*Journal of South Pacific Agriculture, Volume 24, 2021*
http://www.journalofsouthpacificagriculture.com/index.php/JOSPA

# Diversity assemblages of fish genetic resources and conservation necessities in *Hakaluki Haor*, an ecologically sensitive natural wetland in north-eastern Bangladesh

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## ABSTRACT

Natural wetlands of Bangladesh are of great ecological importance and provide tremendous potential for inland freshwater fisheries. However, detailed assessment of fish diversity assemblages are scant. A comprehensive study was undertaken to evaluate the existing fisheries resources and biodiversity of one of the ecologically critical wetland ecosystem in Bangladesh, the *Hakaluki Haor*. Data were collected from 100 fishermen randomly from the whole study area using participatory rural appraisal tools including Focus Group Discussion (FGD), questionnaire surveys of different stakeholders and spot visit to local fish markets in haor area covering two Sub-districts viz. Kulaura and Barlekha of Moulvibazar district. A total of 57 fish species belonging to 42 genera, 23 families and 7 taxonomic orders were reported by the local fishermen; of which 35.08% species were Cypriniformes, followed by Perciformes (26.32%), Siluriformes (21.05%), Synbranchiformes (7.01%), Clupeiformes (5.26%), Osteoglossiformes (3.50%) and Anguiliiformes (1.75%). Further, among the identified taxa 15.79% fish species were reported as Commonly Available Species (CAS), while Moderately (MAS), Less (LAS) and Rarely Available Species (RAS) were accounted for 26.32, 36.84 and 21.05% respectively. Besides, 22.80% of the total species have been found Threatened. In addition, our study noted around 30 different types of fishing gears used by local fishers. According to the report of the fisher groups, inefficient management and policy implications, non-compliance to fisheries laws, extreme climatic events, siltation and transformation to agricultural lands, poor awareness and shortage of alternate income generating sources are the major factors responsible for declining fish species diversity in *Hakaluki Haor*. The overall findings of the study is extremely alarming for fish biological diversity of this wetland. All the stakeholders interviewed highly recommended to strengthen integrated wetland management practices for restoring threatened natural ecosystem and conserving fish biodiversity at *Hakaluki Haor* wetland.

**Keywords:** *Hakaluki Haor*, natural wetland, fish genetic resources, biodiversity degradation

## INTRODUCTION

Bangladesh is blessed with exclusively rich and diverse inland and marine water resources (Iqbal et al., 2015). Country's freshwater bodies like ponds, natural depressions (*haors and beels*), lakes/*baors*, canals, rivers, and estuaries are home of at least 253 fish species and cover around 4.64 million ha area (Department of Fisheries (DoF), 2012; International Union for Conservation of Nature (IUCN), 2015). Fish, Bangladesh's second most valuable agricultural produce, is crucial to the life and livelihoods of millions of people (DoF, 2018; Hasan et al., 2021). Contribution of capture fisheries and aquaculture in national food security and rural diets through providing protein-rich food is noteworthy (Haque et al., 2021). Accordingly, the government of Bangladesh has prioritized the development of the fisheries sector in order to ensure food and nutrition security and income generation opportunities for the country's rapidly rising population.

Internationally, Bangladesh ranked 3rd in inland open water capture fisheries production (Food and Agriculture Organization (FAO), 2018). Although total fish production has increased over time the proportionate growth of capture fisheries has decreased (DoF, 2018). Capture fisheries production depends significantly on different open water resources such as rivers, natural depressions (*haors and beels*) and floodplains (Aziz et al., 2021). As a highly productive natural source of livelihoods, *haor* supports millions of poor people. Fishing communities, in particular, rely on *haor* fisheries-related activities such as fish capturing, trading and drying, and weaving nets to make a living (Iqbal et al., 2015). Moreover, *haors* represent about 10% of Bangladesh's total capture fisheries production though this percentage has been declining over time (DoF, 2018; Aziz et al., 2021).

The *Hakaluki Haor*, located in north-eastern Bangladesh, is one of Asia's largest and unique inland freshwater ecosystem with national and international significance due to its rich and diverse aquatic and terrestrial resources (Hussain, 2021). As a resviour of diverse flora and fauna, it performs a significant role in sustaining genetic and ecological biodiversity. In addition, there is an appreciable assemblage of rare, vulnerable and endangered aquatic animal and plant species. However, a number of species from this ecosystem have already gone extinct due to gradual decline of habitat and extensive exploitation of natural resources (DoF, 2016). Consequently, the

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Government of the Bangladesh declared *Hakaluki Haor* as an Ecologically Critical Area in 1999. Unfortunately, once a source of plentiful aquatic resources covered with swamp forest (Choudhury et al., 2005) is now becoming a fast-degraded landscape (Iqbal et al., 2015). Many of the *beels* in the *haor* ecosystem have been severely degraded and are no longer capable of serving as mother fisheries. An early study in 2005 reported about 100 fish species, with one-third of them being endangered (Choudhury et al., 2005). By 2009, this number had dropped to 75, indicating a clear loss of fish species diversity in *Hakaluki Haor* (Roy & Sharif, 2009). Fish species composition might be affected by a number of factors, including habitat destruction due to agricultural intensification, urbanization, environmental degradation and resource overexploitation (Belton et al., 2011).

