Impacts of temporal and spatial fishing ban on fish and shell-fish biodiversity in two fish sanctuaries in Bangladesh

A thesis Submitted to the Department of Fisheries, University of Dhaka in partial fulfillment of the requirements for the degree of Master of Science (MS) in Fisheries

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Declaration by the student

I hereby declare that the dissertation entitled **"Impacts of temporal and spatial fishing ban on fish and shell-fish biodiversity in two fish sanctuaries in Bangladesh"** submitted to the Department of Fisheries, University of Dhaka for the degree of Master of Science (MS) is based on self-investigation, carried out under the supervision of Professor Dr. Md. Ghulam Mustafa, Department of Fisheries, University of Dhaka, Dhaka-1000, Bangladesh.

I also declare that this or any part of this work has not been submitted for any other degree anywhere. All sources of knowledge used have been duly acknowledged.

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Certificate

I certify that the research work embodied in this thesis entitled **"Impacts of temporal and spatial fishing ban on fish and shell fish biodiversity in two fish sanctuaries in Bangladesh"** submitted by Miss Samapti Saha, roll number : 824, session: 2015-16, registration number: 2010-912-221 has been carried out under my supervision.

This is further to certify that it is an original work and suitable for the partial fulfillment of the degree of Master of Science (MS) in Fisheries from the Department of Fisheries, University of Dhaka.

We wish every success in his life.

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Abstract

Fishing ban, a widely practiced fisheries management tool which impacts the fish biodiversity within and beyond the sanctuary areas. The two months total fishing ban in five riverine hilsa sanctuaries in Bangladesh has been reported to increase hilsa production which also may have impact on overall fisheries biodiversity. Present study was carried out to assess the impacts of temporal and spatial fishing bans on fisheries (fish and prawn/shrimp) biodiversity in two riverine hilsa sanctuaries. Two sites, namely, Chandpur (S_1) and Shariatpur (S_2) landing fish caught within the sanctuary areas of the Meghna and Padma river respectively, and two sites, namely, Naryanganj, (O_1) and Munshiganj (O_2) landing fish caught outside the sanctuary area of the same rivers were selected. Fish and prawn/shrimp samples (10% of total catch) caught by different gears were collected three times (Jun, August and October) from pre-contacted fishers and identified based on morphometric and meristic characteristics. A total of 77 species of fish belonging to 31 families and 11 orders were identified. Cyprinidae was the most abundant with 23.33% individuals and also in all sites and months. In addition, 9 Species of prawn and 1 species of shrimp were also identified. Freshwater-estuarine living and omnivorous fish species were dominant in number among different habitat and feeding groups. Among all species, 20.78% of fish species were found to be threatened according to IUCN conservation status and there was no difference between sanctuary and open areas. The species diversity and evenness evaluated by, equitability (E_H) and richness. The Margaleaf's richness index (d=9.3846) and Shannon-Weiner Diversity Index (H=2.0344) obtained from whole samples indicates high species richness and diversity. However, all sites were less diverse compared to overall value. The fish community was more diverse within the sanctuary compared to outside in Padma river ($S_2 > O_2$), while it was opposite in case of the Meghna river ($O_1 > S_1$). Species diversity was highest in October compared to June and August. The findings of the present study suggest that the impact of fishing ban on riverine fisheries biodiversity is variable among different riverine ecosystems.

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List of acronyms and abbreviations

ANOVA	:	Analysis of Variance
CBFM	:	Community Based Fisheries Management
DoF	:	Department of Fisheries
e.g.	:	example
ECR	:	Environment Conservation Rules
ed.	:	edition
EN	:	Endangered
etc.	:	etcetera
EU	:	European Union
FAO	:	Food and Agriculture Organization
FRSS	:	Fisheries Resources Survey System
GDP	:	Gross Domestic Product
Ha	:	hectare
HFMAP	:	Hilsa Fisheries Management Action Plan
i.e.	:	That is
IUCN	:	International Union for Conservation of Nature
Km	:	Kilometer
LC	:	Least Concern
MOFL	:	Ministry of Fisheries And Livestock
MOL	:	Ministry of Land
MPAs	:	Marine Protected Areas
MT	:	Metric Ton
NGOs	:	Non-Government Organizations
NM	:	Not Mentioned
NT	:	Not Threatened
SPSS	:	Statistical Package for Social Sciences
sq.km	:	Square kilometer
USA	:	United States of America
VU	:	Vulnerable
%	:	Percentage

Chapter 1- Introduction

Bangladesh has been formed as the largest delta at the confluence of three major rivers (the Ganges, Brahmaputra and Meghna) and its tributaries. Thus, Bangladesh has a huge area of water resources of more than 4,575 million hectares making fishing a very important sector and the livelihoods of a large number of people depend on it. In Bangladesh, the fisheries sector can be divided broadly into four main subsectors: inland fishing or open water fishing, fishing in inland waters, marine fisheries industry (trawling) fisheries and marine craft. The total production of fish in the country is 3,548,115 MT, where the contribution of inland catches and fishing culture is 2,952,730 MT (FRSS, 2015). The market value of 77 328 tonnes of fish and fishery products is 48.98 billion taka (DoF, 2015). Its fishing sector contributes 22.60% to the agricultural sectors, 3.69% to national GDP and 2.01% to total exports (DoF, 2015). Production has been mainly achieved from aquaculture in closed inland waters and although the open water production of rivers, rivers, *baors* and *haors* has increased since recent years, its contribution to total production has been Reduced by 50% The last 3-4 decades is alarming. Per capita world consumption of apparent fish increased from an average of 9.9 kilograms (kg) in the 1960s to 19.2 kg in 2012 (FAO, 2014). Over the past five decades, global fish production has grown steadily. In 2012, the total world fish production of 158 million MT, the continental production of catch and culture are 11.6 million MT and 41.9 million MT respectively (FAO, 2014).

1.1 Biodiversity

Biodiversity is the degree of variation of life forms within a species, ecosystem, biome or planet. The 1992, United Nations Earth Summit defined 'biological diversity' as "the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems" (Hawksworth, 1996). This definition is used in the United Nations Convention on Biological Diversity. 'Biodiversity' is most commonly used to replace the more clearly defined and long established terms, species diversity and species richness. Biologists most often define biodiversity as the "totality of genes, species, and ecosystems of a region". An advantage of this definition is that it seems to describe most of the circumstances and introduces a unified view of the three traditional levels in which biological variety has been identified as species diversity, ecosystem diversity and genetic diversity (Ahmed et al., 2014).

1.1.1 Fisheries biodiversity

Fish biodiversity in open water has been drastically reduced; the abundance of many species has reduced so much that they appeared to have reached the bottleneck state and will rapidly extinguish itself from nature. In Bangladesh, fish exhibit wonderful diversity in size, shape, color, habitat, feeding habits and reproductive behavior. Through a series of natural and anthropogenic induced changes, the conditions of open water fish populations have been adversely affected. These include disturbances resulting from rapid population growth, lack of adequate management policy, water management programs (abundant water abstraction for irrigation and construction of dams and dams), human activities that give rise to (Dehydration fishing, poisoning, use of explosives), road communication, sedimentation of bodies of water by natural processes, unregulated introduction of exotic fish species and pollution of industry and agrochemicals. Fisheries were highly developed using a range of fishing gear such as purse seines, gillnets, driftnets and barley lines, targeting a wide variety of fish and shrimp species, which is also responsible for the reduction of fish biodiversity.

1.1.2 Fresh water fisheries biodiversity in Bangladesh

Bangladesh's freshwater resources are currently facing a large decline in fish biodiversity (Hanif et al., 2015). Recently, reducing the abundance of fish species in the inland waters of Bangladesh is a matter of concern in the country. Many fish are in danger of extinction or in critical danger. Some of them have already been extinguished from the waters of Bangladesh. The Red Book of Threatened Fishes of Bangladesh published by IUCN-Bangladesh. According to the Red List, 54 indigenous Indian riverine fish in Bangladesh are threatened, vulnerable, endangered and critically endangered (IUCN-Bangladesh, 2000). For the rapid decline of the fish species population, there is an extinct reduction due to overexploitation and various ecological and environmental changes in their natural habitats. The most diverse freshwater fish among all vertebrates become the most threatened groups through natural and anthropogenic activities, such as river management works, dam construction, land use change in watersheds, and

(Dudgeon et al., 2006, De Silva et al., 2007, Nel et al., 2009). For the construction of embankments due to flood protection, longitudinal and lateral migrations of breeding and feeding of riverine fish have been drastically damaged. As a result, overfishing and other human activities can alter the abundance, size structure and behavior of freshwater species that play a key role in shaping the community structure of these freshwater species causing ecosystem changes. Throughout the world, fishing becomes one of the most significant human impacts on fish stocks, their communities and their habitats (e.g. Tegner and Dayton, 2000, Myers and Worm, 2003) worldwide. Today, a series of partial or complete fishing bans have been implemented around the world with this widespread fishing (Pauly and Froese, 2012) in the hope of restoring fish stocks (Halpern, 2003; Claudet et al. 2008). In Bangladesh, freshwater environments become serious threats to biodiversity today and it is very important to prioritize the search for alternative techniques to promote the conservation and management of fish biodiversity. To this concern, sanctuaries are now used as a key tool for ecosystem-based fisheries management. These are established in order to assess the biodiversity of fish inside and outside a protected coastal area and to ensure the benefits of the protected area of rivers for the biodiversity of riverine fish.

Since hilsa is an anadromous fish, the Bay of Bengal is the main producing region of this species, from where it migrates to the Padma, Meghna and its tributaries rivers for breeding and lactation (Rahaman, 2006). The availability of hilsa now focuses primarily on the Meghna estuary, the Padma river and some coastal areas of Bangladesh. Hilsa contributes 11 percent of the total 2.9 million metric tons of Bangladesh fish production (Rahman et al., 2012). Hilsa contributes only 1.0% of GDP and contributes significantly to foreign exchange earnings (Wahab et al., 2013).

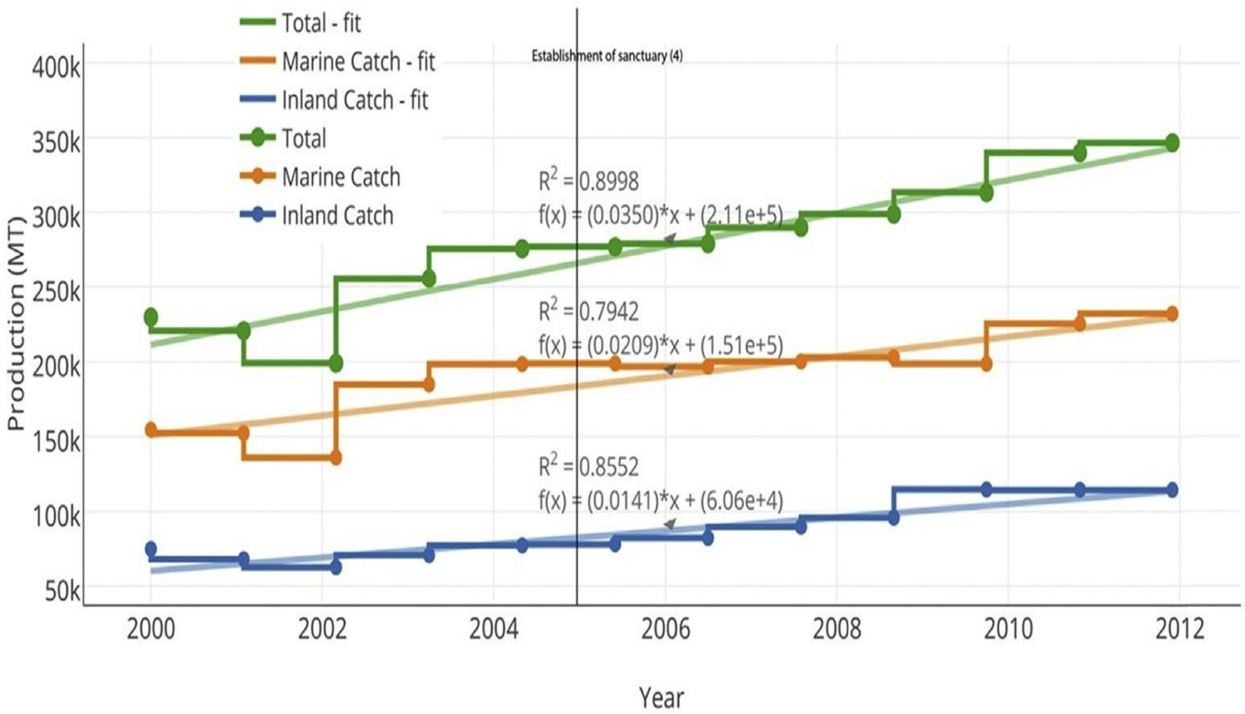


Figure 1 : Trends in hilsa catch in the inland and marine waters of Bangladesh. Data adopted from collected from 2000 to 2012. Production measured in metric tonnes per year.

(Source: FRSS, 2014)

Hilsa was once abundantly available on all 100 rivers in Bangladesh. A gradual decline in the hilsa fishery over the last 30 years (Wahab et al., 2013). The situation appears to be due to a combination of closure of migratory routes, excessive fishing, indiscriminate collection of offspring and juveniles *(jatka*), use of gillnets, mechanization of fishing gear, increased numbers of Fishermen, the hydrological and climatic change of pollution. Such a significant decline in catches of hilsa prompted the Government of Bangladesh to declare four sites on the country's coastal rivers as hilsa sanctuaries restricting fishing during the breeding season. Although the annual growth rate of hilsa production over the period was not stable, total hilsa production increased remarkably. Sanctuaries are implemented mainly to protect the hilsa biodiversity and fishing ban also implemented for hilsa. Although fishing bans are effective for hilsa, it may have also impact on overall fish biodiversity.

Freshwater capture fisheries contribute 9, 46,458MT to total fish production, which represents 28.19% of the country’s total fish production (FRSS 2014). Information on habitat wise fish production in the country is provided in (Table 1) (DoF, 2014-15).

Table 1: Fisheries production in Bangladesh

Sector of Fisheries	Water area (Hectare)	Total production (MT)	%
Inland Fisheries			
(i) **Inland Open Water (Capture)**			
1. River and Estuary	8,53,863	174,878,	4.75 %
2. Sundarbans	1,77,700	17580	0.48 %
3. Beel	1,14,161	92678	2.52 %
4. Kaptai Lake	68,800	8645	0.23 %
5. Floodplain	2692964	730210	19.82 %
Capture Total	**3907488**	**1023991**	**27.79%**
(ii) Inland Closed Water (Culture)			
6. Pond	377968	1610875	43.72 %
7. Seasonal cultured water body	133330	201280	5.46 %
8. Baor	5,488	7267	0.20 %
9. Shrimp/Prawn Farm	275583	223582	6.07 %
10.Pen culture	8326	16084	0.44 %
11.Cage culture	10	1969	0.05 %
Culture Total	800705	2061057	55.93 %
Inland Fisheries Total	**4708193**	**3085048**	**83.72 %**

(Source: DoF, 2014-15)

1.1.3 Diversity indices as measures of biodiversity

An index of diversity is a mathematical measure of the diversity of species in a community. Diversity indices provide more information on community composition than simply species richness (i.e. the number of species present); they also take the relative abundance of different species. Diversity indices provide important information about the rarity and frequency of species in a community. The ability to quantify diversity is an important tool for understanding the structure of the community. Diversity indices provide more information than just the number of species present (i.e., some species are rare and others are common), they serve as valuable tools that help us quantify diversity in a community and describe its numerical structure.

All ecological communities are variable on a scale of spatio-temporal scales, while diversity may be small in small patches at a particular instant, additional diversity may be added by inclusion in diversity component samples due to spatial patterns or temporary.

Biological diversity can be quantified in many different ways. The two main factors that are taken into account when measuring richness and evenness. Richness is a measure of the number of different classes of organisms present in a particular area. For example, species richness is the number of different species present. However, diversity depends not only on richness but also on evenness. Evenness compares the similarity of the population size of each of the species present.

The Shannon index is a statistical index of information, which means that all species are represented in a sample and samples are taken randomly. It is commonly used to characterize species diversity in a community. In general, the Shannon index in real ecosystems ranges from 1.5 to 3.5 (MacDonald, 2003). Because the range is small, the index itself says little about the actual species diversity. The premise of the Shannon index is that the greater the diversity, the smaller the probability.

But species diversity can be measured in two different ways. One is the species richness, which is the number of species in a given ecosystem. The other is the evenness of species, which is the distribution of individuals through the present species, also known as relative abundance. Both measures are important; in a community of high diversity, one would expect to see different types of organisms.

The Shannon index is useful in the sense that the function takes into account both the richness and the evenness (uniformity) of a given ecosystem. The Shannon Index was created to effectively deliver a message regarding species richness and evenness (uniformity) in a given ecosystem. The index implies that as the number of species increases, or when the distribution of species becomes more even (uniform), the better the biological diversity (indicated by a larger number). The small range due to its logarithmic element in the function hinders the effective identification of species diversity, but remains an effective measure to see if the diversity of similar ecosystems is affected by species richness or evenness.

Species composition is the identity of all the different organisms that make up a community. This is important when trying to discover how an ecosystem works, and how important different organisms are to an environment.

1.2 Fishing ban and sanctuaries in fisheries management

The term "fishery" clearly refers to catching activities, which means all open water harvesting activities (natural waters), as opposed to rearing aquatic animals in controlled and human-controlled environments (stocking, feeding etc.). Fisheries were intensively developed using a range of fishing gear such as purse seines, gillnets, driftnets and barley lines, targeting a wide variety of fish and shrimp species, which also contributes to reducing biodiversity of the fish. The biodiversity of freshwater fish is now at risk (Hossain et al., 2012).

The Government of Bangladesh and a number of non-governmental organizations (NGOs) have adopted a number of policy and development interventions for the sustainable management of natural resources in fisheries. These measures include the implementation of the Fisheries Protection and Conservation Act of 1950 and related standards, including the new fisheries management policy (granting of fishing rights directly to true fishermen), Community fisheries management (CBFM) Release of fish seeds and improvement of fish habitat through excavation (Islam et al., 2016). However, it is very difficult to enforce fisheries regulations in Bangladesh because of the institutional weakness of enforcement authorities and the socio-economic conditions of fishermen. On the contrary, the concept of fish sanctuary is easier to adopt than to apply other regulations of the Fisheries Act. Sanctuaries are protected areas where fishing activities are strictly restricted with a widely recommended approach to facilitate the recovery of diminishing freshwater or riverine resources (Lauck et al., 1998; Guenette and Pitcher, 1999; Russ and Alcala, 2003; Gaylord et al., 2005). For the enhancement of fisheries in adjacent areas, these are created mainly (Russ and Alcala, 1999; Roberts et al., 2001; Gell and Roberts, 2003; Willis and Millar, 2005). Sanctuaries as an ecosystem-based management tool are made to delegate the protection of species and their fishing habitats within their boundaries. By creating sanctuaries where fishing is banned or prohibited, it will be possible to overcome many important and pressing problems within protected areas (Dayton et al., 2000; Gell and Roberts, 2002), such as loss of species biodiversity (Jackson et al., 2001), alteration of trophic structures

(Babcock et al., 1999; Castilla, 1999; Jackson et al., 2001; Pauly et al., 1998, 2002), loss of habitat (Sumaila et al., 2000) and over-fishing for a long time (Hutchings, 2000; Jackson et al., 2001; Pauly et al., 1998, 2002).Examples of types of fish sanctuary are given in (Table 2).

Table 2 : Different types of fish sanctuary (Adopted from, MACH Technical Report, 2006)

Type of sanctuary	Objective/Purpose	Characteristics
Seasonal / Temporary	Protect short lived species at a vulnerable stage in their life cycle	Fishing may be closed for breeding season in the breeding ground to allow successful spawning, or in the dry season to project brood stock.
Permanent	Protect brood stock of long lived species as well as of short lived species	Fishing is closed for the whole year for all species to develop/ protect brood stock.
Species specific	To replenish any endangered/ depleted Species of fish.	To protect a particular species in its preferred habitat for all or a major part of its life cycle (fishing for other species may or may not be allowed within the sanctuary)
Harvest reserve	To increase catch and to conserve brood Stock.	Fishing is closed for a certain period in a given area - say 3 or 5 years primarily so that those who stop fishing can at the end of this time get an increased catch but it also helps some fish to breed

Sanctuaries can also play an important role in the conservation of critical habitats and vulnerable species by increasing the stock of brood fish in the sanctuary area, migrating juvenile and adult fish from the protected area to the nearby non-protected area (spillover effect, Rowley, 1994; Stobart et al., 2009) or egg and larval exports towards close or remote areas, potentially allowing stock recovery (Rowley, 1994; Russ et al., 2003; Alcala et al., 2005) and increased mean size of fish within the sanctuary area.

The reserve areas of open water the body where fishing is not allowed. They provide shelters where populations of exploited species can recover and habitats modified by fishing can be regenerated. According to the Fisheries Law, juveniles of Hilsa (Jatka) are prohibited below 23 cm during the period from November to April. The major Jatka fishing gear-current jal (gill net made of monofilament synthetic fiber, upto mesh size 4.5cm) is also prohibited. However, the Government has adopted a special program to protect Jatka by prohibiting all fishing gear in the main fishing areas of Jatka for 2-3 months.

