast ecological tolerance, which enabled them to adapt to a wide range of environmental situations, may be the cause of this consistency (Adamson, 2010). These species can survive in low-oxygen environments, which are frequently encountered in both dry and rainy seasons, thanks to life-history features like territorial behavior and the ability to breathe air (Basavaraja, 2007; Qin et al., 2012; SINGH, 2019). Furthermore, these species' year-round consistent abundance can be linked to their capacity to use a variety of habitats, such as floodplains and permanent water bodies (Roy et al., 2022).

According to Loong (2019), certain species, such *Setipinna phasa*, showed signs of greater abundance during the dry season, indicating a preference for characteristics linked to lower water levels, including fewer suspended particles and slower flow rates. For animals that thrive best in calmer waters with plenty of prey (small fish and crustaceans), the dry season may offer more stable habitats. On the other hand, species such as *Cirrhina reba* showed a notable increase in abundance in the wet season, probably because they depend on periodical flooding for food and breeding(Sarkar & Banerjee, 2010). In order to benefit from increased habitat complexity, decreased predation, and an abundance of food supplies, many fish species time their reproductive cycles to coincide with the start of the monsoon (Hunnam, 2021; Munro, 2019; Sreekanth et al., 2019). This reproductive technique increases the chances that offspring will survive and helps to create seasonal peaks in population abundance(Winemiller et al., 2008). Certain species, such as *Cyprinus carpio var. nudus* and *Amblypharyngodon mola*, showed notable seasonal variations in abundance, suggesting a dynamic reaction to changing conditions in the environment (Singh, 2012). Numerous environmental conditions, like as variations in water temperature, dissolved oxygen levels, and nutrient availability, could be the cause of these alterations. For example, dissolved oxygen levels are essential for respiration, and water temperature affects the growth and metabolic rates of fish species (Davis, 1975; Mallekh & Lagardere, 2002). Increased water velocity and turbulence during the rainy season can raise oxygen levels and assist species that are more vulnerable to hypoxia. On the other hand, during the dry season, less flow and higher rates of decomposition could result in lower oxygen levels, which would have varying effects on different species(Brinson et al., 1981; Laiho, 2006).

The diverse responses to hydrological changes were demonstrated by the patterns of seasonal abundance in several fish species groups. Indicating that they may prefer or be better adapted to stable environments with lower flow velocities, which allow for efficient foraging on periphyton and macrophytes, species like as *Labeo rohita* and Bata, for instance, demonstrated greater abundance during the dry season (Chakraborty & Chakraborty, 2021). Additionally, since some floodplain habitats become less accessible to other species during the dry season, this may indicate less competition for resources (Thomaz et al., 2007). Furthermore, decreasing water volumes during the dry season may benefit species such as *Labeo rohita* by concentrating nutrients and prey and offering improved feeding opportunities (Sharma et al., 2015). Conversely, species like *Rasbora daniconius* and *Securicula gora* showed comparatively constant abundances in both seasons. Their ability to utilize a variety of habitats and food sources, together with their generalist feeding strategies, may have contributed to their stability by reducing their susceptibility to seasonal fluctuations (Gogoi et al., 2024). Since they may adjust their diet and habitat use based on availability, generalist species are frequently better suited to habitats with changing conditions. This allows them to sustain stable populations all year round (Wilson et al., 2008). Certain species, such *Puntius sophore* and *Pethia conchonius*, maintained low abundance levels all year long, indicating that they may have restricted responses to seasonal variations or may be preferring certain, less common locations (Alam et al., 2023). On the other hand, species such as *Lepidocephalichthys guntea* and *Botia darlo* demonstrated moderate increases in abundance during the rainy season, maybe as a result of increased habitat availability or spawning activity (Kar et al., 2010). According to Welcomme (2018), floodplain overflow during the wet season can produce temporary habitats that are perfect for breeding and abundant in nutrients for young fish, resulting in seasonal population peaks.