All of these findings point to the importance of conducting extensive water body specific biodiversity studies in order to assess its current state and ensure its longterm management (Imteazzaman & Galib, 2013). Although numerous researches on fish biodiversity have been performed around the world (Goswami et al., 2012; Shinde et al., 2009a, b; Raghavan et al., 2008); however the number of such studies in Bangladesh is considerably lower (Galib et al., 2009; Mohsin et al., 2009; Rahman et al., 2016). Again, development of database is a pre-requisite for preparation of detailed fish inventory. Furthermore, in order to preserve biodiversity in a given area, we need to understand the fish assemblage. Therefore, the present study aims to carry out the fish assemblage description of the *Hakaluki Haor* and the factors responsible for these changes.

## MATERIALS AND METHODS

### Profile of the study area

The *Hakaluki Haor*, an intricate ecosystem, is consists of more than 238 inter-connecting beels or Jalmohals and located in the North-East part of Bangladesh, between latitude 24º35' N to 24 º45' N and longitude 92º00' E to 92º08' E (DoF, 2016). The haor extends over 18,000 ha during the rainy season (IUCN, 2004); however, the total area of *beels* shrinks to approximately 4600 ha in dry season and remains underwater for up to five to six months (Iqbal et al., 2015). Administratively it lies in five Upazila (subdistricts) of Sylhet and Moulvibazar district– the Fenchuganj and Golapganj from Sylhet and the Barlekha, Juri, and Kulaura from Moulvibazar (IUCN, 2004; Rahman et al. 2016). This study was conducted in two Upazilas of Moulvibazar district viz. Kulaura and Barlekha Shown in Figure 1.

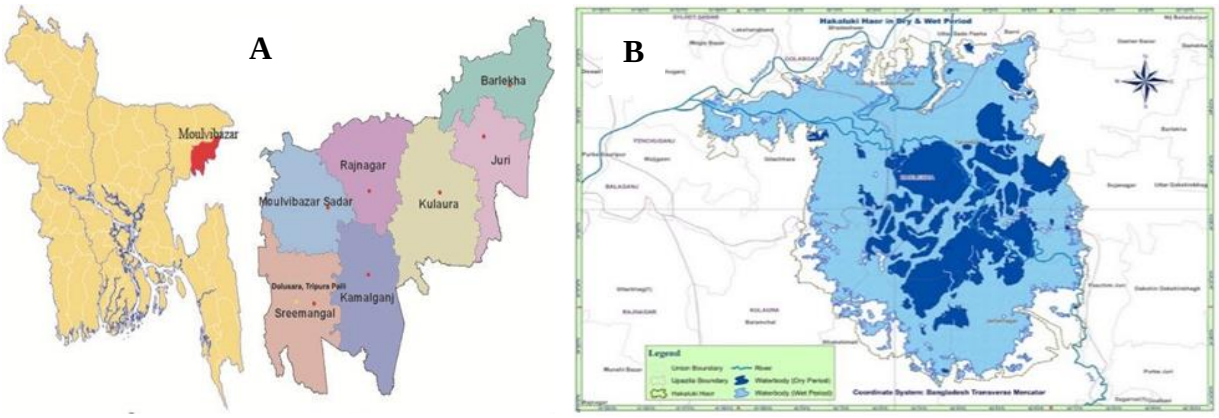


**Figure 1.** Map showing Moulvibazar district with Kulaura and Barlekha Upazila **(A)** and *Hakaluki Haor* in dry and wet season **(B)** (IWM 2020)

### Data collection and survey methodology

For collection of data in *Hakaluki Haor* areas, the survey was carried out in aforementioned upazila's from 15th February to 30th April, 2021. Data were collected from 100 fishermen and other stakeholders using participatory rural appraisal tools including Focus Group Discussion (FGD), direct interviews of different stakeholders viz. Key Informant Interview (KII), Personal Interview (PI) and spot visit to fish landing centers. Public consultation and interviews were made using several sets of pre-structured and pre-tested questionnaires. Fishermen were randomly selected to generate information related to fish species diversity. Total 5 FGDs, each composed of 20 fishermen, were carried out within the study site. Again, Personal Interviews (PIs) were conducted among alit person (i.e. local inhabitants) and fish traders at landing centers and local markets. Total 10 alites and 10 fish traders were interviewed. Further, Key Informant Interview (KII) were conducted with Upazila Fisheries Officers (UFO) of Barlekha and

Kulaura upazila. During the study period, a total of 4 fish landing centers/local fish markets were visited namely Kanongo bazar, Pakhiala bazar, uttar bazar and Loskorpur bazar.

All these interviews covered physical characteristics of *Hakaluki Haor*; present status of fisheries resources, fish and habitat diversity of the *haor*; potential causes of fish biodiversity and habitat degradation; government role and involvement in *haor* management; suggestive mitigating measures as well as overall improvement of *haor* ecosystem diversity and conservation of fish genetic resources in *Hakaluki Haor* wetland. A comprehensive list of the available fishes in the study area was compiled based on fishermen's answers and cross-checked by experienced fishers as well as Upazila Fisheries Officers. The fish species were then identified based on expert knowledge sharing, secondary document consultation and finally fine-tuned by cross-checking with the IUCN Red List of Bangladesh Freshwater Fishes (IUCN 2015).