The fishing ban has been used as a common tool for fisheries management in overexploited stocks around the world (Gell et al., 2003). The studies reported that the fishing ban helps restore target fish stocks and lead whole communities to non-target areas. (Bevilacqua et al., 2006; Guidetti, 2006; Micheli et al., 2004; Sala et al., 1998; Shears and Babcock, 2002). Closure of protected areas for a limited time (temporary and spatial prohibition of fish) to all forms of harvesting during active spawning and breeding seasons can directly reduce fishing mortality (Gruss and Robinson, 2015; Clarke et al., 2015; Murawski et al., 2000) and increase population size, and reproductive capability inside the protected areas (Bohnsack, 1998). There are two mechanisms through which sanctuaries are expected to benefit adjacent fisheries: net migration of adults and juveniles across borders, termed ‘spillover’ (Rowley, 1994). Due to improved production of eggs and larvae within protected areas which is expected to lead to net export and increased settlement of juvenile animals outside the protected areas (Alcala et al., 2005; Gell and Roberts, 2002; Roberts and Polunin,1991). Detecting and measuring the expected effects of protection on the general biodiversity of fish (e.g., increase in average size and abundance) is hampered by natural intrinsic spatial and temporal variability. Protective measures that increase the mean values and affect the temporal trends of some theoretical variables, such as the abundance and size of a hypothetical commercial overexploited fish. Although the variables investigated (i.e., fish abundance and size) may vary in space and time, the detection of a significant protective effect does not depend only on spatial and temporal comparisons. The response is required to be different in the protected area from natural changes occurring in unprotected areas. Therefore, protection measures may or may not be effective, but they would be detectable through the statistical interaction between temporary changes and spatial differences in the fishing ban.

1.3 Fish Sanctuaries in Bangladesh

Sanctuary of fish means establishing and maintaining a particular area in the body of water as a permanent shelter for the protection of the fish for natural propagation. In other words, the fish sanctuary is a demarcated protected area, where the target fish will not be disturbed or captured. The establishment of an aquatic sanctuary is one of the effective tools to conserve fish stocks, preserve biodiversity and increase fish production. In some cases, restoration as well as habitat conservation may be possible by establishing an aquatic sanctuary. Therefore, Sanctuary serves as a powerful tool for the protection and conservation of fish stocks in Bangladesh. Under the development and management program of the Department of Fisheries, some 23 strategically located deposits (*Jalmohals*) were formally established for the first time in 1991 in fish sanctuaries during the period 1960-65 under the development and management program of the Department of Fisheries. Another 25 sanctuaries were approved by the DoF and established during 1965-70 under another scheme for encouraging results. In order to establish sanctuaries, these bodies of water were delivered to the MoFL / DoF by the Ministry of Land (MoL), but on the basis of the regular payment of the lease money to MoL. For permanent continuity, sanctuaries were planned and fishing activities were completely closed throughout the year in the total *jalmohal.* Management actions included placing bamboo shelters and brushes in deeper parts of water bodies and employing paid guards. For the evaluation of the impact of the sanctuaries, there were no provisions. Under the project, the money from the lease was paid from the provision of the fund. The protection was inadequate and inefficient. Sometimes the same guards pampered themselves in illegal fishing. Although it was planned that the sanctuaries would be permanent continuing perpetually, after the period of the plan had ended, DoF could not pay the lease and the MoL took these bodies of water again and rented them. In 1987, with an area of 8,000 hectares, ten jalmahals were again declared sanctuaries under the Integrated Fisheries Development Project of the DoF. The procedure for establishing and administering these sanctuaries was the same as in the 1960s and the condition was also the same. Regulations related to the implementation of NBSAP: Bangladesh has a number of laws dealing with various aspects of environmental issues. The following are the major legal instruments related to biodiversity (IUCN, 2014):

• The Environment Conservation Act, 1995
• Environment Conservation Rules (ECR), 1997
• The Environment Court Act, 2000
• The Forest Act, 1927 (amendment in 1990, 2000)
• Protection and Conservation of Fish Act, 1950 (amendment in 1963, 1970m 1982m 1995, 2002)
• Protection and Conservation of Fish Rules, 1985 (amendment in 1987)
• Marine Fisheries Ordinance, 1983
• Agricultural Pesticide Ordinance, 1971
• The Fertilizer Regulation Order, 1995

The Fish Act 1950 provides regulations for:

> (i) restriction on capture size of some fish for a specific period, (ii) restriction on catch of any species for specific time or season, (iii) closure of fishing in any water body for any stipulated time period, (iv) restriction of fishing by dewatering or any other destructive method, (v) restriction on the use of any kind of gear and mesh size of net, and (vi) restriction on placing fixed engine in a water course, which may restrict fish migration.

Among all measures, it has been found that fish sanctuary is most effective for fish biodiversity conservation, while other measures are difficult to implement in the present administrative and social contexts. Fish sanctuary that is declared by the Government, fishing is prohibited there for all the times to come or for a specified period by law and order of competent authority mainly with the objective of conserving the fish biodiversity. The total number of permanent fish sanctuaries is 463, covering an area of 1,745 ha have been established in 98,405 ha water bodies by 2007 (Islam et al., 2016). A number of the sanctuaries have been closed at the end of the projects. Because of arising conflict of interests among the stakeholders, lack of funding and lack of coordination among the organizations, management has been deteriorated in many sanctuaries.

1.3.1 Hilsa fish sanctuary

Five sites on the Meghna and Padma rivers and some coastal marine areas have been declared as hilsa sanctuaries under the Protection and Conservation of Fish Act of 1950, intended for the conservation of jatka in the main nursery areas and maintenance of the Biodiversity of fish (Table. 3). To protect hilsa (*Tenualosa ilisha*) populations, shelters have been established on the Padma and Meghna rivers and coastal waters of Bangladesh since 2005. In particular, fish sanctuaries play an important role in protecting critical habitats and in the reduction effort of directed fishing during the spawning aggregations (Kincaid et al., 2014; Leleu et al., 2012). In sanctuaries, the prohibition of hunting jatka (hilsa <25 cm) during certain periods of the year is especially imposed. Depending on the occurrence of jatka the prohibition period differs in sanctuaries.

In order to prevent a decline in catches of hilsa, the Fisheries Department implemented the hilsa Fisheries Management Action Plan (HFMAP) in 2003. In particular, the hilsa decline was halted between 2002 and 2003. For this subject, the Government of Bangladesh declared four areas as Hilsa in 2005 and one fifth in 2011 that helped to significantly increase the production of hilsa (Islam et.al, 2016) (Table 3). There are clear indications that the establishment of sanctuaries has succeeded in reducing the decline in the hilsa population, as reflected in the higher catch level of total hilsa production in both the inland and marine waters of Bangladesh (FRSS, 2014; Mohammed and Wahab, 2013). However, there are no studies that have explored the impacts of the ban on fishing on the general biodiversity of fish and shell fish in within and outside the hilsa sanctuaries in Bangladesh.

Table 3 : Hilsa sanctuaries in Bangladesh (adopted from IUCN, 2011)

Hilsa fish sanctuary area	**Ban period**
From Shatnol of Chandpur district to char Alexander of Lakshmipur (100 km of lower Meghna estuary)	March to April
Madanpur/Char Ilisha to Char in Bhola district (90 km area of Shah Bajpur river, a tributary of the Meghna)	March to April
Bheduria of Bhola district to char Rustam of Patuakhali district (nearly 100 km area of Tetulia river)	March to April
Whole 40 km stretch of Andharmanik river in Kalapara upazila of Patuakhali district	November to January
20 km stretch of lower Padma river between Shariatpur in the north and Chandpur and Shariatpur in the south	March to April

1.4 Conservation status of Fishes in Bangladesh

For conservation purposes in 2000, the IUCN Country Office in Bangladesh, with the support of the IUCN Global Office, published the first Red Data Book in Bangladesh. In that book, a total of 895 species (including 266 species of freshwater fish) were evaluated. Among them, there were 54 threatened species of fish. In Bangladesh, the IUCN Red Papers are widely consulted by the government, nongovernmental organizations and practitioners in the country and, in many ways, effectively guide the country's conservation policies and initiatives for fish conservation. In the latest Bangladesh Red List Assessment, there have been changes in threat levels as human activities have increased tremendously, while some efforts have been made to protect some species. The previous Red List is also obsolete, as several new species have been explored in recent times. All these demanded the Updating Species Red List in Bangladesh. The freshwater fish species are no exception to this. Therefore, there was an urgent need for Bangladesh to reassess the situation of freshwater fish. The red categories of IUCN are shown in figure.2.

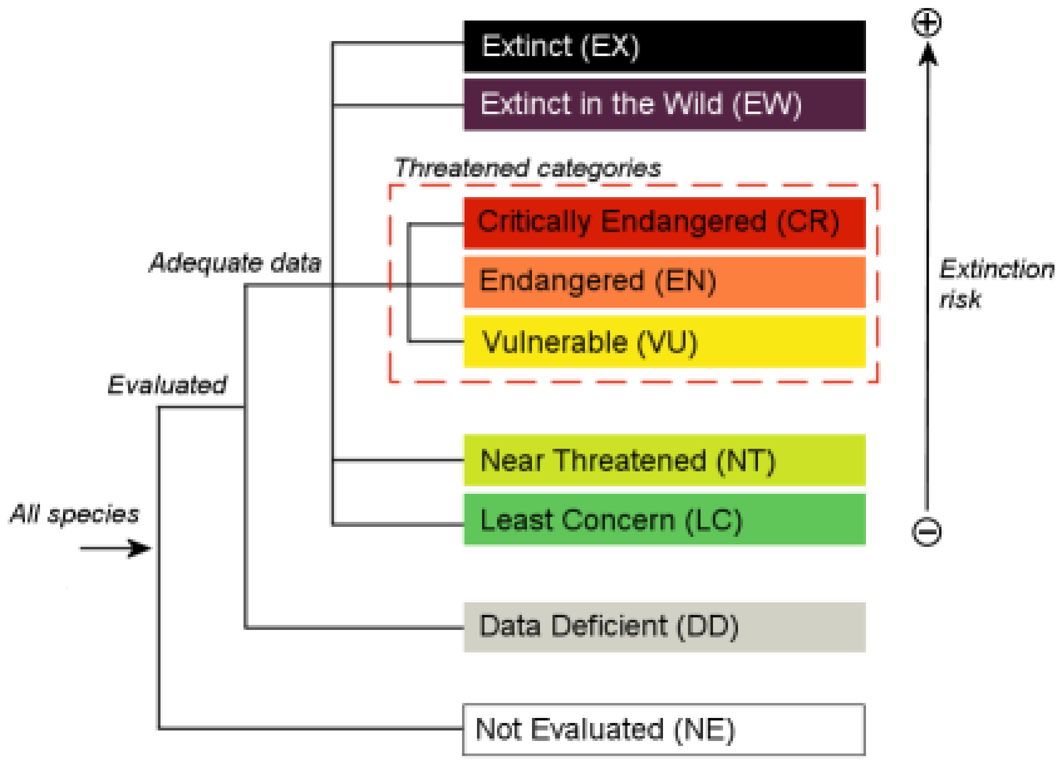


Figure 2 : Red List categories (Regional/National Level) (IUCN 2012).

1.5 Research gap

Fishing ban, whether permanent, seasonal or temporary, is applied to protect target species, limit catches of undersized fish or control specific gear in many fishery management (Ward et al., 2001). Fish sanctuaries are mainly essential to protect critical habitat and reduce excessive fishing effort in spawning accumulations (Kincaid et al., 2014; Leleu et al., 2012). Hilsa shad (*Tenualosa ilisha*) contributes as the largest single species fishery of Bangladesh in terms of catch weight and employment (Islam et al., 2016). It contributes with 11% of the total catch of fisheries, employments for 0.5 million fishermen directly and another 2 million people indirectly, and about 1% to GDP (BOBLME, 2012; Mohammed and Wahab, 2013) which comes after establishing hilsa fish sanctuary. Anadromous hilsa species migrate from the open sea (i.e. the Bay of Bengal) into inland freshwater system, primarily the Meghna, Tetulia and Andermanik

Rivers to spawn (Hossain et al., 2014; Rahman et al., 2014) and gradually develop into juveniles (locally known as 'jatka'). The application of the fishing ban at the time of its spawning period helps to mature the juvenile hilsa. In this way the hilsa biodiversity is protected in the sanctuary area. A 2006 MACH Technical Report has reported that increases in fish catches during the period 2000-2005 indicate the positive impact of sanctuaries in wetlands along with other management interventions such as excavation, seasonal closure of the fishing, and the reduction in the use of destructive fishing by the current *jal* (Ali, et al., 2006). The catch of hilsa has gradually declined significantly since 1970 due to the high market price. For this reason, policymakers and the Government of Bangladesh have adopted some management activities through the development of the hilsa sanctuary. The hilsa production of fish reached 34.0000 MT in 2010-2011 FY (Wahab et al., 2013). In the base year (1991-1992), total hilsa production was 188,460 metric tons from both inland and marine sources (FRSS, 2012). Although the hilsa production rate was not stable over the period of time, total hilsa production increased dramatically (Wahab et al., 2013). An investigation into the impact of the fifteen-day fishing ban on the main spawning grounds of hilsa on its reproductive success was published in 2015 (Rahman et al., 2015), which shows only the 15-day fishing ban in Spawning hilsa. Another research paper on community based fish sanctuaries was published in 2014 (Mustafa, 2014). This document has only worked for the improvement and protection of inland fisheries. This paper does not show the effects of prohibiting fishing on global fish biodiversity by comparing in and out of hilsa fish sanctuary areas. There are also few research publications on fish biodiversity in inland water bodies in Bangladesh. Rahman et al. (2012), in this study it was analyzed that the biodiversity of the fish and the main threats to the biodiversity to provide recommendations for the conservation in the river Padma. This study only works on the Padma river; there is a large scope to work in sanctuary areas and to estimate the effects of prohibition on fish biodiversity in those areas. There are also few works on the Meghna River, such as a study to evaluate the status of fish diversity in relation to the main hydrological and meteorological parameters in both spatio-temporal scales. But there are no such types of research work in sanctuary areas related to banning fish. According to Mohsin et al. (2014), the fish fauna and its seasonal abundance have been studied in the Andharmanik River of the Patuakhali district. In the research work Hanif et al. (2015), this study has only evaluated the threat of fish diversity and its conservation recommendations. This study was only estimating the abundance of fish that did not find the impact of the fishing ban. If we look at the research work abroad there are some types of research work already done, but not done in our country. According to Sarkar et al. (2012), this study was conducted to assess the biodiversity of fish inside and outside a protected river area, and to assess whether the protected river area offers some benefits to the biodiversity of riverine fish Gerua River in India. But this type of study still does not work in our country. Therefore, it is necessary to carry out this type of research work in our country. According to Consoli et al. (2013), this study aimed to investigate the early effects of protection measures in the fish assembly in the Plemmirio marine reserve and to evaluate its level of implementation. But there are no such suspect types of study in Bangladesh. Alan et al. (2001) evaluated the impact of limited domestic ranges and the high degree of habitat specificity in many ornamental marine fish that make marine reserves a highly effective strategy for managing these resources. Most published articles dealing with the evaluation of the effects of MPAs on only commercial fish at sea compare one protected with an unprotected site (e.g. Bell, 1983; Dufour et al., 1995; Harmelin et al., 1995). Other authors (e.g. Francour, 1994) used unbalanced sampling designs replicating locations partially protected, but sampling a single integrally protected and unprotected location for each of the habitat types examined. Overviewing most studies on fish biodiversity there is no clear evidence of impacts of fishing ban on fish biodiversity in sanctuaries comparing to control area. However, impacts of fishing ban have not yet been systematically evaluated on overall fish biodiversity in the sanctuaries. Although fisheries sanctuaries are considered to be an effective management tool for protecting the habitat of *Tenualosa ilisha*, there are no studies that whether or not the hilsa sanctuaries work as an effective management tool to protect the other fish biodiversity by protecting their habitat. So, effects of fishing ban on overall fish biodiversity in sanctuary area. A study was carried out by the Global Environmental Fund about the impact of the jatka fishing ban. The study revealed that an estimated 45% increase in hilsa landing at four major landing sites could be achieved through restriction of jatka fishing. From the previous study it was also evident that effective measures of application at critical sites and during the critical hilsa breeding period could significantly contribute to increasing the production and maintenance of biodiversity (Haldar, 2004). Therefore, it is shown that hilsa sanctury with ban fishing has a positive impact on hilsa production. It is necessary to assess how the impacts of the fishing ban on the overall fish biodiversity. For evaluating this ban impact there is needed a comparison between sanctuary and control areas in Bangladesh to estimate the impact of fishing ban on overall fish biodiversity. Therefore, this study has been conducted to assess the impacts of fishing ban on Shariatpur and Chandpur hilsa fish sanctuary. This study will help to estimate the fish ban impact on fish biodiversity and their abundance and also help to identify the richness, evenness and composition of fish biodiversity in sanctuary and control area. So, it is needed to be studied the fish ban impact on fish biodiversity.

1.6 Study aim and objectives

The aim of this study was to assess the impact (s) of fishing ban on fish biodiversity in hilsa sanctuaries in Bangladesh. The objectives of this study were to-

I. estimate species composition and the temporal and spatial abundance of fish and shell fish communities within and outside the two hilsa sanctuaries;

II. estimate the biodiversity, richness and evenness indices of fish and shell fish communities within and outside the two in hilsa sanctuaries;

III. assess the conservation status of fish within and outside the two in hilsa sanctuaries in Bangladesh;

IV. evaluate the impact (s) of fishing ban by comparing the various indices and conservation status within and outside the two hilsa sanctuaries;

Chapter 2 –Materials and Methods

This chapter contains the research methodology of the study including study area selection, sample size determination, research design, methods for data collection, data processing and analysis (Figure 3).

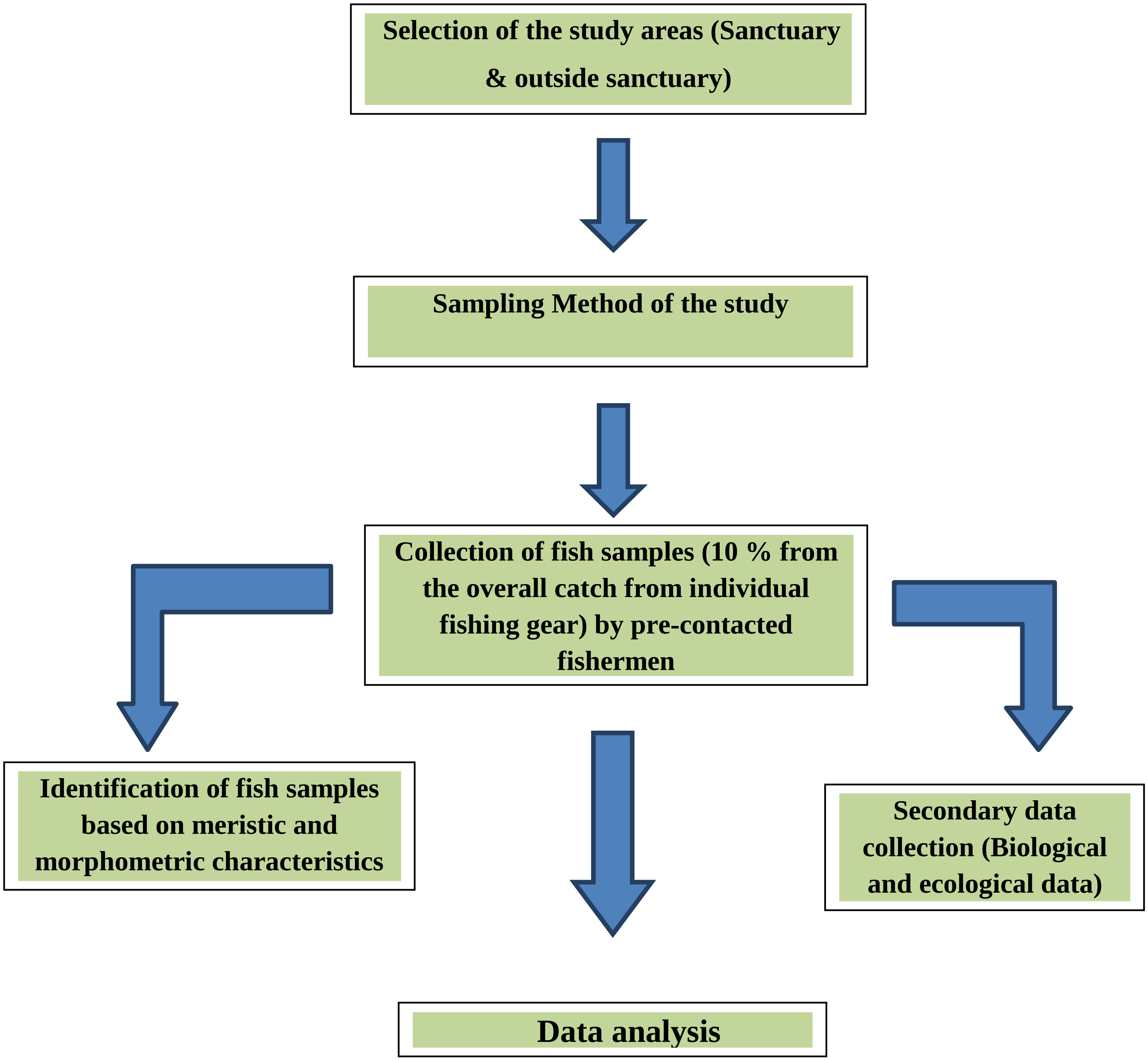


Figure 3 : Overall methodology followed for this study.

2.1 Selection of the study sites

The present study was conducted within and outside the two-hilsa sanctuaries in the two major rivers in Bangladesh, namely, the Padma and the Meghna river. Four fish landing sites were selected to collect the fish catch data of which one landing station was within each sanctuary area and the one outside the sanctuary area in the same river. Four study sites including two major rivers are shown in figure 4.