The seasonal patterns in fish abundance found in the third and fourth groups of species highlighted how various species react to changes in their environment. Certain species, including *Glossogobius giuris* and *Chanda nama*, showed a notable increase in abundance during the dry season, whereas others, like *Trichogaster fasciata* and *Parambassis lala*, were more common during the rainy season. This suggests that certain species, like *Trichogaster fasciata*, may have evolved particular systems for feeding or reproductive strategies that correspond with periodic flooding to enable them to flourish in the extremely dynamic conditions of the rainy season (Kumar & Sharma, 2022; Moniruzzaman et al., 2021; Neta). On the other hand, species such as *Glossogobius giuris* and *Chanda nama* may be more suited to the more stable conditions of the dry season due to their dependence on locations less affected by increased flow and turbidity and their benthic lifestyle (Ghosh & Biswas, 2017). According to , the notable rise in the number of species such as *Glossogobius giuris* during the dry season can also be attributed to their capacity to take advantage of refuges such deeper pools or backwaters, which are accessible even during periods of low water levels (Batuwita et al., 2022). Certain species, such as *Mastacembelus armatus* and *Nandus nandus*, showed low but fluctuating populations throughout the seasons, indicating that they may be somewhat impacted by changes in the environment or have adaptable life-history features that enable them to adjust to new circumstances (Ali et al., 2013). On the other hand, species such as *Macrognathus pancalus* and *Mystus cavasius* exhibited very consistent abundance in both seasons, suggesting either high resilience or a stable ecological niche that is not greatly affected by seasonal fluctuations (Samal et al., 2016). These species' steady abundance may also indicate that, despite seasonal variations, they live in environments that offer a steady supply of resources (Morgan Ernest & Brown, 2001). In both wet and dry seasons, species such as *Rita rita* and *Pangasius pangasius* consistently showed low abundance. This trend might be a sign of low reproductive success, a limited predilection for a particular habitat, or other ecological restrictions that restrict their populations in the current environment (Jenkins & Hockey, 2001). Although they haven't been specifically evaluated in this study, overfishing and habitat degradation may possibly be putting pressure on these species (Myers & Ottensmeyer, 2005).

The diversity index (H), which peaked at roughly 3.3 in July and dropped to a low of roughly 2.8 in February, showed a general decrease from summer to winter. According to this pattern, species diversity peaks during the monsoon season and troughs during the parched winter months. The expansion of the river's floodplain and the formation of varied habitats that sustain a wide range of species are responsible for the higher diversity observed during the rainy season (Turner, 2003). On the other hand, as only species that have evolved specifically to survive in these conditions may flourish during the dry season, decreased water quantities and habitat heterogeneity may lead to a decline in species variety (Tonkin et al., 2017). Monthly variations were also seen in the species richness index (D), with summer values being the highest and winter values the lowest. In tropical riverine ecosystems, where seasonal flooding during the monsoon generates a multitude of habitats that sustain higher species richness, this trend is compatible with natural cycles (Junk, 2005). The noteworthy decline in richness that was noted in February might be the result of a combination of factors, including diminished habitat accessibility, heightened rivalry for scarce resources, and environmental stressors like elevated temperatures and low dissolved oxygen concentrations (Abdel-Meguid, 2017; Mamfengu, 2007). During the summer, the evenness index (E) showed higher values, indicating a more equal distribution of species. On the other hand, evenness decreased in the fall and winter, indicating that some species became more prevalent while others decreased. Seasonal variations in the suitability of the environment, the availability of food, and interactions between species may cause this, favoring some over others (Connell & Orias, 1964; Varpe, 2017). Furthermore, the greater accessibility of microhabitats in the rainy season should lessen interspecies competition and promote a more uniform distribution.