### Statistical analysis

SPSS (Statistical Packages for Social Sciences, Version-25) and Microsoft Office Excel 2013 softwares were used for data curation and analysis.

## RESULTS

### Fish species composition

A total of 57 fish species belonging to 42 genera, 23 families and 7 taxonomic orders were recorded in the study area; of which 09 fish species (15.79%) were listed as Commonly Available Species (CAS), 15 fish (26.32%) as Moderately Available Species (MAS), 21 fish (36.84%) as Less Available Species (LAS), and 12 fish (21.05%) as Rarely Available Species (RAS) (Table 1, Figure 2). Again, from this study, Cypriniformes (carps and minnows) was found as the most represented taxonomic order comprising 35.08% of the total number of species; followed by Perciformes (26.31%), Siluriformes (21.05%), Synbranchiformes (7.01%), Clupeiformes (5.26%), Osteoglossiformes (3.50%) and Anguiliiformes (1.75%), representing 20, 15, 12, 4, 3, 2 and 1 species respectively (Table 1, Figure 3).

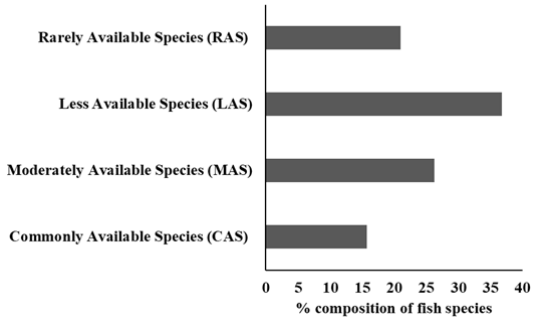


**Figure 2.** Proportional distribution of available fish species in different categories

Besides, Cyprinidae with 16 fish species constituting 28.07% of the total recorded species was found as the most dominant family. Bagridae with 5 species (8.77%) is the 2nd highest next to Cyprinidae. Other diverisified families were Channidae (7.01%), Clupeidae (5.26%), Mastacembelidae (5.26%), Osphronemidae (5.26%), Siluridae (5.26%), Ambassidae (3.50%), Cobitidae (3.50%), Notopteridae (3.50%), Schilbeidae (3.50%). Further, only one species belonged to family Anabantidae**,** Anguillidae, Aplocheilidae, Badidae, Balitoridae, Belontidae, Centropomidae, Clariidae, Gobiidae, Heteropneustidae, Nandidae and Synbranchidae (Table 1). According to the fishermen, fish species with highest representation in the catch included Striped dwarf catfish, Nama chanda, Mola carplet, Ganges River-sprat and Pool barb. In against, the species with lowest representation were Long-whiskered catfish, Rita and Hilsa.

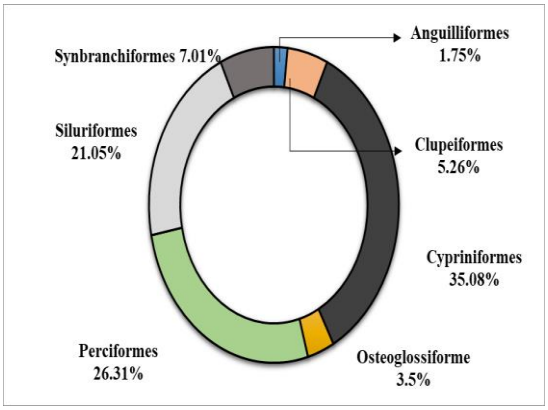


**Figure 3.** Contribution of different fish taxonomic orders in the study area of *Hakaluki Haor*

**Table 1. List of different fish taxa with scientific identity, local or vernacular Bengali and common English name, availability status in *Hakaluki Haor*** (Status Code according to IUCN 2015: CR- Critically Endangered, EN- Endangered, VU- Vulnerable, NT- Near Threatened, LC- Least Concern, DD- Data Deficient, NE- Not Evaluated)