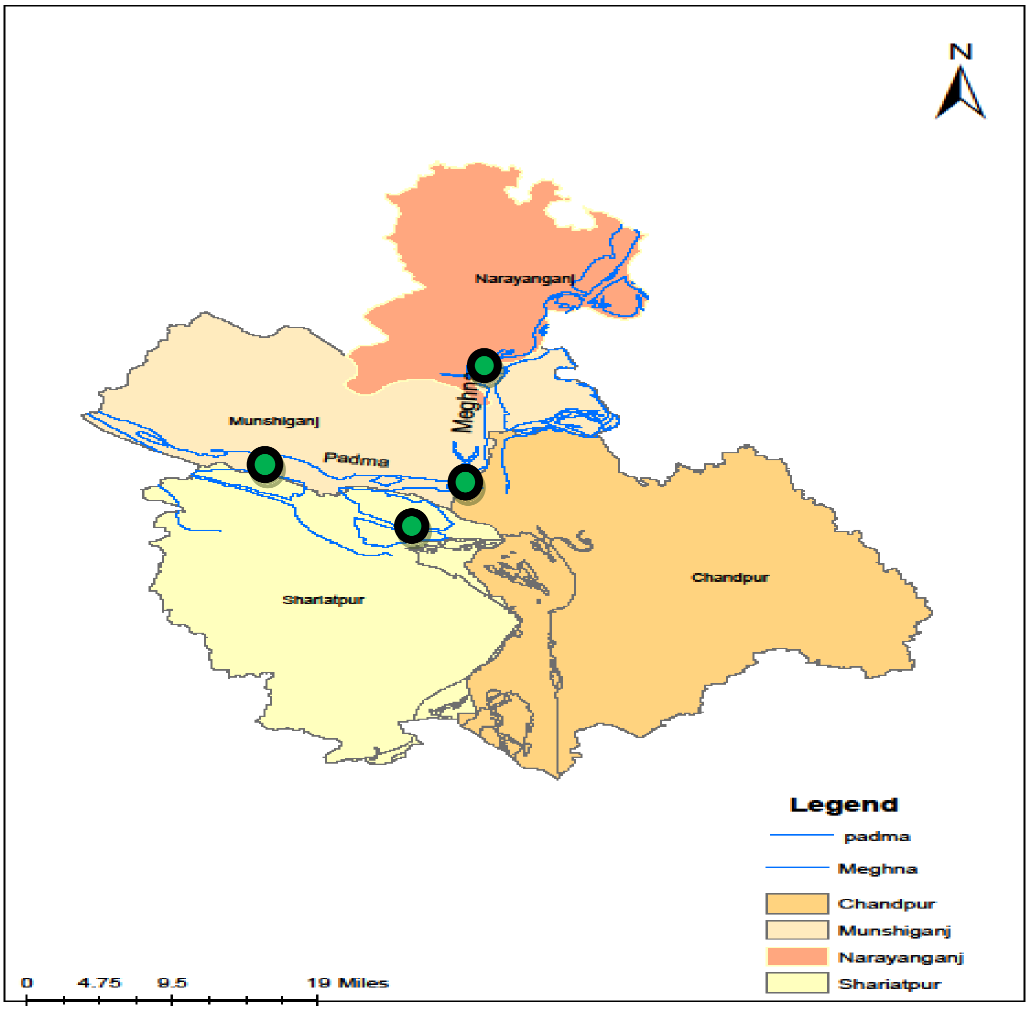


Figure 4 : Four study sites (within and outside sanctuaries) in Bangladesh are marked by green circle.

The landing sites within the sanctuaries were located close to the middle of the respective sanctuaries to ensure the fish landed were collected within the sanctuary areas. The stations outside the sanctuaries were more than 10 km upstream from the border of the respective sanctuaries but near enough to have similar habitat characteristics. Before selection of the specific landing stations information on type of fish, fishing area of the fishing boats landed, diversity, fishing gears in multiple landing stations were collected through key informant interviews with Upazila Fisheries Office, NGO workers, *arotdars* (the fish marketing middleman). Then the stations were selected based on the following criteria:

a) Landing of fish caught only within the respective target area;

b) Presence of catch landings by multiple gears covering all layers and parts of river channel;

c) Regularity of fish landings; and

d) Convenience for sampling operation

The selected fish landing sites were as below:

Within Sanctuary areas (temporal fishing ban implemented)

1. Bahariya Market in Chandpur receiving the fish caught within the Meghna river sanctuary (S_1)

2. Chairman Station, Bhedorganj in Shariatpur receiving the fish caught within the Padma river sanctuary (S_2)

Outside the sanctuary areas (considered as control area without any fishing ban)

1. Boidder bazar, Meghna ghat in Narayanganj receiving the fish caught outside the Meghna river sanctuary (O_1)

2. Maowa ghat, Louhojong upazila in Munshiganj receiving the fish caught outside the Padma river sanctuary (O_2)

2.1 Sampling method

2.1.1 Sample collection

Fish samples were collected from the selected landing centers from previously contacted fishers that were gear specific during pre-monsoon (June), monsoon (August) and post monsoon (October). Local fishers were solicited not to throw the non-target species by explaining the implication of both target and non-target species for this study. 10% of the total catch for each type of gear landed on were collected as sample following Mohsin et al. (2013). The collected samples were immediately stored in insulated box with sufficient ice for identification in laboratory. The local names of the fish in each sample were recorded on the spot upon discussion with the local fishers. Some fishing gears are represented in figure 5.

Figure 5 : Fishing mechanism by using different types of gear.

2.1.2 Identification of fish species

In the laboratory, the samples were identified to species level based on the morphometric and meristic characteristics following Shafi and Quddus (1982) and Rahman, (1989) (Appendix-1).

2.1.3 Biological and ecological data collection

For this study we collected various types of secondary data from various research articles and different types of books. The habitat type, dietary habits and the conservation status of each identified fish and shellfish species were also recorded following, Shafi and Quddus, (1982); Ataur Rahman, (1989) and the IUCN Red List, (2015).

2.2 Data analysis

Several methods were used to evaluate the diversity, richness and evenness (uniformity) of fish and shellfish species.

To estimate diversity and evenness (uniformity) of fish and shellfish species, the Shannon - Wiener diversity index (1949) was used. The Margalef's index (1958) was used to calculate species richness. The total H-value indicates the presence of a wide range of species. Species richness, evenness and biodiversity were calculated using Excel to estimate the impacts of the fishing ban on fish diversity in sanctuary and control areas. All types of data analyzes and graphical analyzes were also performed using Microsoft excel-2010.

2.2.1 Estimation of species richness

The total number of species present in per sample is a measure of richness. The more species present in a sample, the "richer" the sample will be. Richness of species as a measure alone does not take into account the number of individuals of each species present. It gives as much weight to those species that have very few individuals as those that have many individuals.
Margalef's index was used as a simple measure of species richness (Margalef, 1958).

$$\text{Margalef's index, } d = (S - 1) / \ln N \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

S = total number of species

N = total number of individuals in the sample

In = natural logarithm

The species richness was calculated by extracting 1 from the total number of species (S-1), and then the value was divided by multiplying the total number of individuals in the sample by natural logarithm. The more species present in a sample, the 'richer' the sample.

2.2.2 Calculation of diversity indices

Shannon – Wiener diversity index

The diversity index was calculated by using the Shannon – Wiener diversity index (1949) using the equation 1.

$$H = - [\sum Piln\ Pi] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, Pi = S / N

H=……………………

S = number of individuals of one species

N = total number of all individuals in the sample

In = natural logarithm

The larger value of H represents higher diversity status. Therefore, the greater the number, the more diversity. There is no mathematical reason why the logarithmic value has to be the natural log as compared to log10 or log2, but there is a movement to standardize the value so that the scientific community can communicate effectively (Magurran, 2004). It is easy to see that the greater the number of species (S), the greater the Shannon index (H).

2.2.3 Estimation of evenness

Evenness is a measure of the relative abundance of the different species making up the richness of an area. Shannon's equitability (E_H) can be calculated by dividing H by can be calculated by

$$E_H = H / H_{max} = H / \ln (S) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

H = Shannon – Wiener diversity index

S = total number of species in the sample

Equitability assumes a value between 0 and 1.

The evenness of the species varies from zero to one, with zero meaning no evenness and one, a complete evenness.

Chapter 3 – Results

3.1 Community compositions

3.1.1 Fish and shell fish species composition under different families and orders

Total composition of fish and shell fish species

A total of 77 fish species belonging to 31 families and 11 orders and also with 10 shell fish (shrimp/ prawn) species in 2 families (Penaeidae and Palaemonidae) under the order Decapoda were recorded from the four study areas (two sanctuary and two outside sanctuary area) during the overall study period Cyprinidae (21 species), was the most dominant family constituting (27.27 %) of the total fish population followed by the family Bagridae (9.09 %) and Gobidae (6.49%). A total of 20 families including Aplocheilidae, Mugilidae, Cobitidae, Notopteridae and so on were the least numerous families, constituting only 1.3 % each of the total fish composition (Figure 6) (Appendix-2) .The identified fish and shell fish species were shown in figure 7 (Appendix-2) .

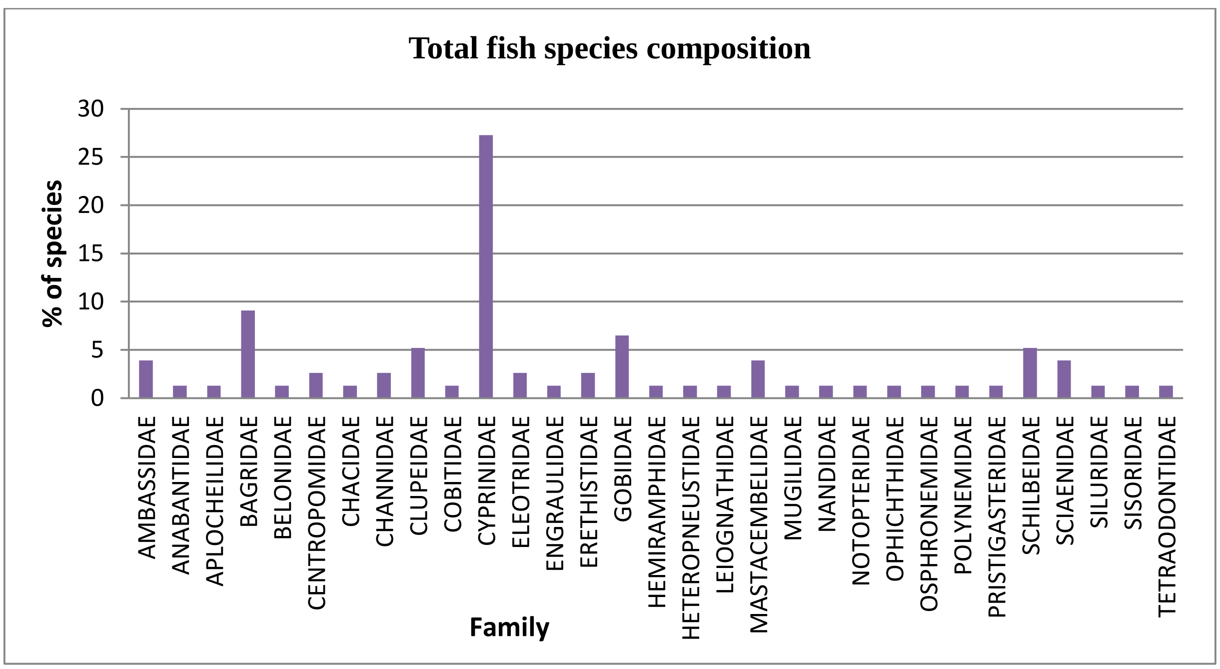


Figure 6 : Overall fish composition under different families contributing the highest percentage in Cyprinidae family during overall time period.

Tetraodon cutcutia
(Hamilton, 1822)

Amblypharyngodon mola
(F. s Hamilton, 1822)

Puntius sophore
(Hamilton, 1822)

Megarasbora elanga
(Hamilton, 1822)

Hyporhamphus limbatus
(Valenciennes, 1847)

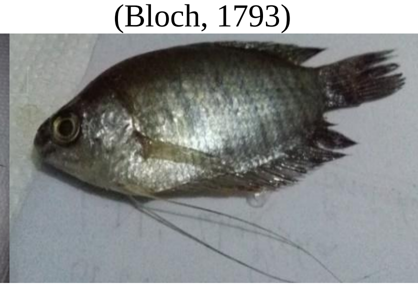
Xenentodon cancila
(Hamilton, 1822)

Mastacembelus pancalus
(Hamilton, 1822)

Channa punctatus
(Bloch, 1793)

Aspidoparia morar
(Hamilton, 1822)

Polynemus paradiseus
(Linnaeus, 1758)

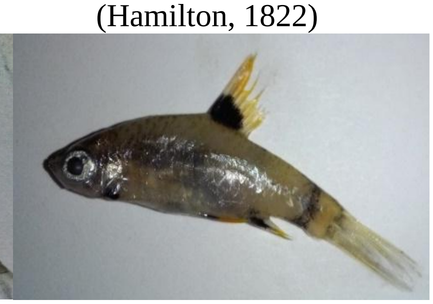


Trichogaster labiosu
(Hamilton, 1822)

Pethia conchonius
(Hamilton, 1822)

Botia dario
(Hamilton, 1822)

Ailia coila
(Hamilton, 1822)



Pethia gelius
(Hamilton, 1822)

Figure 7 : Identified fish species from four different study sites (rests are given in appendix - 2)

In terms of shell fish species, the highest percentage (80%) was recorded in Palaemonidae family and the lowest (20%) was in the family of Penaeidae (Figure 8) (Appendix-2).

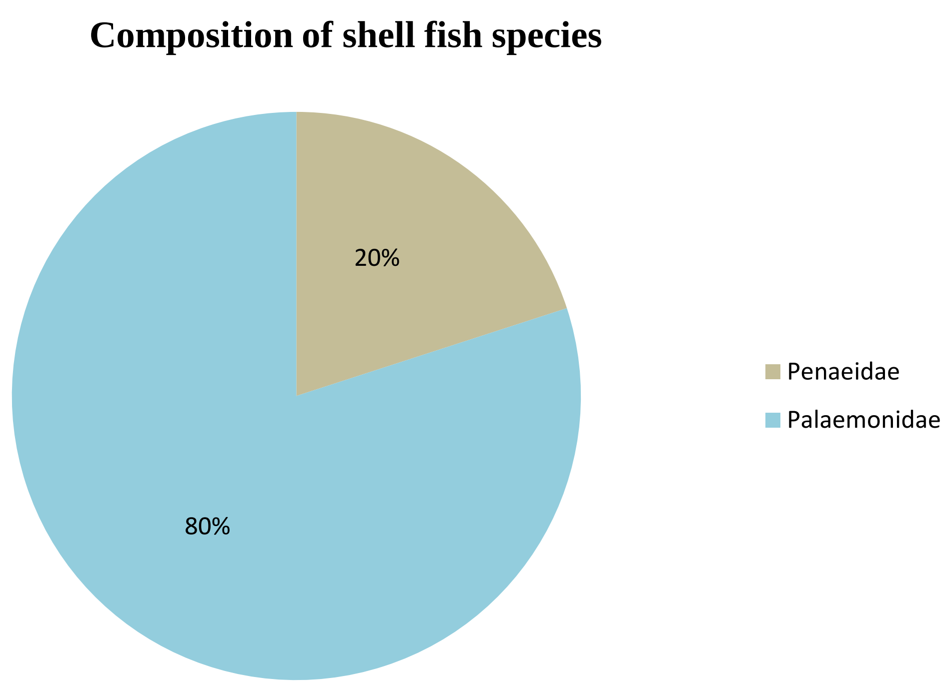


Figure 8 : Total composition of shell fish species under two families contributing the highest percentage in Palaemonidae family in overall time period.

On the other hand, according to different orders, Cypriniformes and Perciformes were the most dominant orders contributing 28.05% among the total fish population whereas, a total of 5 orders were the least contributing 1.3% each in total fish population (Figure 9) (Appendix -2).

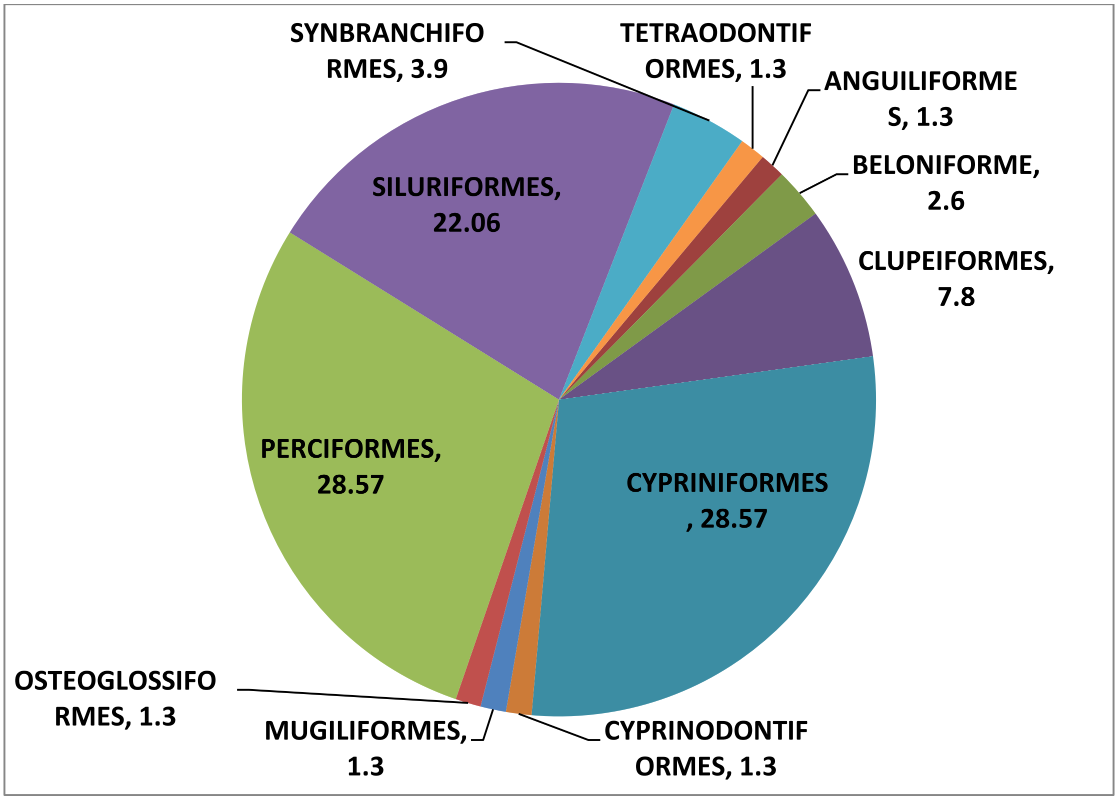


Figure 9 : Total fish species composition under different orders where the order Cypriniformes and Perciformes were contributing the maximum percentage of species in overall time period.

Site wise fish species composition

Cyprinidae the most dominant family in each study sites was recorded in this study in overall time period. The maximum percent composition of fish species was 33.33% under the family of Cyprinidae in Munshiganj (O_2) among the four study sites. In contrast the minimum (1.96%) was recorded in Narayanganj (O_1) and Munshiganj (O_2) under numerous families including Anabantidae, Belonidae, and Chacidae and so on (Table 4) So, among all the sites the maximum diversified groups of fish species were belonging to the Cyprinidae family (Figure 10).