4.3 Qualitative Assessment of the fish diversity in the Jamuna River

Fishing communities in the Jamuna River have provided a qualitative assessment of the diversity of fish, which provided significant data about how fish populations have changed over the previous fifty years. The catchers' reports of declining fish populations were consistent with wider patterns recorded in several freshwater environments in South Asia, where fish populations were said to have been negatively impacted by pollution, overfishing, habitat loss, and climate change (Sarkar et al., 2012).

Observations from other river systems in Bangladesh, where related species have also showed declining patterns, seemed comparable with the observed loss in fish species, including baghair, ayr, baush, bacha, and piyali, in the Jamuna River (Hossain et al., 2016). Based on the fishers's suggestions, overfishing, the usage of damaging fishing gear (such as fine-mesh nets), and habitat alteration caused by human activity might be the causes of this fall. Fish stocks in Bangladeshi rivers have been found to be significantly reduced as a result of overfishing, especially when non-selective fishing gear is used (M. B. Rahman et al., 2015). Furthermore, fishers have identified the usage of current nets as a concern when it comes to catching fish. This is because these nets have the capacity to capture fish of all sizes, including juveniles, which makes it difficult for fish populations to repopulate (Murray et al., 1999).

The fishers's observations of seasonal variations in fish catches provide further support to the scientific literature on the influence of seasonal hydrological fluctuations on fish variety in the Jamuna River and other comparable riverine ecosystems. Some species were reported to be more abundant during the rainy season, including tengra, taki, bele, and bowal. This is consistent with studies that show a significant increase in productivity of fish during monsoon flooding, when breeding grounds are more accessible and nutrients are more widely dispersed (George et al., 2011). On the other hand, the increased variety of fish observed during the dry season indicates the concentration of fish in the remaining bodies of water. This is a typical occurrence in floodplain rivers, where the decreased water levels drive fish to congregate in smaller regions (Ouma, 2020).

The regular discarding of defective fishing gear into rivers raised concerns as it may worsen the issue of aquatic pollution, according to this study's disturbing findings. Fish populations that were already experiencing declines may be further stressed by "ghost fishing," a phenomenon caused by lost or abandoned gear continuing to catch fish and other aquatic life (Matsuoka et al., 2005). This phenomenon can be caused by the buildup of fishing nets and other debris. Stelfox et al. (2016) have established that this poses a serious environmental hazard in a variety of aquatic environments worldwide. On the plus side, though, the majority of fishers said that they were aware of sustainable practices, such as releasing young fish and bycatch, indicating a potential basis for conservation and management plans.

An opportunity to improve community-based management measures in the Jamuna River appeared to be present given the fishers's general willingness to abide by local fishing restrictions. Research has indicated that improved conservation outcomes can result from including local communities in the management of fishing resources (d'Armengol et al., 2018). Traditional knowledge is essential to sustainable resource management, and this is especially crucial in developing places where regulatory capacity may be constrained (Danielsen et al., 2007).

4.3.1 Risk Assessment

The introduction of exotic species like grass carp (Ctenopharyngodon idella) and silver carp (Hypophthalmichthys molitrix) into the natural waters of Bangladesh, likely through flood-induced escapes from aquaculture ponds, poses significant ecological risks. These species have already been documented in various water bodies, such as Chalan Beel, Halti Beel, and Bookbhara Baor, where their presence has contributed to a decline in native fish diversity (Galib et al., 2009; Imteazzaman & Galib, 2013; Mohsin & Emdadul Haque, 2009).

Studies highlight the difficulty of eradicating invasive species once established, as noted by (Meyer & Hinrichs, 2000), and emphasize the need for continuous monitoring to avoid further impacts on local ecosystems (Filiz et al., 2011; Galib et al., 2013; Imteazzaman & Galib, 2013). In addition to the threat posed by non-native species, the degradation of natural habitats, over-exploitation of fish using illegal methods, and the use of toxins in aquaculture are major contributors to the declining fish populations in Bangladesh (IUCN Bangladesh, 2000). The situation in the Jamuna River is particularly alarming, with moderate to high ecological threats from toxic metal contamination(Kormoker et al., 2022), compounded by human interventions leading to increased siltation and narrowing of the river channel (Sarkar et al., 2023). Moreover, this increasing industrialization andconsequent agricultural revolution have already brought negative impact on the waterqualit(Kamrujjaman & Nabi, 2015). This combination of biological invasion and habitat degradation underscores the urgent need for effective management strategies to protect Bangladesh's aquatic biodiversity.