| Sl. No. | Taxonomic Order | Family | Vernacular Bengali Name | English Name | Scientific Name | IUCN Status in BD | IUCN Global Status |
|---|---|---|---|---|---|---|---|
| ***Commonly Available Species (CAS)*** | | | | | | | |
| 1 | Clupeiformes | Clupeidae | Kechki | Ganges River-sprat | *Corica soborna* | LC | LC |
| 2 | Cypriniformes | Cyprinidae | Jati-punti | Pool barb | *Puntius sophore* | LC | LC |
| 3 | Cypriniformes | Cyprinidae | Mola | Mola carplet | *Amblypharyngodon mola* | LC | LC |
| 4 | Perciformes | Ambassidae | Nama chanda | Elongate glass-perchlet | *Chanda nama* | LC | LC |
| 5 | Perciformes | Anabantidae | Koi | Climbing perch | *Anabas testudineus* | LC | DD |
| 6 | Perciformes | Channidae | Taki | Spotted snakehead | *Channa punctatus* | LC | LC |
| 7 | Siluriformes | Siluridae | Boal | Freshwater shark | *Wallago attu* | VU | NT |
| 8 | Siluriformes | Bagridae | Tengra | Striped dwarf catfish | *Mystus vittatus* | LC | LC |
| 9 | Synbranchiformes | Synbranchidae | Kuchia | Swamp eel | *Monopterus cuchia* | VU | VU |
| ***Moderately Available Species (MAS)*** | | | | | | | |
| 10 | Cypriniformes | Cyprinidae | Chap chela | Indian glass barb | *Chela laubuca* | LC | NE |
| 11 | Cypriniformes | Cyprinidae | Darkina | Indian flying barb | *Esomus danricus* | LC | LC |
| 12 | Cypriniformes | Cyprinidae | Kalibaus | Black rohu | *Labeo calbasu* | LC | LC |
| 13 | Cypriniformes | Cyprinidae | Kanchan punti | Rosy barb | *Pethia conchonius* | LC | LC |
| 14 | Cypriniformes | Cyprinidae | Katal | Catla | *Catla catla* | LC | NE |
| 15 | Cypriniformes | Cyprinidae | Rui | Rohu | *Labeo rohita* | LC | LC |
| 16 | Cypriniformes | Cyprinidae | Teri puti | One spot barb | *Puntius terio* | LC | LC |
| 17 | Cypriniformes | Cobitidae | Gutum | Guntea loach | *Lepidocephalichthys guntea* | LC | LC |
| 18 | Cyprinodontiformes | Aplocheilidae | Kanpona | Blue Panchax | *Aplocheilus panchax* | LC | LC |
| 19 | Perciformes | Channidae | Shol | Striped snakehead | *Channa striatus* | LC | LC |
| 20 | Perciformes | Channidae | Telo taki | Walking snakehead | *Channa orientalis* | LC | LC |
| 21 | Perciformes | Nandidae | Meni | Gangetic leaffish | *Nandus nandus* | NT | LC |
| 22 | Siluriformes | Clariidae | Magur | Walking catfish | *Clarias batrachus* | LC | LC |
| 23 | Siluriformes | Schilbeidae | Kajoli | Gangetic Ailia | *Ailia coila* | LC | NT |
| 24 | Synbranchiformes | Mastacembelidae | Tara baim | One-stripe spinyeel | *Macrognathus aculeatus* | NT | NE |
| ***Less Available Species (LAS)*** | | | | | | | |
| 25 | Clupeiformes | Clupeidae | Chapila | Indian river shad | *Gudusia chapra* | VU | LC |
| 26 | Cypriniformes | Balitoridae | Balichata/Biltari | Mottled loach | *Acanthocobitis botia* | LC | LC |
| 27 | Cypriniformes | Cobitidae | Rani/Bou | Bengal loach | *Botia dario* | EN | NE |
| 28 | Cypriniformes | Cyprinidae | Bata | Bata labeo | *Labeo bata* | LC | LC |
| 29 | Cypriniformes | Cyprinidae | Chala punti | Chola barb | *Puntius chola* | LC | LC |
| 30 | Cypriniformes | Cyprinidae | Mrigel | Mrigal | *Cirrhinus cirrhosus* | NT | VU |
| 31 | Cypriniformes | Cyprinidae | Narkeli chela | Large razorbelly minnow | *Salmophasia bacaila* | LC | LC |
| 32 | Osteoglossiformes | Notopteridae | Chital | Clown knife fish | *Chitala chitala* | EN | NT |
| 33 | Osteoglossiformes | Notopteridae | Foli | Grey featherback | *Notopterus notopterus* | VU | LC |
| 34 | Perciformes | Belonidae | Kakila | Asian needlefish | *Xenentodon cancila* | LC | NE |
| 35 | Perciformes | Gobiidae | Bele | Gangetic tank goby | *Glossogobius giuris* | LC | LC |
| 36 | Perciformes | Osphronemidae | Khailsa | Striped gourami | *Trichogaster fasciata* | LC | LC |
| 37 | Perciformes | Osphronemidae | Lal Khailsa | Dwarf gourami | *Trichogaster lalius* | LC | LC |
| 38 | Siluriformes | Bagridae | Bujuri Tengra | Striped dwarf catfish | *Mystus tengara* | LC | LC |
| 39 | Siluriformes | Bagridae | Kabasi tengra | Gangetic mystus | *Mystus cavasius* | LC | LC |
| 40 | Siluriformes | Heteropneustidae | Shing | Scorpion/Stinging catfish | *Heteropneustes fossilis* | LC | LC |
| 41 | Siluriformes | Schilbeidae | Batasi | Indian potasi | *Pseudeutropius atherinoides* | LC | LC |
| 42 | Siluriformes | Siluridae | Madhu pabda | Pabda catfish | *Ompok pabda* | EN | NT |
| 43 | Siluriformes | Siluridae | Kani pabda | Butter catfish | *Ompok bimaculatus* | EN | NT |
| 44 | Synbranchiformes | Mastacembelidae | Baim | Zig-zag eel | *Mastacembelus armatus* | EN | NE |
| 45 | Synbranchiformes | Mastacembelidae | Guchi | Barred spinyeel | *Macrognathus pancalus* | LC | LC |
| ***Rarely Available Species (RAS)*** | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 46 | Anguilliformes | Anguillidae | Banehara | Indian Mottled Eel | *Anguilla bengalensis* | VU | NT |
| 47 | Clupeiformes | Clupeidae | Ilish | Hilsa | *Tenualosa ilisha* | LC | LC |
| 48 | Cypriniformes | Cyprinidae | Dhela | Cotio/Dhela | *Osteobrama cotio* | NT | LC |
| 49 | Cypriniformes | Cyprinidae | Mola punti | Glass barb | *Puntius guganio* | LC | LC |
| 50 | Cypriniformes | Cyprinidae | Phulo-chela | Finescale razorbelly minnow | *Salmostoma phulo* | NT | LC |
| 51 | Perciformes | Ambassidae | Lal Chanda | Highfin glassy perchlet | *Pseudambassis lala* | LC | NE |
| 52 | Perciformes | Badidae | Napit koi | Blue perch | *Badis badis* | NT | LC |
| 53 | Perciformes | Centropomidae | Ranga chanda | Indian Glass Perch | *Pseudambassis ranga* | LC | LC |
| 54 | Perciformes | Channidae | Pipla shol | Barca snakehead | *Channa barca* | CR | DD |
| 55 | Perciformes | Osphronemidae | Chuna Khalisha | Honey gourami | *Trichogaster chuna* | LC | LC |
| 56 | Siluriformes | Bagridae | Ayre | Long-whiskered catfish | *Sperata aor* | VU | LC |
| 57 | Siluriformes | Bagridae | Rita | Rita | *Rita Rita* | EN | LC |