Table 4 : Site wise (within sanctuary and outside sanctuary) fish species composition under different families

Family	% of fish species			
	S_1 (Chandpur)	**S_2 (Shariatpur)**	**O_1 (Narayanganj)**	**O_2 (Munshiganj)**
AMBASSIDAE	5.405405	3.030303	3.921569	3.921569
ANABANTIDAE	0	3.030303	1.960784	0
APLOCHEILIDAE	0	0	0	1.960784
BAGRIDAE	2.702703	0	11.76471	7.843137
BELONIDAE	2.702703	3.030303	1.960784	1.960784
CENTROPOMIDAE	5.405405	0	0	0
CHACIDAE	0	0	1.960784	0
CHANNIDAE	5.405405	6.060606	0	1.960784
CLUPEIDAE	8.108108	3.030303	7.843137	3.921569
COBITIDAE	2.702703	0	3.921569	3.921569
CYPRINIDAE	21.62162	18.18182	11.76471	33.33333
ELEOTRIDAE	2.702703	3.030303	5.882353	1.960784
ENGRAULIDAE	0	3.030303	0	0
ERETHISTIDAE	0	0	0	1.960784
GOBIIDAE	10.81081	9.090909	7.843137	3.921569
HEMIRAMPHIDAE	0	0	1.960784	1.960784
HETEROPNEUSTIDAE	2.702703	0	1.960784	0
LEIOGNATHIDAE	2.702703	0	1.960784	1.960784
MASTACEMBELIDAE	2.702703	6.060606	5.882353	3.921569
MUGILIDAE	2.702703	3.030303	1.960784	1.960784
NANDIDAE	2.702703	3.030303	1.960784	1.960784
NOTOPTERIDAE	2.702703	0	1.960784	0
OPHICHTHIDAE	0	0	0	1.960784
OSPHRONEMIDAE	2.702703	3.030303	1.960784	1.960784
POLYNEMIDAE	0	3.030303	1.960784	0
PRISTIGASTERIDAE	0	3.030303	1.960784	0
SCHILBEIDAE	2.702703	15.15152	5.882353	9.803922
SCIAENIDAE	2.702703	9.090909	3.921569	1.960784
SILURIDAE	2.702703	0	3.921569	1.960784
SISORIDAE	2.702703	3.030303	1.960784	1.960784
TETRAODONTIDAE	2.702703	3.030303	1.960784	1.960784

N.B.: S = Within sanctuary and O = Outside sanctuary

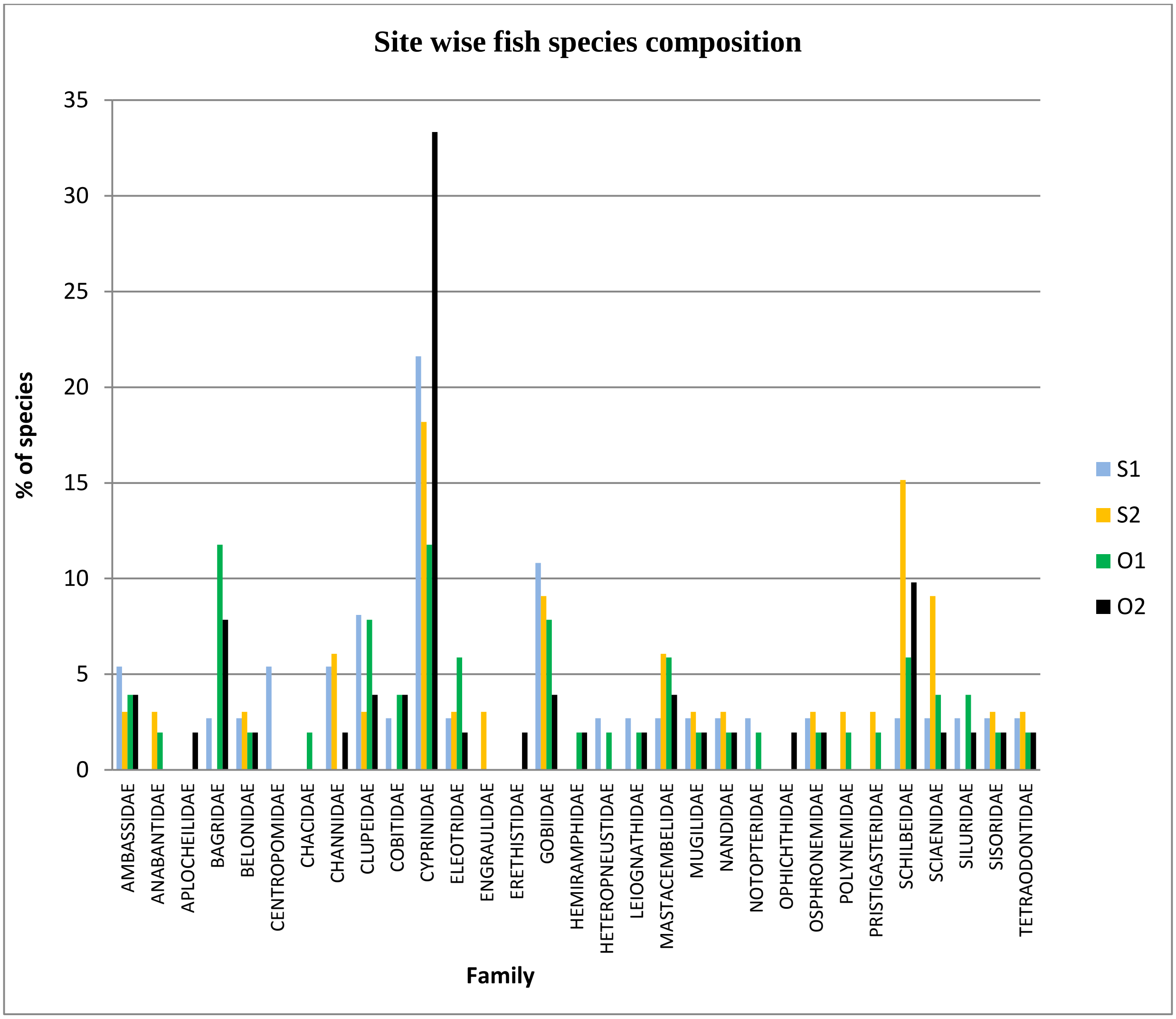


Figure 10 : Site wise fish species composition under different families contributing highest percentage in Cyprinidae family in Munshiganj (O_2).

Time wise fish species composition

The maximum percentage of fish species in this study, 72.35% was recorded during October and the lowest 2.38% was recorded both on the month of June and August (Table 5). The most diversified groups were belonging to the family Cyprinidae and in contrast the less diversified groups were belonging to many different families. So, Cyprinidae was the most dominant family in each study period (Figure 11).

Table 5 : Time wise fish species composition under different families

Family	% of fish species		
	June	**August**	**October**
AMBASSIDAE	7.142857	4.651163	10.33592
ANABANTIDAE	7.142857	2.325581	5.167958
APLOCHEILIDAE	0	0	0
BAGRIDAE	0	4.651163	10.33592
BELONIDAE	2.380952	2.325581	5.167958
CENTROPOMIDAE	7.142857	0	0
CHACIDAE	2.380952	0	0
CHANNIDAE	4.761905	4.651163	10.33592
CLUPEIDAE	7.142857	6.976744	15.50388
COBITIDAE	2.380952	0	0
CYPRINIDAE	14.28571	32.55814	72.35142
ELEOTRIDAE	2.380952	4.651163	10.33592
ENGRAULIDAE	0	0	0
ERETHISTIDAE	0	0	0
GOBIIDAE	7.142857	4.651163	10.33592
HEMIRAMPHIDAE	0	2.325581	5.167958
HETEROPNEUSTIDAE	2.380952	2.325581	5.167958
LEIOGNATHIDAE	2.380952	2.325581	5.167958
MASTACEMBELIDAE	7.142857	4.651163	10.33592
MUGILIDAE	2.380952	2.325581	5.167958
NANDIDAE	2.380952	2.325581	5.167958
NOTOPTERIDAE	0	0	0
OPHICHTHIDAE	0	0	0
OSPHRONEMIDAE	2.380952	2.325581	5.167958
POLYNEMIDAE	0	2.325581	5.167958
PRISTIGASTERIDAE	0	0	0
SCHILBEIDAE	7.142857	6.976744	15.50388
SCIAENIDAE	4.761905	2.325581	5.167958
SILURIDAE	2.380952	0	0
SISORIDAE	0	2.325581	5.167958
TETRAODONTIDAE	2.380952	0	0

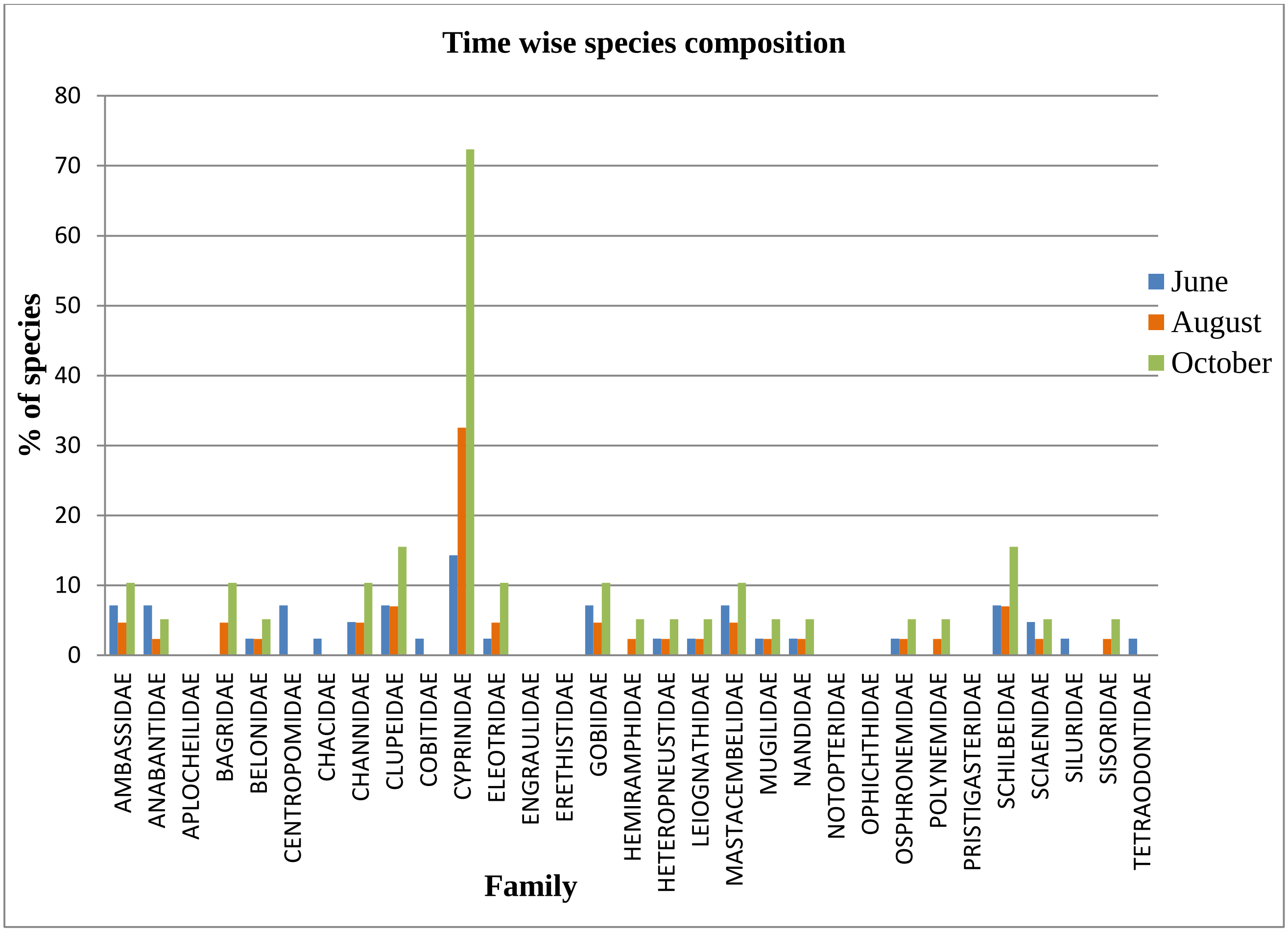


Figure 11 : Fish species composition under different families contributing the highest percentage in October in Cyprinidae family.

3.2 Composition of fish species within sanctuaries and outside sanctuaries

The maximum percentage of fish species composition (25.00%) was recorded in this study under the family of Cyprinidae and the minimum was 1.47% under the families of Aplocheilidae, Anabantidae, Chacidae and so many in outside sanctuaries (Table 6).But in sanctuaries the highest percentage (18.18%) was found in Cobitidae family and the lowest was in so many families. Comparing between within and outside sanctuaries the highest percentage (25.00%) of fish species was found in outside sanctuaries under the family of Cyprinidae (Figure 12).

Table 6: Composition of fish species showing the highest percentage in outside sanctuaries comparative to within sanctuaries under different families.

Family	% of fish species	
	Sanctuaries (S_1 & S_2)	**Outside sanctuaries (O_1 & O_2)**
AMBASSIDAE	5.454545	2.941176
ANABANTIDAE	1.818182	1.470588
APLOCHEILIDAE	7.272727	1.470588
BAGRIDAE	1.818182	8.823529
BELONIDAE	1.818182	0
CENTROPOMIDAE	1.818182	0
CHACIDAE	3.636364	1.470588
CHANNIDAE	7.272727	1.470588
CLUPEIDAE	1.818182	5.882353
COBITIDAE	18.18182	2.941176
CYPRINIDAE	1.818182	25
ELEOTRIDAE	1.818182	4.411765
ENGRAULIDAE	7.272727	0
ERETHISTIDAE	1.818182	1.470588
GOBIIDAE	1.818182	7.352941
HEMIRAMPHIDAE	5.454545	2.941176
HETEROPNEUSTIDAE	1.818182	1.470588
LEIOGNATHIDAE	1.818182	1.470588
MASTACEMBELIDAE	1.818182	4.411765
MUGILIDAE	1.818182	1.470588
NANDIDAE	1.818182	1.470588
NOTOPTERIDAE	1.818182	1.470588
OPHICHTHIDAE	7.272727	1.470588
OSPHRONEMIDAE	3.636364	1.470588
POLYNEMIDAE	1.818182	1.470588

PRISTIGASTERIDAE	1.818182	1.470588
SCHILBEIDAE	1.818182	5.882353
SCIAENIDAE	1.818182	2.941176
SILURIDAE	0	2.941176
SISORIDAE	0	1.470588
TETRAODONTIDAE	0	1.470588

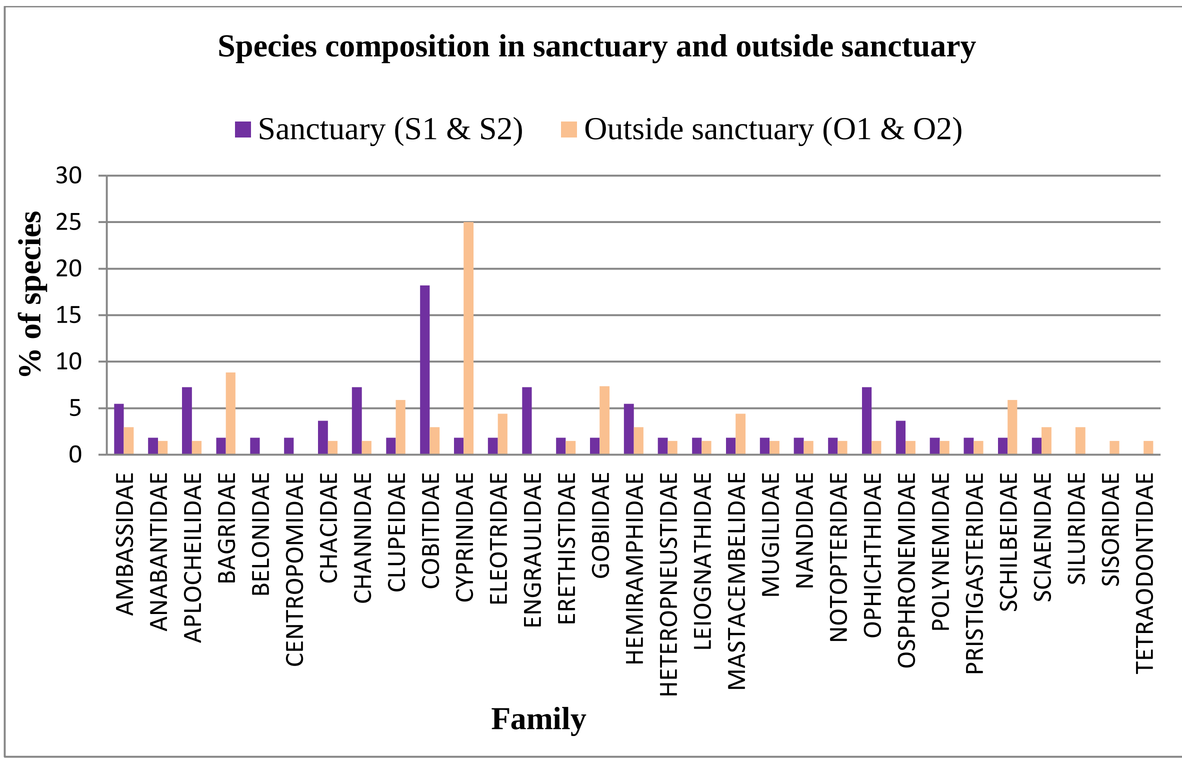


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Figure 12 : Fish species composition showing the highest percentage in outside sanctuary in Cyprinidae family under different families.

3.1.2 Composition of fish individuals based on habitat type

In this study four types of habitat were found among the fish species: freshwater, freshwater-estuary, freshwater-marine- estuary and marine water- estuary. Among the four types of habitat the individuals of freshwater-estuarine habitat was the highest dominant habitat comprising

(77.90%). Nearest dominant habitats were freshwater and freshwater-estuarine-marine comprising 41.40 % and 36.50 % respectively (Figure 13). The least dominant habitat was marine water- estuary comprising 1.50% (Appendix-3). In overall study period, it was found that the numbers of freshwater-estuarine fish species are high in number whereas the marine water-estuarine fish species are low in number. During the overall time period habitat composition (freshwater-estuary) was high in Chandpur and Shariatpur and low in Narayanganj and Munshiganj in overall time period.

It was recorded that highest percentage of freshwater-estuarine species was recorded in outside sanctuaries (66.00%) than that of within sanctuaries (50. 60%) (Figure 14).So, the numbers of individuals of freshwater-estuarine habitat were dominant in sanctuary areas.

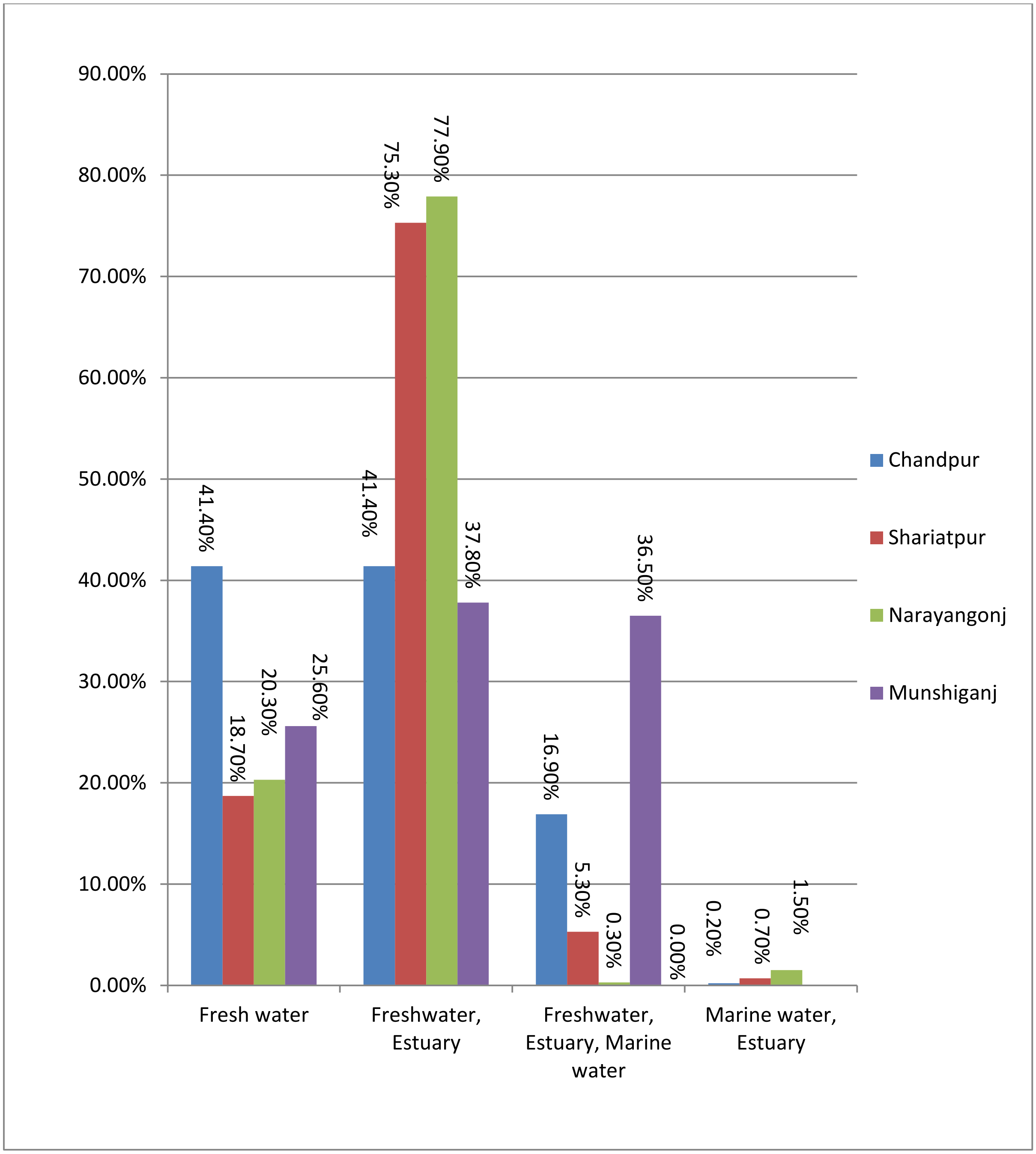


Figure 13 : Composition of fish individuals based on their habitat type showing the maximum percentage of freshwater-estuarine fishes among the four study sites.