4.4 Limitations and Future Research

Although this study offers a thorough evaluation of ichthyo-diversity in the Jamuna River number of limitations are there. First, descriptive rather than inferential statistical analysis is the foundation for the seasonal abundance patterns reported in this work. Heatmaps and variety indexes were used to visually and qualitatively evaluate patterns, however formal statistical tests (such as ANOVA and PERMANOVA) were not used to examine the significance of seasonal differences. Furthermore, the study's temporal coverage was bound to July 2022–June 2023. Although this provided a comprehend annual cyclical patterns, it was impossible to evaluate interannual variability, such as the impacts of anomalous rainfall, temperature swings, or human disturbances. The robustness of observed trends would be enhanced by long-term monitoring over several years. Additionally, the social survey component was not quantitatively evaluated via standardized qualitative or mixed-methods frameworks, even though fishers's qualitative insights enhanced the ecological understanding. The scientific basis for conservation planning and sustainable fisheries management in the Jamuna River and other tropical river systems will be strengthened if these limitations are addressed in further studies.

Chapter 5 Concluding Remarks

Concluding Remarks

This study reveals the complex biological dynamics of a large river system in a monsoon-dominated environment by highlighting the significant seasonal fluctuation in fish species abundance, diversity, and richness in the Jamuna River. The results show that fish communities in the Jamuna River exhibit strong seasonal responsiveness, with different patterns of abundance associated with dry and wet seasons. During the rainy season, species like *Xenetodon cancila* and *Hyporhamphus limbatus* were more common, probably as a result of the extension of floodplains and the availability of more food. Some species, such as *Setipinna phasa*, on the other hand, were more common during the dry season, indicating a preference for the steady, low-flow conditions connected with this time of year. Additionally, the study demonstrates that although particular species show greater seasonal changes, generalist species, which may utilize a variety of environments and food sources, maintain relatively stable populations year-round. The significance of understanding the hydrological and environmental elements influencing fish communities in tropical riverine environments is shown by these patterns. Factors such as water temperature, dissolved oxygen concentrations, seasonal floods, and habitat heterogeneity would play significant role in determining the composition and structure of fish assemblages in the Jamuna River. The study also emphasizes the necessity of sustainable management strategies that take into account the seasonal variability of fish populations as a natural occurrence, particularly in considering the ongoing changes to the environment brought about by overfishing, habitat degradation, and climate change. To further understand how climatic fluctuation and human activity may impact the ecological balance of the river, future research should concentrate on long-term monitoring of fish communities and their habitats. Furthermore, learning more about the unique ecological needs and life-history characteristics of various fish species will be extremely helpful in developing efficient management plans and conservation initiatives.

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Appendices

Appendix 1

For the purposes of this study, the fishers were asked a series of questions related to their use and disposal of fishing gear, observed interactions with biodiversity, and their knowledge of fisheries regulations:

- What type of fishing gear did you use?
- How often did you replace it?
- How did you dispose of old gear?
- Did you ever see animals other than fish caught in nets?
- If yes, what kinds of animals did you see?
- Were the animals in the nets usually dead or alive?
- Were the animals caught in active nets (currently in use for catching fish) or derelict nets (no longer in use for catching fish)?
- Were you aware of any rules and regulations related to fishing gear that could be used?

Ethical Permission for FGD from fishers of the Jamuna River

For the purpose of M.Phil. research of Mst. Ashifa Aketr, Ichthyo diversity of Jamuna river; we agreed to use our information and knowledge.

Appendix 2 FGDs conducted in the study area with the community members