**Distribution of available fish species on IUCN red list**

The percent distribution of fish species found in *Hakaluki Haor* in different IUCN categories has shown in Figure 4. During the study period, a total of 13 threatened fish species (6 vulnerable, 6 endangered, and 1 critically endangered) belonging to 10 families were reported in the study area which was 22.80% of the total species reported. However, of all the fish species found, 66.66% fell into the "Least Concern (LC) category with 10.52 % being Near Threaned (NT), Vulnerable (VU), Endangered (EN) edangered, and 1.75 % critically endangered (CR).

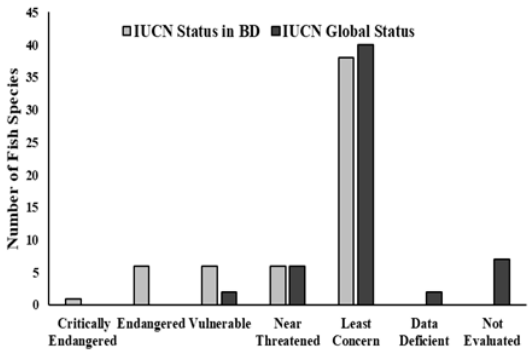


**Figure 4.** Status of available fish species of *Hakaluki Haor* in different categories according to IUCN (2015)

**Present fishing practices and fishing gears**

In order to determine the impact of fishing practices and gears on existing fisheries resources and biodiversity, current fishing practices and gears were given due importance while interviewing different stakeholder groups. The survey found around 30 different types of fishing gears used in the *Hakaluki Haor* throughout the year, which can be further categorized into four major groups viz. nets, traps, wounding gears and hook and lines (Table 2). Some of the gears are species specific, while others caught multiple species during the operation indicating the multispecies nature of the fishing. These gears, many of which are locally known by several names vary in size, shape; and are used in different seasons for fish harvesting. Aside from these gears, pump fishing and hand picking have been observed too. Different sorts of materials are utilized to manufacture these fishing tools including fibre and nylon net, twine, fasteners, clips and swivels, ropes, steel wire ropes, combination wire ropes, polyester, polyethylene, nylon, cotton, mixed fibers, floats and sinkers, barbed and barbless iron stick, bamboo, wood etc. (Table 2).

Acccording to the fishermen, the highest number of fish species are caught by fishing nets. Around 15 types of nets are used by local fishermen. Rui, Catla, Mrigal, Barbs, Large Razorbelly Minnow, Orange Fin Labeo, Loach, Snakeheads, Catfishes, Dwarf Gourami, Gora-chela etc. are the most common species caught using these nets. On the other hand, 7 fishing traps of different sizes and shapes were found in *Hakaluki Haor*. Various kinds of large and small fish species including Small Prawn, Barbs, Glassy Perchlets, Catfishes, Zig-Zag Eel are caught by these fishing traps. Furthermore, different types of hook and lines are also commonly used for fishing. Fish species like Wallago Catfish, Climbing Perch, Spotted Snakehead, Snakehead Murrel and Zig-Zag Eel are caught by them. In against, both small and large fishes are caught by different wounding gears. More details on fishing gear used for fish catching in *Hakaluki Haor* are described in Table 2.

**Potential causes of fish biodiversity decline in *Hakaluki Haor***

During consultation and discussion meetings with concerned stakeholders one of the important quarries were asked regarding potential causes of fish biological diversity degradation of *Hakaluki Haor* wetland. In reply, each group members were telling in detail the reasons behind those facts and majority of their opinion were almost similar which has shown in Figure 5. Broadly, the factors responsible for fish biodiversity decline in *Hakaluki Haor* can be categorized into three major groups i.e. anthropogenic, socioeconomic, and climatic factors.