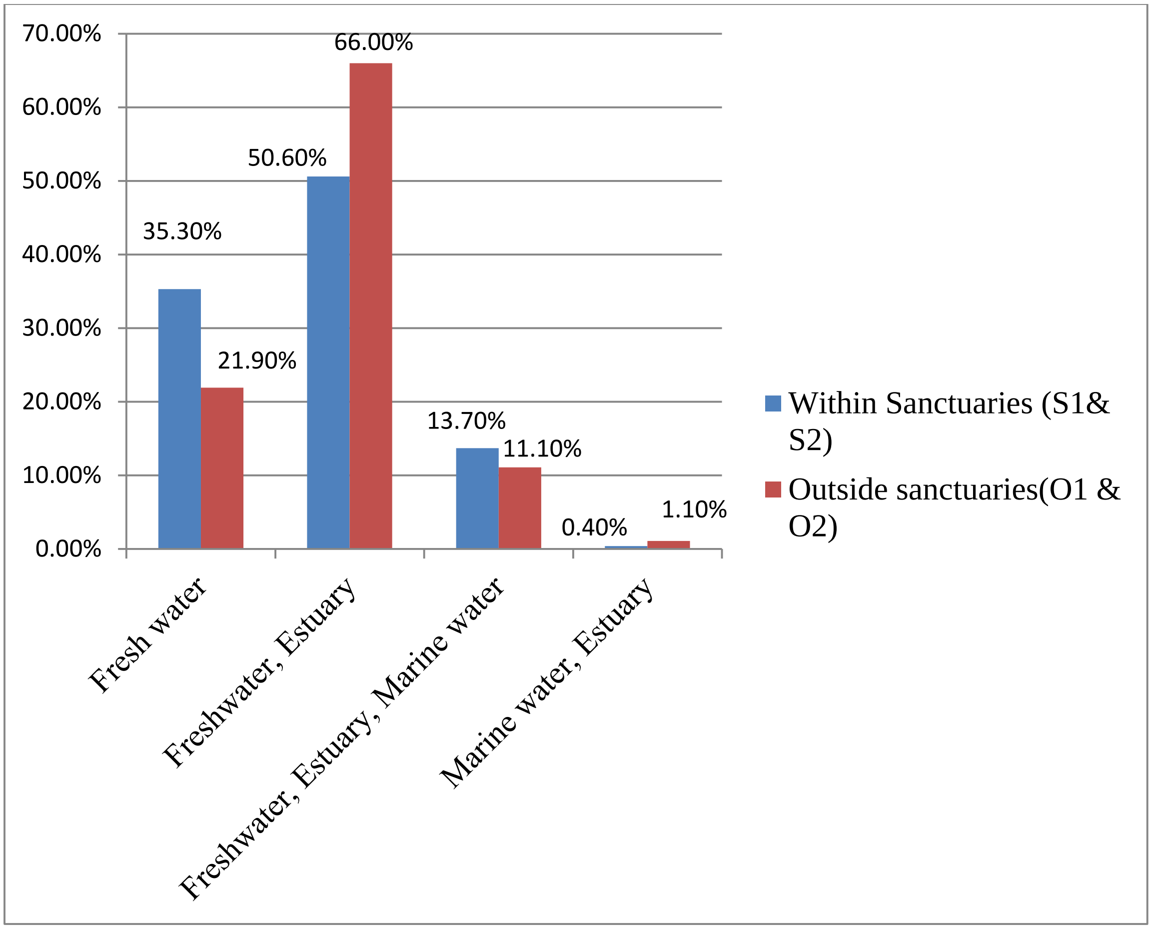


Figure 14 : Composition of fish individuals based on habitat type showing highest percentage in outside sanctuaries than within sanctuaries.

3.1.3 Composition of fish individuals based on their feeding habit

In this study, the identified species were categorized into three different types of feeding habit; herbivorous, carnivorous and omnivorous. Herbivorous fishes were dominating in three sites (Chandpur, Narayanganj and Munshiganj) among the four (except Shariatpur). In Shariatpur, where omnivorous fishes were the dominating group (Figure 15).

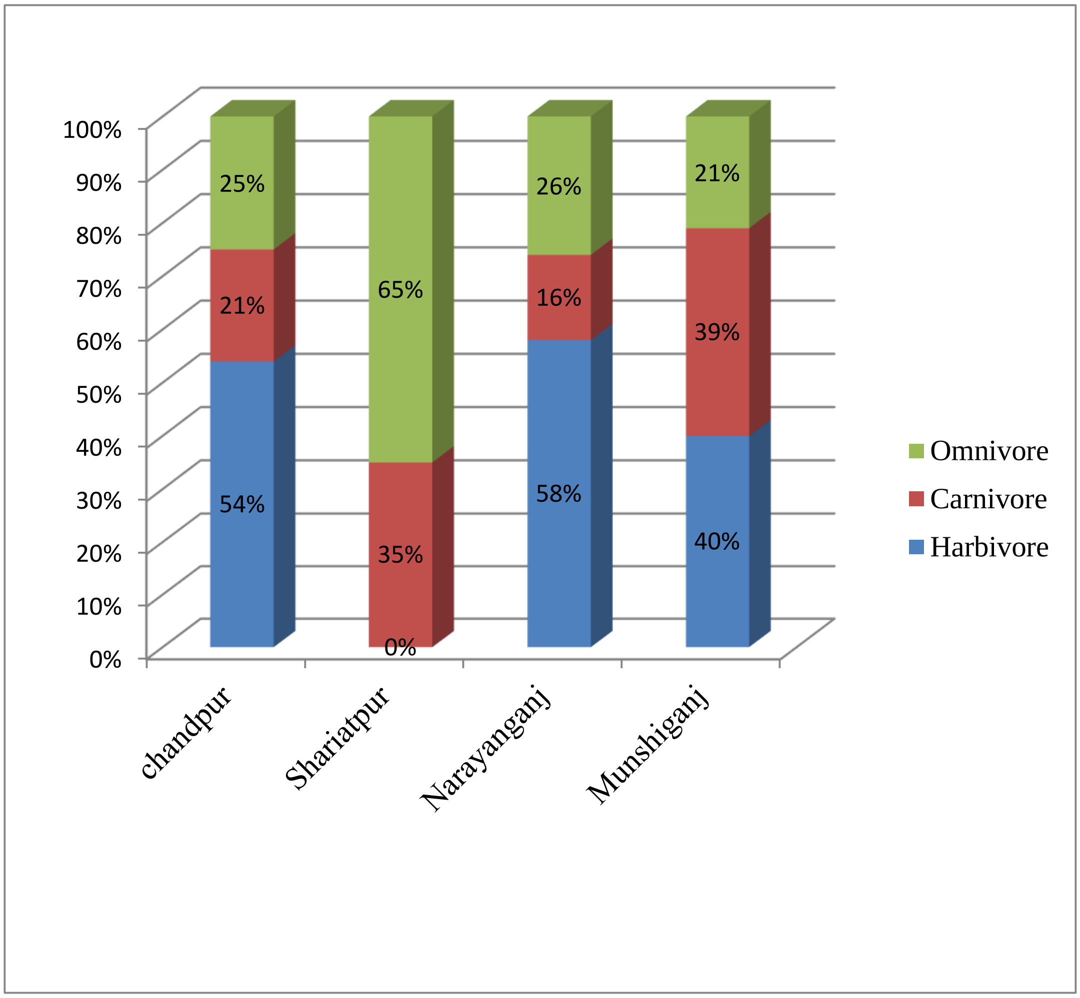


Figure 15 : Composition of fish individuals based on their feeding type, showing the highest percentage of omnivorous fishes in three study sites except Shariatpur where carnivorous fishes were dominant.

In relation between, within and outside sanctuaries the highest percentage of herbivorous omnivorous fishes were recorded in outside sanctuaries (O_1 & O_2) whereas the lowest were observed in within sanctuaries (S_1 & S_2).On the other and, carnivorous fishes were found high within sanctuaries and low in outside sanctuaries (Figure 18) (Appendix-3).

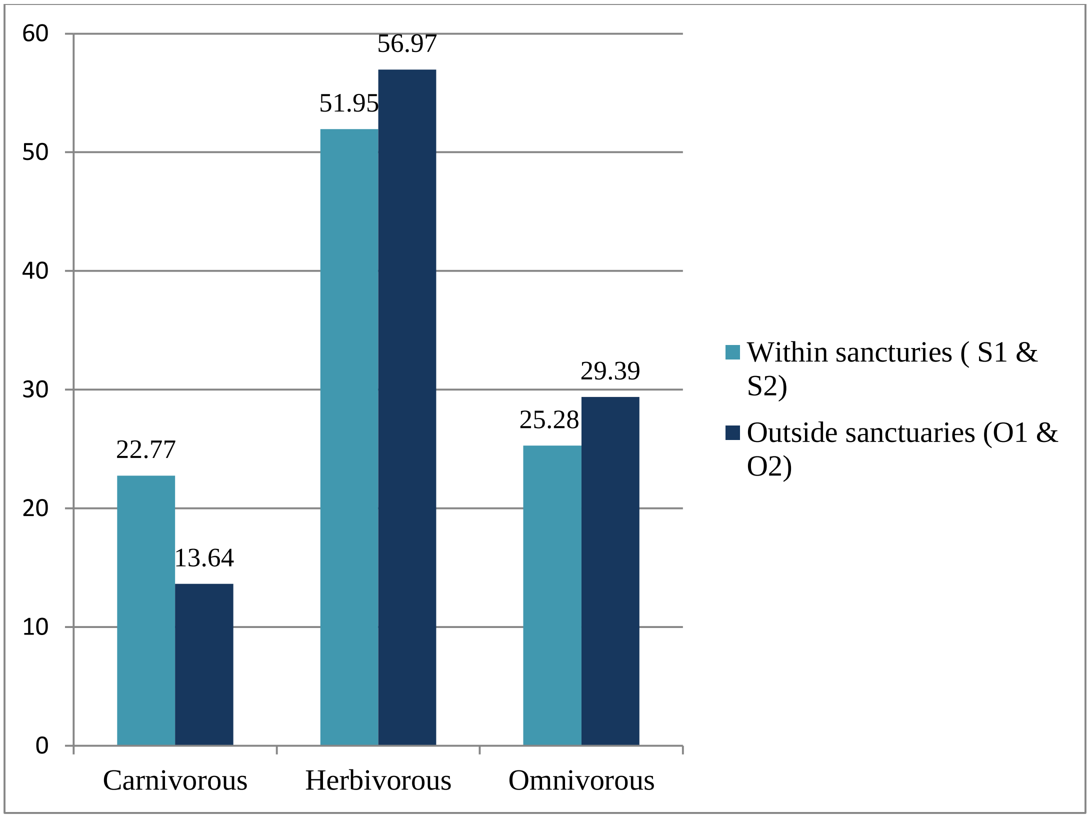


Figure 16 : Composition of individual of fishes based on their feeding type where herbivorous and omnivorous groups were highest in outside sanctuaries and carnivorous group highest in within sanctuaries.

3.2 Temporal and spatial pattern of abundance of fish species

Table.6 represents the site and month wise abundance of fish species. Major variations were observed in species abundance in relation to study sites. Maximum number (51) of fish species were recorded in Munshiganj whereas the lowest number (32) of fish species was observed in Shariatpur.

A total of 3270 individuals were enumerated which comprises of 77 species of finfish (Table 7). Maximum number of individuals (1765) and minimum for many species (1) which are 53.98 % and 0.03% of total individuals respectively. Highest number (1337) of individuals was counted in Narayanganj throughout the study period whereas lowest number (150) of individuals was found in Shariatpur in throughout the period. *Corica soborna* was the dominant species among all the fish species.

Temporal variations were observed in species availability. The maximum number (52) of fish species were recorded in the month of October whereas the lowest number (42) of fish species was observed in August. A little variation was found in species abundance in relation to months. *Corica soborna* was the dominant species among all the fish species in relation to months.

Highest number (1969) of individuals was recorded in June and the lowest (618) in August. The monthly abundance for each study period was sharply decrease from June to August and gradually increased from August to October (Table 7).

Table 7 : Temporal and spatial fish species abundance and distribution based on the species collected in this study.

Fish species	**Total**	**%**	**Study site** (S1=Chandpur, S2= Shariatpur, O1=Narayangonj,O2=Munshiganj)				**Study period**		
			S_1	S_2	C_1	C_2	June	August	October
Acentrogobius viridipunctatus	1	0.03	1						1
Ailia coila	20	0.61	3	1	7	9	1	7	12
Amblypharyngodon mola	36	1.11			10	26	9	27	
Anabas testudineus	5	0.15		4	1			4	1
Apocryptes bato	30	0.92	20	2	6	2	30		
Apocryptes lanceolatus	7	0.22			7				7
Apocryptes serperaster	8	0.25	2	3	3		2	6	
Apolocheilus panchax	1	0.03				1			1
Aspidoparia joya	1	0.03				1			1
Aspidoparia morar	3	0.09				3		2	1
Barilius vagra	1	0.03				1			1
Botia dario	4	0.12			2	2			4
Chaca chaca	1	0.03			1		1		
Chanda nama	24	0.74	2		1	21	2	21	1
Channa punctatus	12	0.37	7	4		1	1	4	7
Channa striatus	7	0.21	4	3			1	2	4

Cirrhinus cirrhosus	5	0.15	3	1		1		5	
Clupisoma garua	3	0.09		1	1	1	3		
Corica soborna	1765	53.97	752		770	243	1522	195	48
Eleotris fusca	49	1.50	26	5	15	3	23	22	4
Erethistes pusillus	1	0.03				1			1
Eutropiichthys muris	18	0.60	13	4		1	1	17	
Gagata gagata	76	2.32	12	4	58	2	2	2	72
Gebelion catla	1	0.03				1		1	
Glossogobius giuris	110	3.36	29	42	19	20	68	24	18
Gobioides rubicurdus	1	0.03			1			1	
Gobius criniger	65	1.99	65				65		
Gobius personatus	8	0.24	8				8		
Gonialossa manminna	7	0.22			7				7
Heteropneustes fossilis	22	0.67	18		3	1	2	1	19
Gudusia chapra	117	3.58	3	3	65	46	8	62	47
Hyporhamphus limbatus	105	3.21			1	104		104	1
Ilisha melastoma	23	0.70		1	22				23
Johnieops volgeri	10	0.31		3	7				10
Johnius coitor	1	0.03		1			1		
Labeo calbasu	2	0.06			2			1	1
Labeo rohita	1	0.03				1		1	
Leiognathus fasciatus	31	0.95	5		8	18	1	1	29
Lepidocephalichthys guntea	15	0.46	8		4	3	5		10
Macrognathus aculeatus	15	0.46		2	13		13	2	
Mastacembelus armatus	8	0.24	1		5	2	4		4
Mastacembelus pancalus	11	0.34		2	4	5	6	3	2
Megarasbora elanga	25	0.76	21			4			25
Mystus cavasius	1	0.03			1				1
Mystus gulio	1	0.03				1			1

Mystus tengara	96	2.94	20		74	2	8	1	87
Mystus vittatus	13	0.39			13		13		
Nandus nandus	35	1.07	8	1	23	3	4	5	26
Notopterus notopterus	5	0.15	2		3				5
Ompok bimaculatus	1	0.03			1		1		
Ompok pabda	19	0.60	11		7	1			19
Osteobrama cotio	1	0.03				1		1	
Oxygaster phulo	19	0.58	2		13	4	18	1	
Panna microdon	13	0.39	5	2	3	3	4	5	4
Pethia conchonius	6	0.18	3			3			6
Pethia gelius	1	0.03				1			1
Pethia ticto	13	0.39	7	4		2	2	11	
Pisodonophis cacrivorus	4	0.12				4			4
Polynemus paradiseus	11	0.34		3	8			8	3
Pseudambassis baculis	15	0.46	2		6	7	7	8	
Pseudambassis ranga	2	0.06		2			2		
Puntius phutunio	1	0.03	1						1
Puntius sophore	77	2.36		2	67	8	11	3	63
Puntius stigma	52	1.60	34	3	10	5	19	3	30
Rasbora daniconius	6	0.18		6				6	
Rhinomugil corsula	35	1.07	2	30	1	2	22	12	1
Rita gogra	2	0.06	2				2		
Salmostoma bacaila	69	2.11	22	3	28	16	38	22	9
Setipinna phasa	1	0.70		1					1
Silonia silondia	22	0.67	5	2	12	3		5	17
Sperata aor	4	0.12			2	2		3	1
Sperata seenghala	2	0.06	1			1	1		1
Systomus sarana	1	0.03				1			1
Tenualosa ilisha	7	0.21	6		1		4	3	
Tetraodon cutcutia	8	0.24	2		5	1	7		1
Trichogaster labiosu	38	1.16	30	2	3	3	3	1	34

Xenentodon cancila	33	1.01	2	3	13	15	24	5	4
Total	3270		1170	150	1337	613	1969	618	683

3.3 Different diversity indices

3.3.1 Diversity status of fish species

The value of Shannon Wiener diversity index (H), Margaleaf's richness (M) and evenness were calculated according to month and study areas.

After polling whole samples (77), the overall *H* value was 2.0344. The fish community was highly diverse where Shannon diversity index was found to be the highest (*H*=2.7240) among all sites, which was similar to the overall value for all sites. In contrast Chandpur was the lowest species diversity (*H*= 1.7720) (Table 8). The overall *H* value was 3.1909 in October (Table 9). The fish community was highly diverse when Shannon diversity index was found to be the highest (*H*=3.1909) among three study period, which was similar to the overall value for all study periods (Figure 17). In contrast, June was the lowest species diversity (*H*= 1.7720) (Table 9) Diversity also depends on species richness and evenness. The more the number of individuals, the lower the diversity, evenness and richness of the species. Diversity depends on the number of individuals. When the numbers of individuals become high the diversity becomes low in different study sites with different study period (Figures 17 & 18).

Evenness index value for pooled 77 samples was 0.5396 (overall value). The highest evenness (0.7860) was found in Shariatpur that represents the amounts of habitats of each species are more similar than the lowest value of evenness (0.4772) in Chandpur among the all study sites. (Table 8). Highest evenness value was found 0.7999 in October and lowest value observed 0.3257 in June that's mean the amounts of each habitat are more similar in October than in June among the three study period (Table 9). The more the evenness, the diversity will become more. Evenness also depends on the number of individuals. When the numbers of individuals become high the evenness becomes low in different study sites with different study period (Figures 17 & 18).

The overall Margaleaf's richness value for pooled 77 fish samples was 9.3846. The maximum value Margaleaf's richness was observed 7.7901 in Munshiganj where minimum was observed 5.8035 in Chandpur (Table 8). Here the maximum value of species richness means that the maximum numbers of different species are present in Munshiganj among all sites which was similar to the overall value for all sites in contrast minimum numbers of different species are present in Chandpur (Figure 17). Margalef's richness value was maximum (8.1207) was found in October where minimum value (5.5370) was observed in June among the three study period (Figure 18). The maximum and minimum value of species richness that represents the maximum different species was present in October and minimum in June. The more the species richness, the more the diversity. Richness also depends on the number of individuals. When the number of individuals becomes high the richness becomes low in different study sites with different study periods (Figure 17 & 18).

Table 8 : Shannon-Weiner biodiversity and equitability indices and Margalef's richness of fish species within and outside sanctuaries showing the highest index value (*)

Study sites		Total number of individuals(n)	Diversity status		
			Shannon-Weaver diversity index (H)	Evenness (E)	Margalef's richness index (*d*)
Within sanctuaries	Chandpur (S_1)	1170	1.7720	0.4772	5.8035
	Shariatpur (S_2)	150	2.7240*	0.7860*	6.1868
Outside sanctuaries	Narayanganj (O_1)	1337	2.0114*	0.5196*	6.5294*
	Munshigonj (O_2)	613	2.4058	0.6119	7.7901*

Table 9 : Shannon-Weiner biodiversity and equitability indices and Margalef's richness of fish species within and outside sanctuaries showing the highest index value (*) each study period

Time (Month)	Total number of individuals	Diversity status		
		Shannon-Weaver diversity index (H)	Evenness (E)	Margalef's richness index (*d*)
June	1969	1.2249	0.3257	5.5370
August	618	2.5779	0.6897	6.3798
October	683	3.1909*	0.7999*	8.1207*

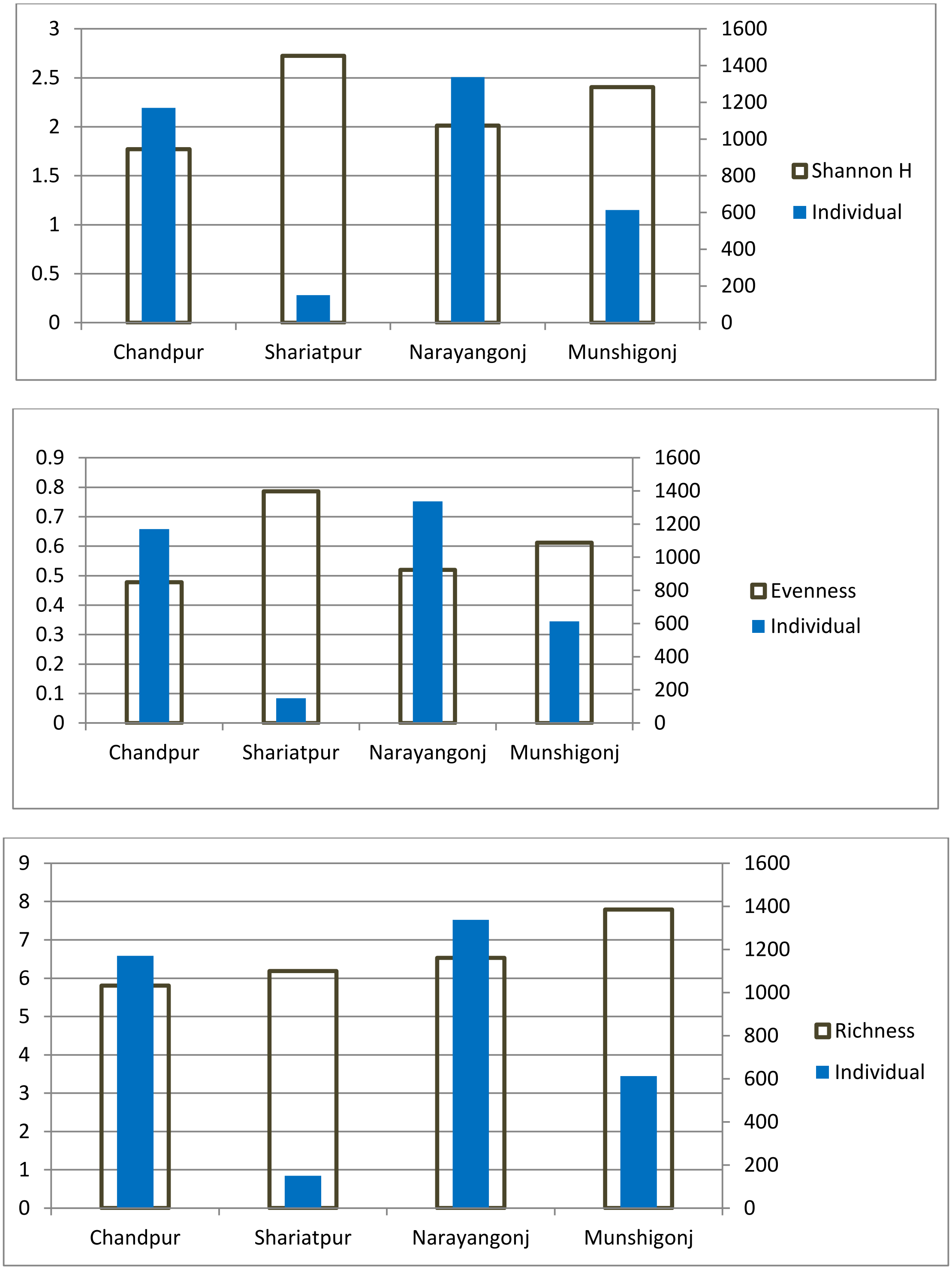


Figure 17 : Different fisheries diversity status (Diversity, evenness and richness) for fish species according to study sites.