**Table 2.** Fishing Gears Used in *Hakaluki Haor*

| Group Name | English Name | Bangla Vernacular Name | Materials Used | Species Caught |
|---|---|---|---|---|
| Fish Net | Drift net | Current jal | Synthetic twine, rope, float, sinkers | All types and size of fishes |
| | Push net | Thela jal | Bamboo pole, synthetic twine, rope | Small fishes |
| | Lantern net | Chabi jal | Bamboo stick, synthetic twine, rope | Small to medium size fishes |
| | Lift net | Dharma jal | Bamboo stick, synthetic twine, rope | Small to medium size fishes |
| | Seine net | Ber jal | Twine, float, rope | All types and size of fishes |
| | Fixed net | Gon Jal/Ghuraina Jal | Nylon, thick rope, floats, sinker | Small to large size fishes |
| | | Khora jal | Synthetic twine, rope, bamboo pole | Medium to large size fishes |
| | | Gor Jal | Nylon rope, bamboo pieces, plastic papers | All species which come through the current |
| | Drag net | Kodi Jal, Horhor Jal | Nylon net and rope, float, sinkers, bamboo pieces | Bottom dwelling species |
| | | Ichar Jal/ Ram Jal | Nylon net, nylon rope, bamboo | Mainly Prawn and small fishes |
| | Gill net | Koi Jal/ koiya Jal | Mono-filament fibre net, nylon rope, floats | Mostly Perch. Other species are also caught |
| | | Chela Jal | Mono-filament fibre net, nylon rope, floats, sinkers | Mainly large razorbelly minnow, Gora-chela |
| | Cast Net | Koni Jal/ Jhaki Jal | Natural fibre, Sinkers, Rope | Small indigenous species, IMCs, and others species |
| Fish trap | Basket trap | Baga, Cheng, Chandi bair | Bamboo plates and metallic wire | Small size fishes |
| | Box trap | Darkee | Bamboo plates and metallic wire | Small size fishes |
| | Tubular trap | Bair | Bamboo plates and metallic wire | Small size fishes |
| | Bush trap | Hogra | Bamboo plates and metallic wire | Small size fishes |
| | Cover pot | Polo | Bamboo sticks and metallic wire | Medium to large sizes fishes |
| Wounding gears | Hand harpoon | Ek-kata, Te-kata | Bamboo handle and barbed iron stick | Indian Major Carps (IMCs), Sankehaeds etc. |
| | | Koach | Bamboo handle and barbless iron prong | Indian Major Carps (IMCs), Sankehaeds, Catfishes etc. |
| Hook and Lines | Long Line | Tuni Borshi, Dori Borshi | Metallic iron hook and thread | Mainly Snakeheads and Catfishes |
| | Floating Hook | Dati Borshi, Bokha | Metallic iron hook and thread | Catfishes and snakeheads |
| | | Fol | Metallic iron hook and thread | Mainly Catfishes, Perches and Snakeheads |
| | Hook for Handling | Chip Borshi, Borshi | Metallic iron hook, Bamboo/Plastic handle and thread | Mainly IMCs, Catfishes, Perches, Snakeheads |

*Anthropogenic factors*

In this study, destructive anthropogenic activities, including the use of banned and illegal fishing gears, destructive fishing methods (fishing by dewatering of waterbodies, use of toxic chemicals), overfishing, fishing at breeding season, habitat destruction by conversion to agricultural lands, indiscriminate use of agricultural pollutants (pesticides, insecticides), irresponsible tourism practices, hunting of migratory and endemic birds showed positive relationship with reduced fish species diversity in *Hakaluki Haor*.

*Socioeconomic factors*

This study reported that extreme dependence of the inhabitants on natural resources of *Hakaluki Haor* has direct negative impacts on fish biodiversity. From FGDs, it was evident that many other socioeconomic factors like low literacy rate, non-compliance to fisheries laws, poor knowledge and understanding of fishers adversely affecting fish genetic resources of this critical wetland.

Introduction of improper Jalmohal leasing system in haor has found as a major threat to the biodiversity and fishing community. Further, our study revealed that poor management and policy implementation characterized by the unplanned construction of dams, roads, bridges and flood control drainage structures, non-transparent socio-political representation of Governments' departments and administrative bodies and lack of synchronized collaborative efforts make the scenario more complex. Moreover, political obstacles, lack of community participation in the discussion and decision making; low literacy rate, poor health, hygiene and sanitation facilities of inhabitants accelerated the risk towards sustainable management of this ecologically critical natural wetlands.

*Climatic factors*

During this study, extreme climatic events and other natural disasters e.g. siltation and sediment intrusion from upper hill deforestation, erratic and heavy rainfall, temperature fluctuations, drought, flash flood

and river erosion were found as focal climatic factors causing fish biodiversity degradation in *Hakaluki*.