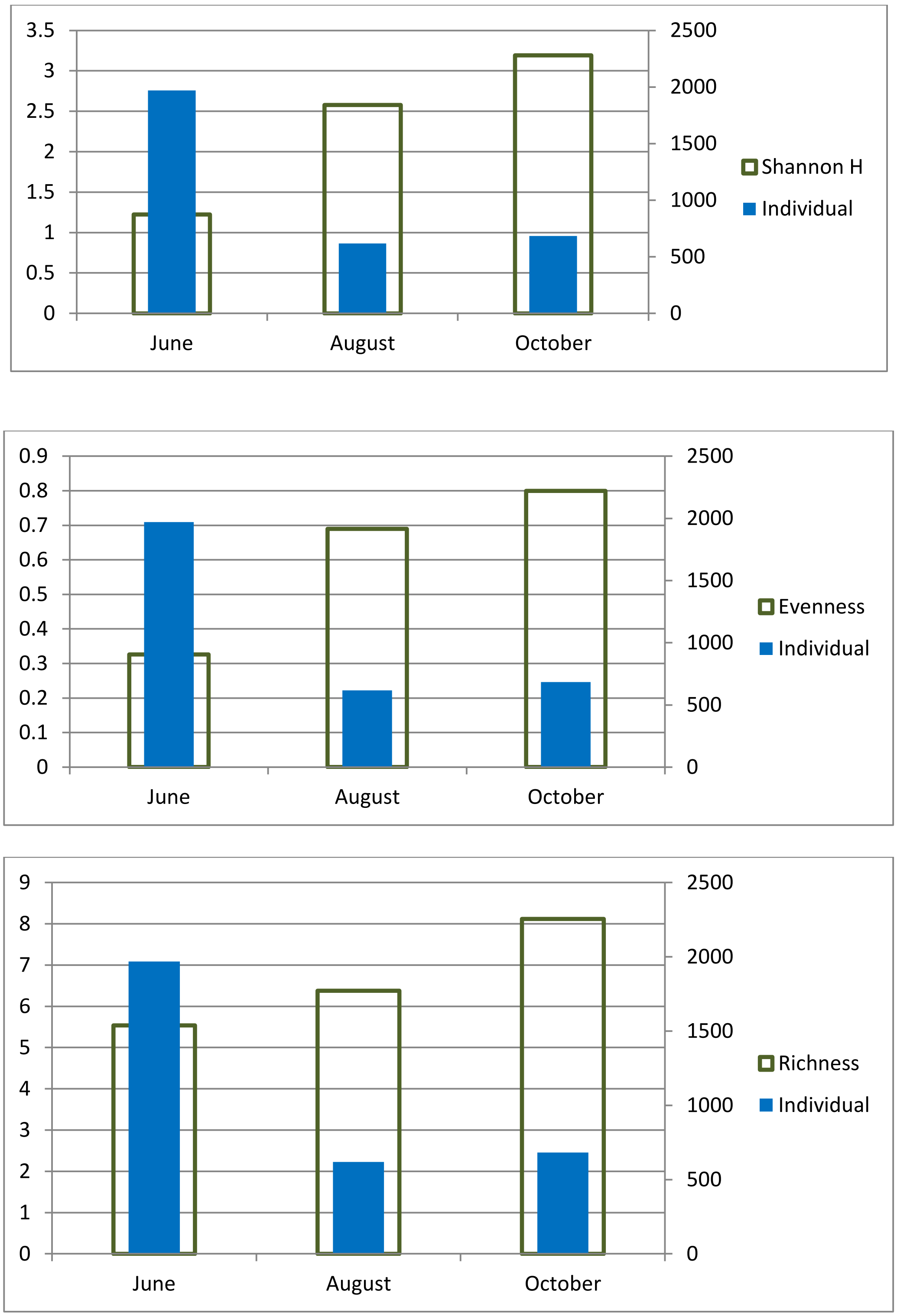


Figure 18 : Different fisheries diversity status (Diversity, evenness and richness) for fish species according to study period.

3.3.2 Diversity status of prawn and shrimps

In case of prawn and shrimps species the value of Shannon Wiener diversity index (H), evenness and Margaleaf's richness (M) were calculated according to month and study area. After polling whole samples (8), the overall *H* value was 1.3616. In Shariatpur, the non-fish community was highly diverse where Shannon diversity index was found to be the highest (*H*=1.4442) among all sites, which was similar to the overall value for all sites (Table 10) .In contrast Narayanganj was the lowest species diversity (*H*= 1.0646) (Table 10). The highest H value was 1.4308 in August (Table 11).The fish community was highly diverse when Shannon diversity index was found to be the highest (*H*= 3.1909) among three study period, which was similar to the overall value for all study periods. In contrast October was the lowest species diversity (*H*= 1.3612) (Table 11) Diversity also depends on species richness and evenness. The more the number of individuals, the lower the diversity. When the numbers of individuals become high the diversity becomes low in different study sites with different study period (Figure 19).

Evenness index value for pooled (8) samples was 0.6548 (overall value). The highest evenness (0.8060) was found in Shariatpur that represents the amounts of habitats of each species are more similar than the lowest value (0.5689) in Munshiganj among the all study sites. (Table 10). Highest evenness value was found 0.8399 in June and lowest value observed 0.6546 in October that's mean the amounts of each habitat are more similar in October than in June among the three study period (Table 11). The more the evenness, the diversity will become more. Evenness also depends on the number of individuals. When the numbers of individuals become high the evenness becomes low in different study sites with different study period (Figure 19 & 20).

The overall Margaleaf's richness value for pooled (8) samples was the maximum value Margalef's richness was observed 1.8515 in Shariatpur where minimum was observed 0.5981 in Narayanganj (Table:10).Here the maximum value of species richness means that the maximum number of different species are present in Shariatpur among all sites which was similar to the overall value for all sites (Figure 19) in contrast minimum number of different species are present in Narayanganj Margalef's richness value was maximum (1.2027) was found in June where minimum value (0.9067) was observed in August among the three study period (Figure 20) The maximum and minimum value of species richness that represents the maximum different species are present in October and minimum in June (Table 11). The more the species richness, the more the diversity. Richness also depends on the number of individuals. When the numbers of individuals become high the richness becomes low in different study sites with different study period (Figures 19 & 20).

Table 10 : Shannon-Weiner biodiversity and equitability indices and Margalef's richness of shell-fish species within and outside sanctuaries showing the highest index value (*)

Study sites		Total number of individuals (n)	Diversity status		
			Shannon-Weaver diversity index (H)	Evenness (E)	Margalef's richness index (*d*)
Within sanctuaries	Chandpur (S_1)	420	1.4319*	0.7992*	0.7634*
	Shariatpur (S_2)	270	1.4442*	0.8060*	1.8515*
Outside sanctuaries	Narayanganj (O_1)	803	1.0646	0.6614	0.5981
	Munshigonj (O_2)	392	1.1071	0.5689	0.9683

Table 11 : Shannon-Weiner biodiversity and equitability indices and Margalef's richness of shell-fish species within and outside sanctuaries showing the highest index value (*) in each study period

Time (Month)	Total number of individuals (n)	Diversity status		
		Shannon-Weaver diversity index (H)	Evenness (E)	Margalef's richness index (*d*)
June	1969	1.2249	0.3257	5.5370
August	618	2.5779	0.6897	6.3798
October	683	3.1909	0.7999	8.1207

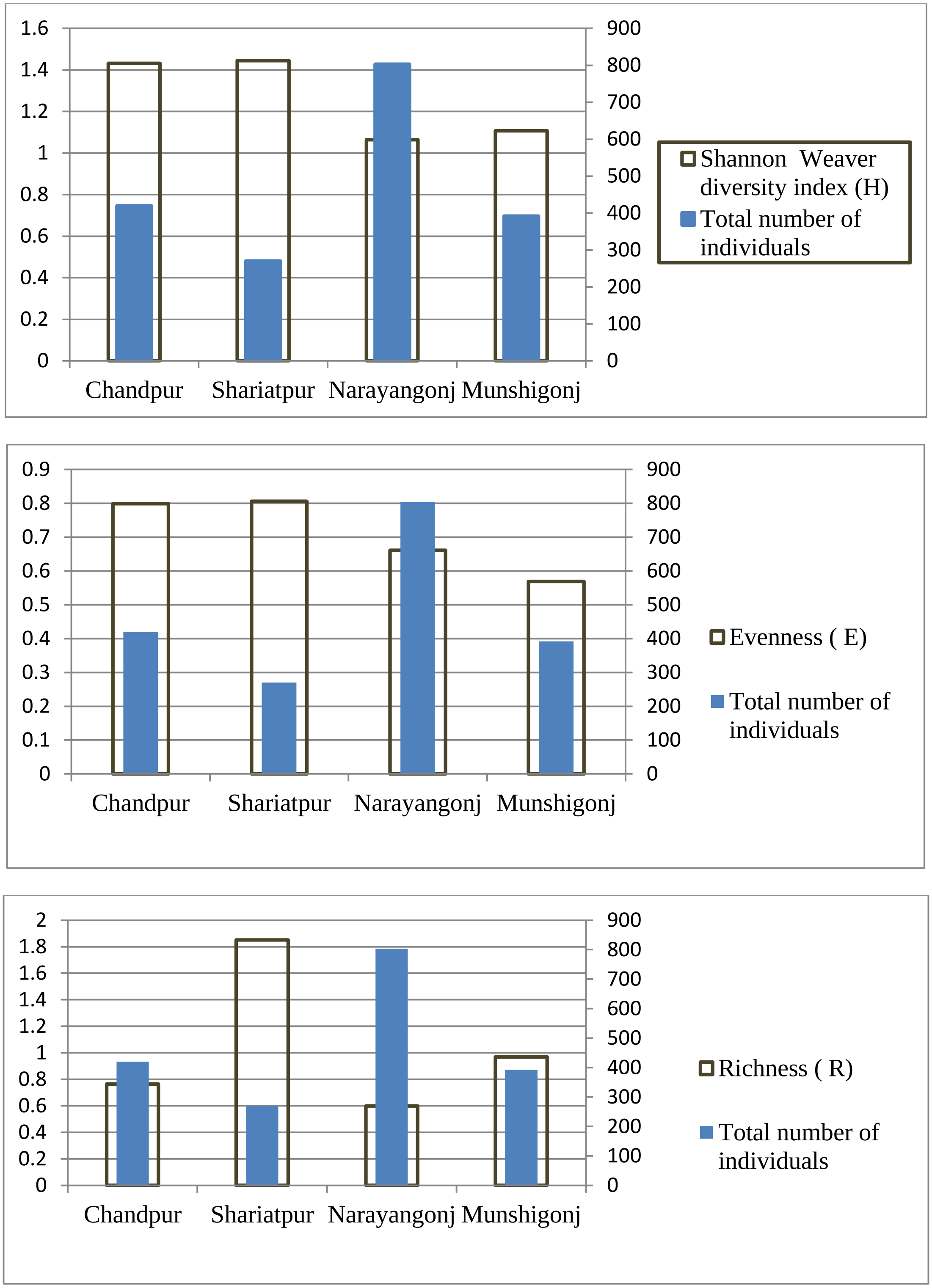
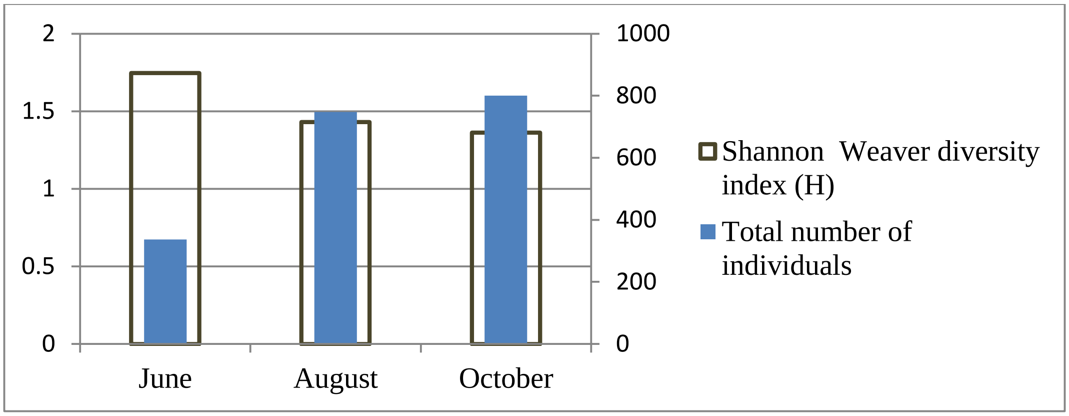
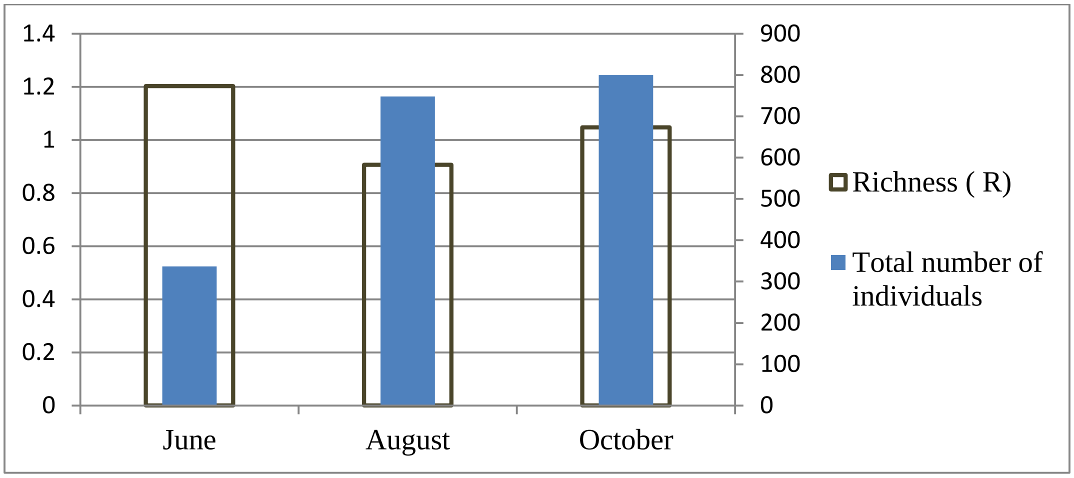


Figure 19 : Different fisheries diversity status (Diversity, evenness and richness) for shell fish species according to study sites.





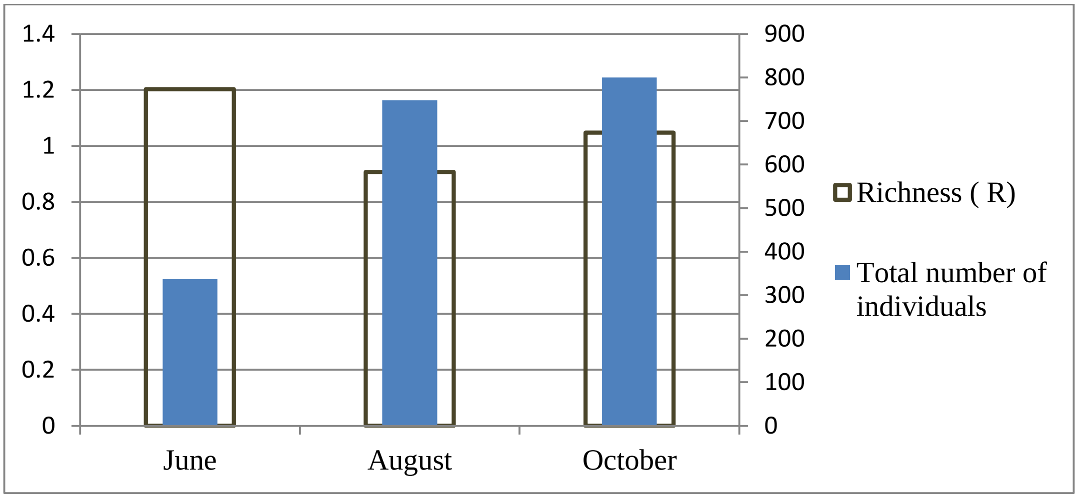


Figure 20 : Different fisheries diversity status (Diversity, evenness and richness) for shell fish species for each study period.

3.4 Month wise fish species availability

Availability of fish species according to sampling period in the respective study areas shown in Figure 23. In the month of June 15 fish species were recorded in the order of Cypriniformes and the maximum 15 fish species were recorded in the order of Perciformes in the month of June and October respectively, whereas minimum 1 fish species were found in the month of September in the order Anguilliform, Cyprinodontiformes and Osteoglossiformes in the month of October, Mugiliformes in the overall time period and Tetraodontifomes in the month of June and October (Figure 21). In terms of non-fish species maximum 8 species (shrimp/Prawn) in order Decapoda were founded in the month of August and October and minimum (5) were in the month of June.

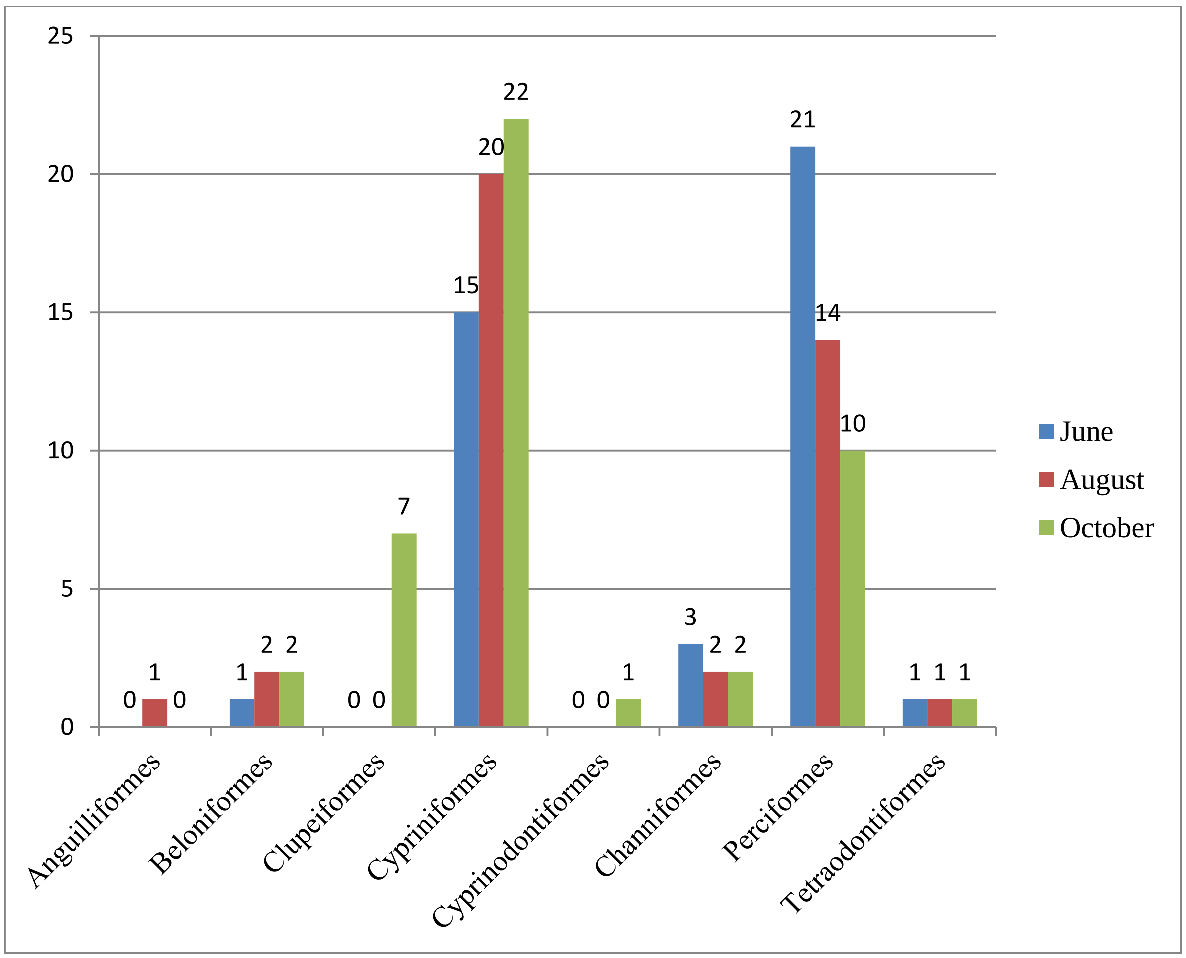


Figure 21 : Month wise fish species availability according to sampling period showing the highest number of species in Cypriniformes order in October.

3.5 Conservation status of fish species

A considerable portion fishes were found in the month of October in this study. In Bangladesh 54 of total species of Bangladesh was declared threatened in the red book of threatened fishes, published by IUCN Bangladesh (IUCN, 2014); according to this red list, (9) endangered and 7 vulnerable fish were present in the respective study area (Table 12). Around 20.78% of fish species were found to be threatened. Two fish species species (2.6%) had been recorded as data deficient (*Ilisha melastoma and Chanda nama*) respectively by IUCN Bangladesh (IUCN, 2014) (Table 12 and Figure 22).Status of a considerable portion 49 (65.82%) of recorded fish species were least concern. On the other hand, in terms of shell-fish species all of their conservation status was data deficient (DD).

Table 12 : Conservation status of fish fauna recorded at four study sites of Bangladesh

Order	Family	Species	Local name	IUCN Category
ANGUILLIFORMES	OPHICHTHIDAE	*Pisodonophis cacrivorus*	Snake eel	VU
BELONIFORMES	HEMIRAMPHIDAE	*Hyporhamphus limbatus*	Ek thuta	LC
	BELONIDAE	*Xenentodon cancila*	Kakhila	LC
CLUPEIFORMES	CLUPEIDAE	*Gudusia chapra*	Chapila	VU
		Gonialossa manminna	Goni chapila	LC
		Tenualosa ilisha	Padma ilish	LC
		Corica soborna	Kachki	LC
	PRISTIGASTERIDAE	*Ilisha melastoma*	Khorchuna	DD
	ENGRAULIDAE	*Setipinna phasa*	Phasa	LC
CYPRINIFORMES	CYPRINIDAE	*Gebelion catla*	Catla	LC
		Pethia conchonius	Chanchon punti	LC
		Osteobrama cotio	Cotio	NT
		Rasbora daniconius	Darkina	LC
		Puntius stigma	Deto puti	LC
		Pethia gelius	Gili punti	NT

		Pethia ticto	Titputi	VU
		Megarasbora elanga	Along	EN
		Puntius sophore	Jat punti	LC
		Aspidoparia joya	Joya	LC
		Labeo calbasu	kalbaush	LC
		Barilius vagra	koksha vagra	EN
		Amblypharyngodon mola	Mola	LC
		Aspidoparia morar	Morari	VU
		Cirrhinus cirrhosus	Mrigel	NT
		Salmostoma bacaila	Narikel chela	LC
		Oxygaster phulo	Phul chela	LC
		Puntius phutunio	Phutani punti	LC
		Botia dario	Rani	EN
		Labeo rohita	Rohu	LC
		Systomus sarana	Shor puti	NT
	COBITIDAE	*Lepidocephalichthys guntea*	Gutum	LC
CYPRINODONTIFORMES	APLOCHEILIDAE	*Apolocheilus panchax*	kanpona	LC
MUGILIFORMES	MUGILIDAE	*Rhinomugil corsula*	Kholla	LC
OSTEOGLOSSIFORMES	NOTOPTERIDAE	*Notopterus notopterus*	Foli	VU
PERCIFORMES	GOBIIDAE	*Glossogobius giuris*	Bele	LC
		Apocryptes bato	Dali Chewa	LC
		Apocryptes serperaster	Dora chew	LC
		Apocryptes lanceolatus	Sobuj chew	LC
		Acentrogobius viridipunctatus	Spotted green goby	NE
	NANDIDAE	*Nandus nandus*	Bheda	NT
	CENTROPOMIDAE	*Gobius criniger*	Giri bele	LC
		Gobius personatus	Nadu bele	LC

	AMBASSIDAE	*Pseudambassis baculis*	Kata chanda	NT
		Chanda nama	Nama chanda	DD
		Pseudambassis ranga	Ranga chanda	LC
	OSPHRONEMIDAE	*Trichogaster labiosu*	Khailsa	LC
	ANABANTIDAE	*Anabas testudineus*	Koi	LC
	ELEOTRIDAE	*Eleotris fusca*	Kuli Bele	LC
		Gobioides rubicurdus	Shada chew	LC
	SCIAENIDAE	*Panna microdon*	Lombu poa	LC
		Johnieops volgeri	Meto poa	LC
		Johnius coitor	Poa	LC
	LEIOGNATHIDAE	*Leiognathus fasciatus*	Taka chanda	LC
	CHANNIDAE	*Channa punctatus*	Taki	LC
		Channa striatus	Sholl	LC
	POLYNEMIDAE	*Polynemus paradiseus*	Taposi	LC
SILURIFORMES	BAGRIDAE	*Sperata aor*	Ayer	VU
		Mystus tengara	Bajari tengra	LC
		Rita gogra	Gogra rita	EN
		Mystus cavasius	GolshaTen gra	NT
		Sperata seenghala	Gujji ayer	VU
		Mystus gulio	Nuna tengra	NT
		Mystus vittatus	Tengra	LC
	SISORIDAE	*Gagata gagata*	Gang tengara	LC
	CHACIDAE	*Chaca chaca*	Gangania	EN
	SCHILBEIDAE	*Clupisoma garua*	Gharua	EN
		Ailia coila	Kajuli	LC
		Eutropiichthys muris	Muri bachha	LC
		Silonia silondia	Shilong fish	LC

	SILURIDAE	*Ompok bimaculatus*	Kani pabda	EN
	ERETHISTIDAE	*Ompok pabda*	Pabda	EN
		Erethistes pusillus	Kutakanti	LC
	HETEROPNEUSTIDAE	*Heteropneustes fossilis*	Shing	LC
SYNBRANCHIFORMES	MASTACEMBELIDAE	*Mastacembelus pancalus*	Guchi baim	LC
		Mastacembelus armatus	Shal baim	EN
		Macrognathus aculeatus	Tara baim	NT
TETRAODONTIFORMES	TETRAODONTIDAE	*Tetraodon cutcutia*	Potka fish	LC

*Based on IUCN Red list Book: LC=Least concern; DD = Data deficient; EN = Endangered; NE= Not evaluated; NT = Not threatened; VU = Vulnerable

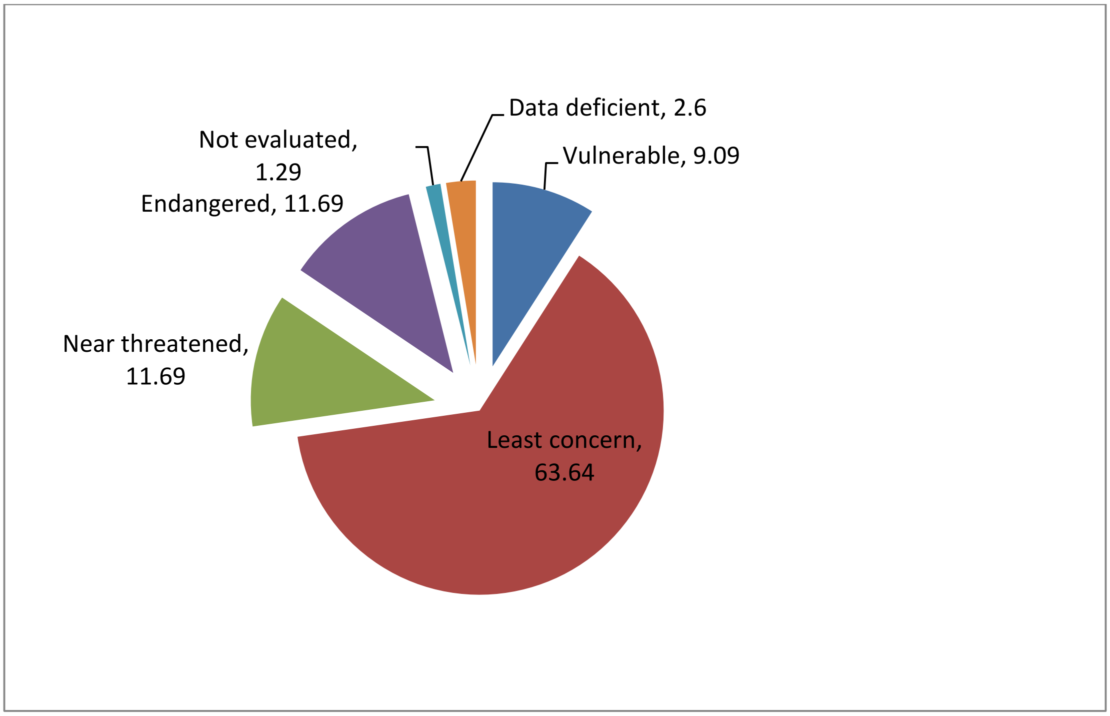


Figure 22 : Conservation status of fish fauna in overall study sites in Bangladesh based on IUCN Red list-2015.

3.6 Impacts of fishing ban on fish and shell fish biodiversity in Sanctuaries

The species diversity and evenness evaluated by Shannon-Weiner Diversity Index (*H*), equitability (E_H) and richness respectively. In this study, the overall *H* value (2.0344) indicates the presence of a wide range of species. The fish community was highly diverse where Shannon diversity index was found to be the highest (*H*=2.7240) among all sites. In contrast, the individual sites were less diverse. Among the four sites the highest *H* was found at Shariatpur due to the presence of freshwater- estuarine species, while the lowest was at Chandpur. The fish and prawn/shrimp were more diverse with higher *H* values within the sanctuaries compared to outside indicating a positive impact of fishing ban on overall fisheries biodiversity. The different species within and outside sanctuary were evenly/unevenly distributed as revealed by E_H values recorded from this study. Considering the conservation status it was recorded in this study that around 20.78% of fish species were found to be threatened and 8.86% are not threatened. The findings of the present study suggest that the temporal fishing ban is positively affecting the fisheries biodiversity within the sanctuary areas. The highest evenness value was recorded in Shariatpur due to fish ban and also in Munshiganj for spillover effects of fish ban. Highest evenness value was found 0.78 and lowest value observed 0.48. No significant difference was found in mean value among these four sites but significant difference was observed among the sites the evenness is lower in higher biodiversity area. The highest richness value (7.79) was found in Munshiganj due to the presence of species availability and lowest in Chandpur (5.80).

There was no clear indication weather fishing ban has any impact on fish biodiversity in rivers. The difference in ecological characteristics and the functional relationships between the two rivers might result in variable impacts of fishing ban.

Chapter 4 – Discussion

Overfishing can have detrimental effects on riverine fish biodiversity and the structure of freshwater ecosystems. Considering this, fish bans are implemented with a view to protect fish and shell-fish biodiversity and ecosystem structure from overfishing. Sanctuaries can help to reverse the decline of riverine ecosystems and biodiversity. Sanctuaries are now seen as a key tool in managing riverine ecosystems, protecting exploited species and restoring natural states of biodiversity (Cote´ et al. 2001, Sala et al. 2002, Halpern 2003, Sobel and Dahlgren 2004, Lester et al. 2009, Molloy et al. 2009). For conservation purposes sanctuaries protect species, communities, biodiversity, and ecosystems inside the protected areas (Babcock et al. 1999, 2010, Castilla 1999, Pinnegar et al. 2000, Cˆote´ et al. 2001, Micheli et al. 2004, Lester et al. 2009).

4.1 Community composition of fish and shell fish

In the present study fish composition was estimated within and outside sanctuaries with different time periods. In this study the composition was highest in Cyprinidae family followed by the order Perciformes and Cypriniformes in overall time period. In relation to the study sites, the largest composition of fish species was found in the Cyprinidae family in outside sanctuary (Munshiganj) or fished area and the lowest were found in within Sanctuaries or unfished areas.It may be due to the spillover effects of sanctuaries. There was a study that sanctuaries have a spillover effect on outside sanctuaries (Ecoutin et al. 2014). On the other hand,in relation to month the species composition was found to increase from June to August in the Cyprinidae family. It was recorded that a number of fish species reproduce during April to July in the coastal and fresh water of Bangladesh which may be the reason behind this increasing pattern (Hanif et al 2015). It was studied that the lowest number of species was recorded during the month of June and July due to heavy rain during this time which makes fishing difficult as the water level reached its maximum level. But in Bangladesh perspective, the greatest diversity of fish is found in rainy season because of recruitment and for the migration of migratory fishes from estuary and marine water to freshwater for their breeding purpose. But in October this number was found to a little reduction in community composition of fish species. This reduction may be happened due to the migration pattern of some migratory fish species and overharvest with due time.

In addition, it was found that the order Cypriniformes and Perciformes was the most diversified groups of fishes in terms of both number of individuals and species followed by the order Siluriformes. These three groups are also the most dominant groups in the freshwater bodies of Bangladesh (Rahman, 2005).

In this study, a total of 77 species of finfish were recorded during the study period. Among them 16 species of fish contributed more than 1% of the composition. Hossain et al. (2007) reported about 161 species collected by different types of nets in the Naaf estuary, where Islam (1987) observed 97 species from the same study area. The reasons for the reduction of species diversity are long-term changes in hydrological and meteorological parameters. The discharge of heavy fresh water from the mark of the adjacent land brings the sediment and causes sedimentation and makes the water turbid which finally effects in number of the species. Increased fishing pressure is the main trigger for the loss of fisheries diversity. The highest number of individuals was observed in outside sanctuary (Narayanganj), this is due to overflow effects (Russ et al., 2011) in contrast the lower number of individuals observed in the Shariatpur. It could be also said in terms of dominant species, this study differs with the findings of Nabi et al. (2011) and Chowdhury et al. (2010). The abundance of species found in the estuary of the Meghna River is composed of a small number of species with high contribution and a large number of species whose contributions are very in significant, a common feature of estuarine faunal populations (Gaughan et al., 1990; Harrison and Whitfield, 1990; Drake and Arias, 1991; Harris and Cyrus, 1995; Whitfield, 1999). In addition, each estuarine system may have a different abiotic environment (Blaber, 2000), which results from tide, freshwater intake, geomorphology and human pressure (Dyer, 1997; McLusky and Elliott, 2004). Therefore, a difference in species abundance with the study area is not likely to be the exception. Many interacting physical and biological factors could influence the occurrence, distribution, abundance, and diversity of freshwater fishes.

In this study it was also estimated the composition of fish species based on their habitat and feeding habit. It was recorded in this study that among the four types of habitat the individuals of freshwater-estuarine habitat was the highest and act as dominant habitat. Marine water- estuarine habitat are least dominant It could be happened due to the change of migration pattern of some species over time. There was another reason which was found in another study that the presence of small numbers of species with high contribution and a large number of species whose contributions are very negligible, a common feature of estuarine faunal populations (Gaughan et al., 1990; Harrison and Whitfield, 1990; Drake and Arias, 1991; Harris and Cyrus, 1995; Whitfield, 1999).That's why the number of marine water, estuarine species become low due to their migration pattern and they were harvested extensively when they come to freshwater for their feeding and spawning purpose. It had clearly showed that the occasional or more frequent contribution of these species to the fish assemblage. However, when these species become adults, they migrate to the ocean to spawn. Besides, as the present study was conducted in freshwater system, the percentages of fish individuals which were belonging to others type of habitat are very rare in this study.

In this study it had been also recorded that the maximum percentage of fish individuals was omnivorous in total time. It was also found that according to time and place in both cases the omnivores were dominant. On the other hand the numbers of herbivorous fish species were high in number compare to carnivore. This may be due to the increase of herbivorous fish and the decrease of large predatory fish. According to Ecoutin et al. (2014), it was reported in his research study that the fishing ban has so far complex effects on global biomass. The biomass of carnivorous fish species was profoundly diminished, while there was a large increase of omnivore species biomass. It was also noted that the size increased in the large fish species, and increased the number of individuals in the large classes made dominant fish species. Most of these large individuals belong to omnivorous fish species in this study. Generally, the changes of species composition are related with changes in size structure (Kartawijaya et al., 2008, Watson et al., 2009, Taylor and McIlwain, 2010).

4.2 Temporal and spatial pattern of abundance

In terms of temporal and spatial patterns of species abundance it has been recorded in this study that the highest number of fish species was found at the outside sanctuaries and the lowest was in within sanctuary areas. It may be due to an excess of immediate fishing effort after the fishing ban. On the other hand, in relation to individual time period, according to site the highest number of fish species was found in October and lowest in August. This is due to increased fishing hour and number of fishing boats immediately after the fishing ban.

The present study was also found similar result in case of the appearance of a set of fish between the sites and seasons. The major contributing species (*Corica soborna*), for all study sites and seasons, are close to other fish species, although their contribution percentage differs from one another. This similarity and dissimilarity may be due to the seasonality that is responsible for the fluctuation of the hydrological and meteorological parameters and, therefore, affects the assembly of fish (Whitfield, 1989, Lonely and Potter, 1990). Seasonality also affects the reproductive activity of fish and ultimately influences the composition of catches (McErlean et al., 1973).

4.3 Biodiversity indices

In this study, the biodiversity indices had been estimated in different study areas with different time period. The value of a diversity index increases when both the number of species and the evenness increase in a population. The species diversity and evenness evaluated by, equitability (E_H) and richness. The Margaleaf's richness index (*d*=9.3846) and Shannon-Weiner Diversity Index (*H*=2.0344) obtained from whole samples indicates high species richness and diversity. However, all sites were less diverse compared to overall value. The fish community was more diverse within the sanctuary compared to outside in Padma river ($S_2 > O_2$), while it was opposite in case of the Meghna river ($O_1 > S_1$). Diversity was highest in October compared to June and August. Large numbers of migratory fish use freshwater bodies in Bangladesh on a seasonal basis such as large breeding, feeding and migratory routes that are connected to the Bay of Bengal (Sharker et al., 2015).It was studied that sudden increase or decrease in water temperature can cause fish mortality (Blaber, 2000). Transparency is one of the factors of hydrological impact that play a role in the distribution of species. So, it can be said that these variations could happen due to the difference in ecological characteristics and the functional relationships between the two rivers. The highest evenness was recorded in the sanctuary and the lowest in the control sites due to the presence of dominant fish species in overall time period.

4. 4 Conservation status

Ecological changes to the fish habitat representing the need of instant comprehensive studies regarding to conservation of fish species. In this present study, the conservation status of identified fish species was also estimated. It was recorded in this study that around 20.78% of fish species were found to be threatened and 8.86% are not threatened. Therefore, it could be said that this threatened condition could be occurred due to the ecological and biological pattern of fish species or to human development activities. However, several reasons including dreadful conditions of natural habitats, excess exploitation using prohibited fishing gears, use of toxins in aquaculture ponds could be responsible for this status. Throughout the decade, increasing natural and anthropogenic hazards span the distribution of species throughout the country, and subsequently many species are classified as endangered in Bangladesh (IUCN Bangladesh, 2015. But in recent years the riverine ecosystems of this area have changed considerably due to human intervention, intense tourism, pollution and even the consequences of global climate change that have resulted in the destruction of migratory routes, altered wild ecosystems and deterioration of the quality of water in these areas (Hossain et al., 2013, IUCN Bangladesh, 2013, Hossain et al., 2014). These factors also provided physiological characteristics such as body morphology and the rate of growth of many fish (Froese, 2006; Tomljanović et al., 2011). In addition, indiscriminate collection of fry and fry, habitat modification, reduced water flow, and increased human intervention in wetlands are also considered significant threats to species diversity (Chaklader et al., 2014).

4.5 Impacts of fishing ban on fish and shell fish biodiversity

Present study assessed the impacts of temporal and spatial fishing ban on fisheries (fish and prawn/shrimp) biodiversity in two riverine hilsa sanctuaries. The species diversity and evenness evaluated by, equitability (E_H) and richness. The Margaleaf's richness index (d=9.3846) and Shannon-Weiner Diversity Index (H=2.0344) obtained from whole samples indicates high species richness and diversity in case of fish species. However, all sites were less diverse compared to overall value. The fish community was more diverse within the sanctuary compared to outside in Padma river (S2>O2), while it was opposite in case of the Meghna river (O1>S1). Species diversity was highest in October compared to June and August. So, it can be said that these variations could happen due to the difference in ecological characteristics and the functional relationships between the two rivers. The findings of the present study suggest that the impact of fishing ban on riverine fisheries biodiversity is variable among different riverine ecosystems.

4.6 Implications for fisheries management

In addition, to increase biodiversity, protection of aquatic habitat and ecosystem and also to conserve the fish and shell-fish species, the following measures can be implemented to restore fish communities in freshwater bodies, restocking economically important fish species, establishing and maintaining fishery sanctuaries, banning indiscriminate fishing and destructive fishing gears such as the *current jal*, regular dredging especially in some important points of the river, identification and protection of the breeding and nursery grounds, encouraging integrated pest management (IPM) techniques to reduce the use of chemical fertilizers and pesticides, introduction of fish bypasses to facilitate fish movement, formulating new legislation concerning the current situation, educating, informing and training of the fishermen, strict implementation of existing conservation regulations.

Furthermore, studies on life histories of threatened species should be strengthened. Information on life histories of endangered species is highly necessary for successful conservation of fishes. In addition, development of techniques for artificial breeding is still indispensable to restore the populations of threatened species because of rapid habitat destruction or degradation.

Chapter 5 – Conclusions and Recommendations

Fish sanctuaries much advocated as a means of protecting biodiversity from overharvest. Fishing ban, a widely practiced fisheries management tool which impacts the fish biodiversity within and beyond the sanctuary areas. The impacts of temporal and spatial fishing ban on fisheries (fish and prawn/shrimp) biodiversity in two riverine hilsa sanctuaries. Fish and prawn/shrimp samples (10% of total catch) caught by different gears were collected three times (Jun, August and October) from pre-contacted fishers and identified based on morphometric and meristic characteristics. The fish community was more diverse within the sanctuary compared to outside in Padma river (S2>O2), while it was opposite in case of the Meghna river (O1>S1). The fish community was more diverse within the sanctuary compared to outside in Padma river (S2>O2), while it was opposite in case of the Meghna river (O1>S1). Species diversity was highest in October compared to June and August. The findings of the present study suggest that the impact of fishing ban on riverine fisheries biodiversity is variable among different riverine ecosystems.