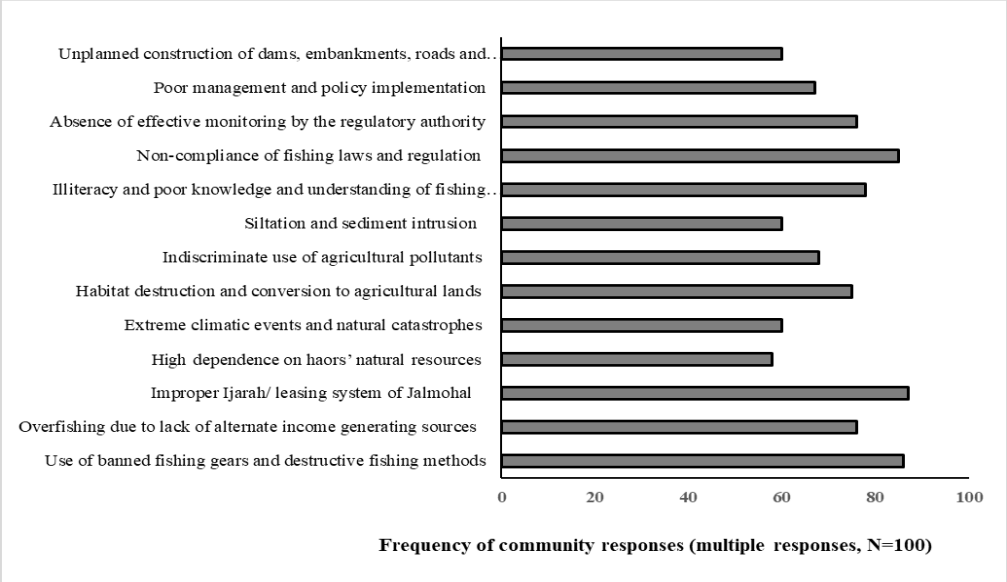


**Figure 5.** Major identified threats to fish biodiversity of *Hakaluki Haor* based on community responses

## DISCUSSION

*Hakaluki Haor* is one of the country's "Mother Fish Stocks" in terms of fish species diversity (Islam and Rahman, 2011; Alam et al., 2015). *Beels* in *Hakaluki Haor* provide winter shelter for the mother fisheries, which produce millions of fries for the downstream fishing communities in the early monsoon (Rahman et al., 2016). In addition, overall fisheries of the *haor* has significant importance to support natural fish production and livelihood of surrounding people (Islam and Rahman, 2011; Uddin et al., 2013). While interviewing the participants in all FGDs, PIs, KIIs and visiting fish markets, the main goal of this study was to determine the status of existing fish genetic resources, present fishing practices and factors affecting fish biodiversity decline and habitat degradation in *Hakaluki Haor*.

As reported by the respondents, total 57 fish species belonging to 42 genera, 23 families and 7 taxonomic orders were identified in the study area. Using similar participatory rural appraisal approaches, Iqbal et al. (2015) identified 83 fish species in *Hakaluki Haor* belonging to 55 genera, 28 families and 10 orders. Likewise, two other studies reported 75 and 82 fish species belonging to 9 and 10 taxonomic orders from the *Hakaluki Haor* (Sayeed et al., 2015; Rahman et al., 2016). In contrast, a survey reported 107 fish species in 1993 in *Hakaluki*; albeit the number declined to 75 in 2009 (IPAC, 2009; Roy and Sharif, 2009). Natural wetlands of Bangladesh, in particular, *haors* in the north-eastern region have considered as major reservoirs of freshwater fish species. Lately, this biodiversity are declining gradually (Rahman et al., 2015). Covering limited area along with short time sampling efforts might be associated with the lesser fish species composition in present study. Fish species count could be higher if continuous sampling round the year with expanded study area coverage was done. Notwithstanding, the findings of a number of studies are more or less aligned to our results. Similar to us, Rahman and Hasan (1992) reported 54 fish species from the *Kaptai* lake while Hussain (2021) recorded 57 fish species in the *Tanguar Haor*. Moreover, similar species composition (43, 58 and 60 fish species) was observed in different types of oxbow lake (Haque et al., 1999).

Again, Miah (2012) noticed order-wise average catch composition in *Hakaluki Haor* were Cypriniformes (54%), Perciformes (13%), Clupeiformes (11%), Channiformes (8%), Chingri (8%) and other orders (6%) which supported the findings of this study. These findings are almost aligned to Sunny et al. (2020) and Aziz et al. (2021). IUCN has listed 64 fish species of Bangladesh as threatened (IUCN Bangladesh, 2015). This wetland is a vital habitat and breeding ground for endangered fish species. Nonetheless, we found a declining fish populations similar to Hossain & Rabby (2020). In against, Iqbal et al. (2015) noticed 41 threatened fish species in *Hakaluki Haor* where 12 were vulnerable, 18 were endangered and 11 were critically endangered. These differences of results might be associated with the variety of extent of the studies.

In accordance to present findings, fishermen were reported to use approximately 30 fishing gears in Halti Beel (BCAS, 1991). However, Sunny et.al. (2020) found 14 types of fishing gears in both *Tanguar and Dekhar Haor*. These gears, many of

which are locally known by several names vary in size, shape; and are used in different seasons for fish harvesting which is supported by Zafar et al. (2007). Our findings are more or less coincided with the results of Rahman et al. (2010, 2016) and Debarshi et al. (2017). Ali et al. (2015) and Debarshi et al. (2017) observed similar type of traps at *BSKB beel* in Khulna and *Hakaluki Haor* in Moulvibazar respectively. This study revealed that a vast majority of fishermen unlawfully use various types of banned fishing nets and gears across the *Hakaluki Haor* wetland throughout all seasons. Our findings are agreed with those of Ali et al. (2014) and Ray et al. (2011). Further, exceedingly harmful lethal harpoons and light fishing are also employed to kill gravid fishes as found similar with Ahmed (2008) and Ahmed et al. (2008). Indeed, seine nets, mono filament nets, hook and line fishing, and other banned fishing tools are being used for fishing in such waterbodies all over the country (Alam et al., 2015).