At present, biodiversity conservation is a very important to sustain our life on the earth. Due to many reasons, many species of fish are disappearing from the country's water bodies. More research efforts are required in every water body of the country to find out the main causes of less species diversity. Data were collected by pre-contacting fishermen. The data were analyzed by following various types of diversity indices. Based on the findings of this study it can be said that fish ban had positive impact on overall fish biodiversity in hilsa sanctuary.

It is very much essential to adjust the existing laws and legislation of the country for integrated resource management to save the fisheries resources. There is still time to act to conserve this fish and shell fish biodiversity. From now on, Bangladesh government, the NGOs and national and international bodies should help fostering a social and technical environment in which the enormous richness of the fisheries resources can stabilize and eventually rebuild so as to continue to feed people of today and tomorrow. Poverty in fishing communities should be reduced in part by ensuring a stable supply of fish; something can only be achieved through improved knowledge, integration of fisheries and freshwater management, and greater public involvement. In case of fishing closure in areas or for certain time, the fishers should be provided with alternative income generating activities, credit with low interest and other sustainable means. Creating public awareness of the importance of maintenance of fish diversity in Bangladesh is extremely necessary and should be the first priority for a lasting change. Sustenance of fish diversity can only be achieved with public support. Bangladeshi fishers, fish farmers, traders, processors, and general people as a whole need to understand the issues, to be involved in the formulation of management plans and to benefit from the whole process.

Furthermore, studies on life histories of threatened species should be strengthened. Information on life histories of endangered species is highly necessary for successful conservation of fishes. In addition, development of techniques for artificial breeding is still indispensable to restore the populations of threatened species because of rapid habitat destruction or degradation. This is the high time to care for the aquatic biodiversity. The national and international bodies should come forward to help conserving aquatic ecosystems. However, far more research and integration is needed before adaptation measures can be implemented.

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Appendices

Appendix 1- Determination of meristic and morphometric characteristics of fish

Figure A1: Determination of meristic and morphometric characteristics of fish

Appendix 2- Community compositions

Table A1: Distribution of number of species belonging to different families in overall study time

Family	Number of species	% of species
AMBASSIDAE	3	3.90
ANABANTIDAE	1	1.30
APLOCHEILIDAE	1	1.30
BAGRIDAE	7	9.09
BELONIDAE	1	1.30
CENTROPOMIDAE	2	2.60
CHACIDAE	1	1.30
CHANNIDAE	2	2.60
CLUPEIDAE	4	5.19
COBITIDAE	1	1.30
CYPRINIDAE	21	27.27
ELEOTRIDAE	2	1.30
ENGRAULIDAE	1	1.30
ERETHISTIDAE	2	2.60
GOBIIDAE	5	6.49
HEMIRAMPHIDAE	1	1.30
HETEROPNEUSTIDAE	1	1.30
LEIOGNATHIDAE	1	1.30
MASTACEMBELIDAE	3	3.90
MUGILIDAE	1	1.30
NANDIDAE	1	1.30
NOTOPTERIDAE	1	1.30
OPHICHTHIDAE	1	1.30
OSPHRONEMIDAE	1	1.30
POLYNEMIDAE	1	1.30
PRISTIGASTERIDAE	1	1.30

SCHILBEIDAE	4	5.19
SCIAENIDAE	3	3.90
SILURIDAE	1	1.30
SISORIDAE	1	1.30
TETRAODONTIDAE	1	1.30
Total	77	100.00

Table A2: Distribution of number of species belonging to different orders in overall study time

Order	**Number of fish species**
ANGUILIFORMES	1
BELONIFORME	2
CLUPEIFORMES	6
CYPRINIFORMES	22
CYPRINODONTIFORMES	1
MUGILIFORMES	1
OSTEOGLOSSIFORMES	1
PERCIFORMES	22
SILURIFORMES	17
SYNBRANCHIFORMES	3
TETRAODONTIFORMES	1
Total	77

Table A3: Fish species composition under various families in Chandpur during overall time period

Family	Number of species	%
BELONIDAE	1	2.439024
CLUPEIDAE	3	7.317073
COBITIDAE	1	2.439024
CYPRINIDAE	8	19.5122
MUGILIDAE	1	2.439024
NOTOPTERIDAE	1	2.439024
AMBASSIDAE	2	4.878049
CENTROPOMIDAE	2	4.878049
CHANNIDAE	2	4.878049
ELEOTRIDAE	1	2.439024
GOBIIDAE	4	9.756098
LEIOGNATHIDAE	1	2.439024
NANDIDAE	1	2.439024
OSPHRONEMIDAE	1	2.439024
SCIAENIDAE	1	2.439024
BAGRIDAE	3	7.317073
HETEROPNEUSTIDAE	1	2.439024
SCHILBEIDAE	3	7.317073
SILURIDAE	1	2.439024
SISORIDAE	1	2.439024
MASTACEMBELIDAE	1	2.439024
TETRAODONTIDAE	1	2.439024
Total	41	100.00

Table A4: Fish species composition under various families in Sharitaypur during overall time period

Family	Number of species	%
AMBASSIDAE	1	3.03
ANABANTIDAE	1	3.03
BELONIDAE	1	3.03
CHANNIDAE	2	6.06
CLUPEIDAE	1	3.03
CYPRINIDAE	6	18.18
ELEOTRIDAE	1	3.03
ENGRAULIDAE	1	3.03
GOBIIDAE	3	9.09
MASTACEMBELIDAE	2	6.06
MUGILIDAE	1	3.03
NANDIDAE	1	3.03
OSPHRONEMIDAE	1	3.03
POLYNEMIDAE	1	3.03
PRISTIGASTERIDAE	1	3.03
SCHILBEIDAE	5	15.15
SCIAENIDAE	3	9.09
SISORIDAE	1	3.03
Total	33	100

Table A5: Fish species composition under various families in Narayangonj during overall time period

Family	Number of species	%
AMBASSIDAE	2	3.92
ANABANTIDAE	1	1.96
BAGRIDAE	6	11.76
BELONIDAE	1	1.96
CHACIDAE	1	1.96
CLUPEIDAE	4	7.84
COBITIDAE	2	3.92
CYPRINIDAE	6	11.76

ELEOTRIDAE	3	5.88
GOBIIDAE	4	7.84
HEMIRAMPHIDAE	1	1.96
HETEROPNEUSTIDAE	1	1.96
LEIOGNATHIDAE	1	1.96
MASTACEMBELIDAE	3	5.88
MUGILIDAE	1	1.96
NANDIDAE	1	1.96
NOTOPTERIDAE	1	1.96
OSPHRONEMIDAE	1	1.96
POLYNEMIDAE	1	1.96
PRISTIGASTERIDAE	1	1.96
SCHILBEIDAE	3	5.88
SCIAENIDAE	2	3.92
SILURIDAE	2	3.92
SISORIDAE	1	1.96
TETRAODONTIDAE	1	1.96
Total	51	100.00

Table A6: Fish species composition under various families in Munshiganj during overall time period

Family	Number of species	%
AMBASSIDAE	2	3.92
APLOCHEILIDAE	1	1.96
BAGRIDAE	4	7.84
BELONIDAE	1	1.96
CHANNIDAE	1	1.96
CLUPEIDAE	2	3.92
COBITIDAE	2	3.92
CYPRINIDAE	17	33.33
ELEOTRIDAE	1	1.96
ERETHISTIDAE	1	1.96
GOBIIDAE	2	3.92
HEMIRAMPHIDAE	1	1.96

LEIOGNATHIDAE	1	1.96
MASTACEMBELIDAE	2	3.92
MUGILIDAE	1	1.96
NANDIDAE	1	1.96
OPHICHTHIDAE	1	1.96
OSPHRONEMIDAE	1	1.96
SCHILBEIDAE	5	9.80
SCIAENIDAE	1	1.96
SILURIDAE	1	1.96
SISORIDAE	1	1.96
TETRAODONTIDAE	1	1.96
Total	51	100

Table A7: Fish species composition under various families in the month of June in the study areas

Family	Number of species	%
AMBASSIDAE	3	7.14
BAGRIDAE	3	7.14
BELONIDAE	1	2.38
CENTROPOMIDAE	2	4.76
CENTROPOMIDAE	1	2.38
CHACIDAE	1	2.38
CHANNIDAE	2	4.76
CLUPEIDAE	3	7.14
COBITIDAE	1	2.38
CYPRINIDAE	6	14.29
ELEOTRIDAE	1	2.38
GOBIIDAE	3	7.14
HETEROPNEUSTIDAE	1	2.38

LEIOGNATHIDAE	1	2.38
MASTACEMBELIDAE	3	7.14
MUGILIDAE	1	2.38
NANDIDAE	1	2.38
OSPHRONEMIDAE	1	2.38
SCHILBEIDAE	3	7.14
SCIAENIDAE	2	4.76
SILURIDAE	1	2.38
TETRAODONTIDAE	1	2.38
Total	42	100.00

Table A8 : Fish species composition under various families in the month of October in the study areas

Family	Number of species	%
AMBASSIDAE	1	1.79
ANABANTIDAE	1	1.79
APLOCHEILIDAE	1	1.79
BAGRIDAE	5	8.93
BELONIDAE	1	1.79
CHANNIDAE	2	3.57
CLUPEIDAE	3	5.36
COBITIDAE	3	5.36
CYPRINIDAE	11	19.64
ELEOTRIDAE	1	1.79
ENGRAULIDAE	1	1.79
ERETHISTIDAE	1	1.79
GOBIIDAE	3	5.36
HEMIRAMPHIDAE	2	3.57
HETEROPNEUSTIDAE	1	1.79

LEIOGNATHIDAE	1	1.79
MASTACEMBELIDAE	2	3.57
MUGILIDAE	1	1.79
NANDIDAE	1	1.79
NOTOPTERIDAE	1	1.79
OPHICHTHIDAE	1	1.79
OSPHRONEMIDAE	1	1.79
Total	56	100.00

Table A9: Fish species composition under various families in sanctuary areas during the overall study period

Family	Number of species	%
AMBASSIDAE	3	5.45
ANABANTIDAE	1	1.82
BAGRIDAE	4	7.27
BELONIDAE	1	1.82
CENTROPOMIDAE	1	1.82
CENTROPOMIDAE	1	1.82
CHANNIDAE	2	3.64
CLUPEIDAE	4	7.27
COBITIDAE	1	1.82
CYPRINIDAE	10	18.18
ELEOTRIDAE	1	1.82
ENGRAULIDAE	1	1.82
GOBIIDAE	4	7.27
HETEROPNEUSTIDAE	1	1.82
LEIOGNATHIDAE	1	1.82
MASTACEMBELIDAE	3	5.45
MUGILIDAE	1	1.82

NANDIDAE	1	1.82
NOTOPTERIDAE	1	1.82
OSPHRONEMIDAE	1	1.82
POLYNEMIDAE	1	1.82
PRISTIGASTERIDAE	1	1.82
SCHILBEIDAE	4	7.27
SCIAENIDAE	2	3.64
SCIAENIDAE	1	1.82
SILURIDAE	1	1.82
SISORIDAE	1	1.82
TETRAODONTIDAE	1	1.82
Total	55	100.00

Table A10 : Fish species composition under various families in outside sanctuaries during the overall study period

Family	Number of species	%
AMBASSIDAE	2	2.94
ANABANTIDAE	1	1.47
APLOCHEILIDAE	1	1.47
BAGRIDAE	6	8.82
CHACIDAE	1	1.47
CHANNIDAE	1	1.47
CLUPEIDAE	4	5.88
COBITIDAE	2	2.94
CYPRINIDAE	17	25.00
ELEOTRIDAE	3	4.41
ERETHISTIDAE	1	1.47
GOBIIDAE	5	7.35
HEMIRAMPHIDAE	2	2.94

HETEROPNEUSTIDAE	1	1.47
LEIOGNATHIDAE	1	1.47
MASTACEMBELIDAE	3	4.41
MUGILIDAE	1	1.47
NANDIDAE	1	1.47
NOTOPTERIDAE	1	1.47
OPHICHTHIDAE	1	1.47
OSPHRONEMIDAE	1	1.47
POLYNEMIDAE	1	1.47
PRISTIGASTERIDAE	1	1.47
SCHILBEIDAE	4	5.88
SCIAENIDAE	2	2.94
SILURIDAE	2	2.94
SISORIDAE	1	1.47
TETRAODONTIDAE	1	1.47
Total	68	100.00

Appendix 3- Composition of fishes based on their habitat

Table A1: Composition of fish individuals based on habitat type

Study sites	Freshwater-estuary	Freshwater	Freshwater-estuarine-marine	Marine water-estuary
Chandpur	41.40%	41.40%	16.90%	0.20%
Shariatpur	18.70%	75.30%	5.30%	0.70%
Narayangonj	20.30%	77.90%	0.30%	1.50%
Munshiganj	25.60%	37.80%	36.50%	0.00%

Table A2 : Composition of fish species based on their habitat types in sanctuaries and outside sanctuaries..

Study sites	Fresh water	Freshwater, Estuary	Freshwater, Estuary, Marine water	Marine water, Estuary
Within Sanctuaries (S1& S2)	35.30%	50.60%	13.70%	0.40%
Outside sanctuaries(O1 & O2))	21.90%	66.00%	11.10%	1.10%

Appendix 4 –Composition of fishes based on their feeding type

Table A1 : Composition of fishes based on their feeding type in four study sites in overall study period

Study area	Distribution of individuals based on feeding type (%)		
	Carnivorous	Herbivorous	Omnivorous
Chandpur	21.07	53.97	24.95
Shariatpur	35.33	0	64.67
Narayangonj	15.78	57.59	26.63
Munshigonj	38.01	39.64	22.35

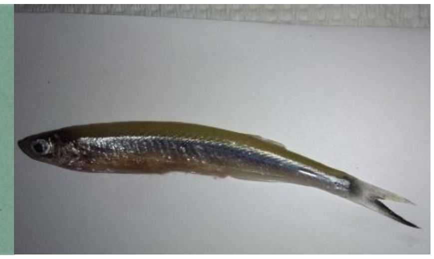
Table A2: Composition of fishes based on their feeding habit within and outside sanctuaries and control areas in overall study period.

Study area	Distribution of individuals based on feeding type (%)		
	Carnivorous	Herbivorous	Omnivorous
Within sanctuaries	22.77	51.95	25.28
Outside sanctuaries	13.64	56.97	29.39

Appendix 5 –A list of identified fish species

Puntius phutunio
(F. Hamilton, 1822)

Eleotris fusca
(Bloch & Schneider 1801)

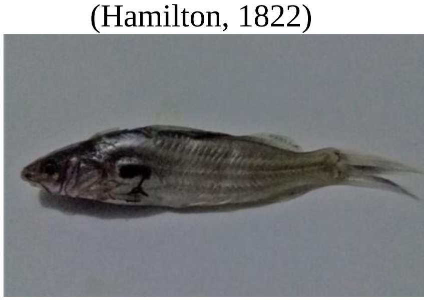


Salmostoma bacaila
(F. Hamilton, 1822)

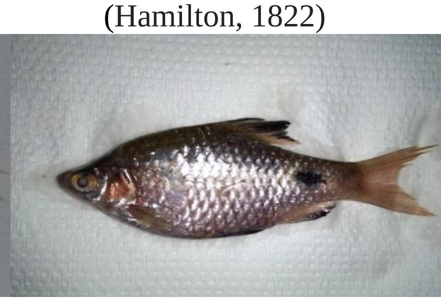
Chanda nama
(Hamilton, 1822)

Apolocheilus panchax
(Hamilton, 1822)

Apocryptes bato
(F. Hamilton, 1822)



Mystus tengara
(Hamilton, 1822)

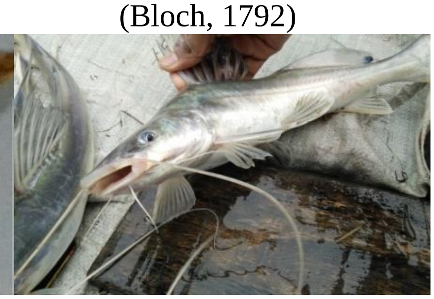


Pethia ticto
(Hamilton, 1822)

Anabas testudineus
(Bloch, 1792)

Mystus vittatus
(Bloch, 1797)

Rasbora daniconius
(Hamilton, 1822)



Sperata aor
(Hamilton, 1822)

Apocryptes serperaster
(Richardson, 1846)

Parambassis ranga
(Hamilton, 1822)

Chaca chaca
(F. Hamilton, 1822)

Gagata gagata
(Hamilton, 1822)

Leiognathus fasciatus
(Lacepède, 1803)

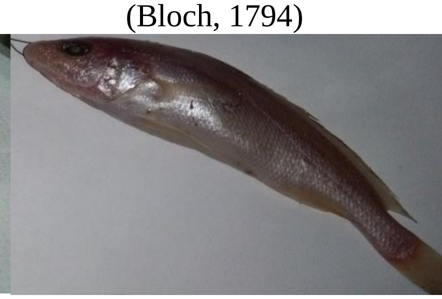
Gobius personatus
(Bleeker, 1849)

Gobius criniger
(Valenciennes, 1837)

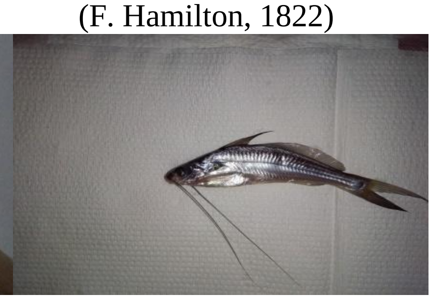
Heteropneustes fossilis
(Bloch, 1794)

Gudusia chapra
(F. Hamilton, 1822)

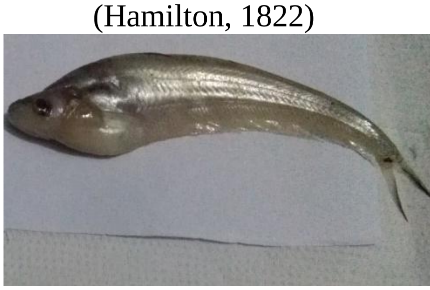
Mystus gulio
(Hamilton, 1822)



Panna microdon
(Bleeker, 1849)



Mystus cavasius
(Hamilton, 1822)



Ompok bimaculatus
(Bloch, 1794)

Macrognathus aculeatus
(Bloch, 1786)

Osteobrama cotio
(Hamilton, 1822)

Glossogobius giurus
(Hamilton, 1822)

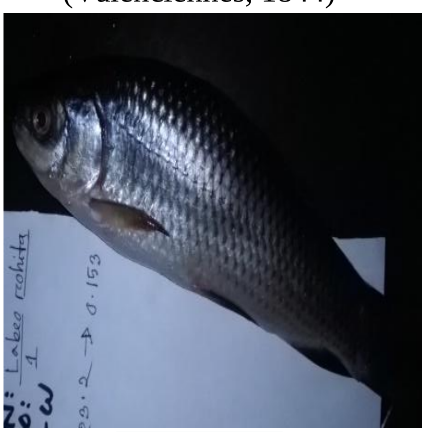
Pisodonophis cacrivorus
(Richardson, 1848)

Lepidocephalichthys guntea
(Hamilton, 1822)

Puntius stigma
(Valenciennes, 1844)

Gobioides rubicundus
(F. Hamilton, 1822)

Pseudambassis baculis
(Hamilton, 1822)



Labeo rohita
(F. Hamilton, 1822)

Corica soborna
(Hamilton, 1822)

Clupisoma garua
(Hamilton, 1822)

Setipinna phasa
(F. Hamilton, 1822)

Silonia silondia
(Hamilton, 1822) shilong

Ompok pabda
(Hamilton, 1822)

Gonialosa manmina
(Hamilton, 1822)

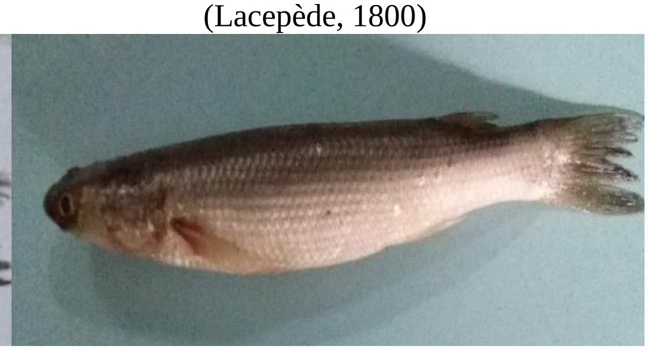
Acentrogobius viridipunctatus
(Valenciennes, 1837) Spotted green goby

Nandus nandus
(Hamilton, 1822)

Notopterus notopterus
(Pallas, 1769)

Mastacembelus armatus
(Lacepède, 1800)

Systomus sarana
(Hamilton, 1822)



Rhinomugil corsula
(Hamilton, 1822)

Johnieops vogleri
(Bleeker, 1853) meto poa

Oxygaster phulo
(Hamilton, 1822)

Sperata seenghala
(Sykes, 1839)

Gagata gagata
(Hamilton, 1822)

Rita gogra
(Sykes, 1839)

Eutropiichthys murius
(Hamilton, 1822) Muri bacha

Channa striatus
*(*Bloch, 1794)

Barilius vagra
(Hamilton, 1822)

Aspidoparia jaya
(Hamilton, 1822)

Gibelion catla
(Hamilton, 1822)

Apocryptes lanceolatus
(Bloch & Schneider, 1801)

Cirrhinus cirrhosus
(Bloch, 1795)

Tenualosa ilisha.
(Hamilton, 1822)

Labeo calbasu
(Hamilton, 1822)

Johnius coitor
(Hamilton, 1822)

Erethistes pusillus
(Müller & Troschel, 1849)