Disappointingly, as evident from this study, the current biodiversity situation of *Hakaluki Haor* is in retrogression. Aquatic ecosystem imbalance, destruction of wetland habitat, degradation of natural fish breeding grounds as well as illegal massive harvest of fish by using various prohibited fishing nets and gears have contributed to the extinction of a substantial number of fish species in this natural habitat, resulting loss of fish genetic resources and posing a great risk to endemic fish species which is further supported by the findings of Oakkas et al. (2020). Similar reasons were also reported as major challenges to fish biodiversity conservation by Alam et al (2015) and Hussain (2021) in *Tanguar Haor*, another Ecologically Critical Wetland and Ramsar site of north-eastern Bangladesh. Therefore, concerns arise about the long term sustainability of the fish biodiversity because of poor institutional and organizational management (Sunny et al., 2020).

In our study, various destructive anthropogenic activities were found to reduce fish species diversity in *Hakaluki Haor*. Similar causes have also been identified by Alam et al. (2015) in *Tanguar haor* wetland. Harmful fishing gears like synthetic gill nets (current jal) and seine nets (ber jal) are used in *Hakaluki Haor* over the years. These along with some other methods (e.g., fishing by complete drying, use of chemicals) make fish and other aquatic organisms vulnerable to exploitation (Islam et al., 2018b). Furthermore, overfishing induced by inadequate income-generating sources and severe proverty is posing serious threat to fish stocks (Islam et al., 2016). *Hakaluki Haor* is in danger of losing nearly 32 fish species because of overfishing (Rahman et al., 2016). Further, around 190,000 people living the surrounding areas utilize the haors' natural resources year-round causing a decline in wetlands (Islam et al., 2011). The indiscriminate fishing by poor, illiterate and experienced fishers have serious consequences in terms of a reduction of fish species diversity in the haors (Iqbal et al. (2015). Moreover, improper *Jalmohal* leasing system, poor governance with top-down policy implication and corrupted socio-political management have exacerbated fisheries resources. These observations are in accordance with Sunny et al., (2020) and Aziz et al. (2021)

As feeding, migration, spawning, and other biological processes are all influenced by a complex set of water quality and weather parameters, fish production and diversity in natural waterbodies is very susceptible to climatic changes (Choudhury et al., 2005; Rahman et al., 2020). Insufficient water supply in the connected rivers and beels of the haor owing to sporadic rainfall hamper the broodfish migration from the deep water shelter to the breeding grounds, consequently affects the breeding activity, larval development (Das et al., 2007) and fish diversity (Chowdhury et al., 2010). Likewise, temperature fluctuations, another key climatic phenomenon, negatively influences fish species diversity by altering physico-chemical parameters of aquatic ecosystem and plankton productivity (Hassan et al. 2020). Further, siltation and sediment intrusion from upper hill deforestation collapsed fish migration routes and habitats, therefore adversely affecting fish production and livelihoods of local communities (Rana et al., 2010). The degradation has increased from 10% of the total beel area in 1980 to more than 75%, causing a steady decline in fisheries resources (Khan et al., 2011). What is more, continuous river erosion resulting from siltation and seasonal changes is worsening the situation. These findings are more or less convincing with the results of Hossain (2017) and Islam et al. (2018b) in Sundarban and Hossain (2013) in haor basins of north-eastern Bangladesh who identified different extreme climatic events including irregular rainfall, drought, river erosion, temperature fluctuations as potential factors causing biodiversity degradation.

## CONCLUSIONS AND RECOMMENDATIONS

Wetlands are the world's most productive ecosystems, supporting extensive food webs and a diverse range of species. Likewise, they also play crucial economic and ecological role in Bangladesh to support life and livelihoods by providing a variety of functions and products. However, it is concerning that the biodiversity of these natural wetlands is in grave danger of consecutive depletion. The present biodiversity status of the Hakaluki Haor is of no difference than other natural wetlands of the country. This study underscores that, various anthropogenic, socioeconomic, and climatic influences are the major threats for the productivity and ecological sustainability of this rich unique ecosystem resulting in serious degradation of fish genetic resources.

It is apparent from the discussions with different stakeholders of the studied area that improved wetland management framework were formulated and implemented by the government to conserve the haor ecosystem. Furthermore, relevant authorities have taken a number of measures including sustainable fishing, establishment of fish sanctuaries, banning of destructive fishing nets and gears, renovation of waterbodies and diversifying alternative income generating sources for fishermen. Nevertheless, management sortcommings and monitoring failure further aggravated the situation. Therefore, a sustainable and coordinated management strategy should be taken by involving all the stakeholders to restore threatened natural ecosystem and conserve fish biological diversity at Hakaluki Haor. Moreover, the findings of the present study could also be helpful to develop a guideline for planning and management of other ecologically vulnerable wetlands in Bangladesh.

## ACKNOWLEDGEMENTS

The authors would like to express their gratitude to fishermen, the staff of the Department of Fisheries (DoF) and other respected stakeholders for their help and support.

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