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RESEARCH PAPER

A Comprehensive Study on Small Indigenous Fish Species (SIS) Diversity, Availability, Conservation and Threatened Status in Sylhet *Haor* Basin, Bangladesh

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Haor, small indigenous species, population trend, conservation status, threats

Abstract

This study investigated diversity, availability, current status, population trend, threats and conservation status of SIS in floodplain-rich *haor* basin from September 2017 to April 2018. A total of 140 SIS belonging to 35 families and 89 genera were collected from 43 sampling sites (10 in *arats*/wholesale fish markets, 16 in retail markets, and 17 in fishing locations). Cypriniformes were the most diverse group. 47%, 29%, 14% and 9% of species were moderately available, commonly available, rarely available and abundantly available, respectively. Fish belonging to Cypriniformes and Siluriformes were under moderately available and rarely available categories. Carnivorous was dominant group (49%). National and global population trends of 44% and 13% recorded fish were declining (Perciformes, Siluriformes and Clupeiformes were dominant), whereas most of the species don't have enough biological information status. Out of the 140 species, 4 belong to 'critically endangered', 18 'endangered' and 14 'vulnerable' at national level, beside the order Osteoglossiformes, Sygnathiformes and Cypriniformes were more threatened. Additionally, *Mastacembelus oatesii* and *Rita rita* were endangered and *Channa orientalis* and *Barilius dogarsinghi* were vulnerable at the global level. Indiscriminate fishing, poisoning, illegal fishing, siltation, pollution and invasive species posed the greatest threat to fish diversity. Climate change is hard to predict and drastically changing fish habitats and putting SIS at risk. Eco-friendly modern fishing technology, restoration, and potent conservation measures are urgently needed at multiple scales to conserve the fish fauna.

INTRODUCTION

Bangladesh is endowed with different habitats for about 265 freshwater fish species, 150 of which are small indigenous species (SIS) (Rahman, 2005; Amin et al., 2009). SIS are those that reach a maximum mature length of 25 cm or 9 inches (Hossain & Afroze, 1991; Felts et al., 1996; Hussain et al., 1999). SIS is important for food and nutrition security because it is high in bioavailable micronutrients like vitamin A, iron, zinc, and calcium, which help impoverished people overcome malnutrition (Bogard et al., 2015; Fiedler et al., 2016; Thilsted & Wahab, 2014). Several SIS are regarded low-cost sources of protein, minerals, and vitamins in several Asian nations, including Bangladesh (Roos et al., 2007a, 2003; Fiedler et al., 2016; Nandi et al., 2013; Thilsted et al., 2016) and enhancing the quality of the wetland ecosystem (Aditya et al., 2012; Chandra et al., 2008; Halwart, 2006; Halwart & Gupta, 2004). It was observed that rural residents obtain 46% protein and 31% calcium from small fish (Roos et al., 2007b). SIS can be found in practically every water body in Bangladesh, but their survival is threatened nowadays by indiscriminate fishing gear, which puts many SIS at risk of extinction (Hanif et al., 2016).

The world is currently under extreme strain on aquatic biodiversity, and SIS is no exception. About 25.3% of freshwater fish species are threatened in Bangladesh (IUCN

Bangladesh, 2015). Very few studies have baseline data on the prevalence and distribution of SIS (Samad et al., 2013; Hanif et al., 2016; Kostori et al., 2011; Rownok et al., 2014). Despite the high number of threatened small native fish species in Bangladesh, there is little concern regarding the continuous reduction of SIS biodiversity (Hanif et al., 2016). Overexploitation, habitat degradation, water pollution, channel fragmentation, and sedimentation all pose a significant threat to SIS (Baishya et al., 2016). Regarding human nutrition, ecological balance, the long-term viability of SIS, and a healthy aquatic environment, it is crucial to conduct a comprehensive assessment of SIS in each aquatic watershed. The *haor* of Sylhet division is a large branch that provides important habitats for fisheries, particularly for SIS. The relevance of acquiring information on SIS can be linked to sustainability, as these fish resources must be utilized in a sustainable manner for future generations (Saha et al., 2018). Sound management of fisheries resources requires understanding the variety of fish in the water (Huda et al., 2009). In the northeastern region of Bangladesh, notably in the entire Sylhet division, detailed studies on small indigenous fish biodiversity are still lacking. However, considering the future potential of SIS in Bangladesh, the current research aims to provide information on the diversity, availability, current status, population trend, threats and conservation status of SIS in Sylhet Division, Bangladesh.

MATERIALS and METHODS

Study Area and Data Collection Framework

The investigation was conducted in the greater Sylhet division from September 2017 to April 2018. The study's sampling locations were divided into three categories, based on their physical similarities (10 fish *arats*/wholesale fish markets, 16 retail fish markets, 17 fishing spots) (Figure 1). The information about prevailing fish species was collected through FGD (Focus Group Discussion) with commercial fishing boat owners, fishermen, auctioneers/wholesalers, retailers, local people, riverside colonials, and other upcoming people from the sampling spots. In addition, discussions were held on fish landing centers, fish markets, and fishery villages with a semi-structured questionnaire.

Fish were sampled from the fishing zones, landing centers, *arats*/wholesale markets, and retail markets as well. The ethical approach recommended by the 'Ethical Approval Committee of Bangladesh Agricultural University Research System (BAURES) was followed in the instance of live fish sampling. Fresh samples were collected and preserved in an icebox with

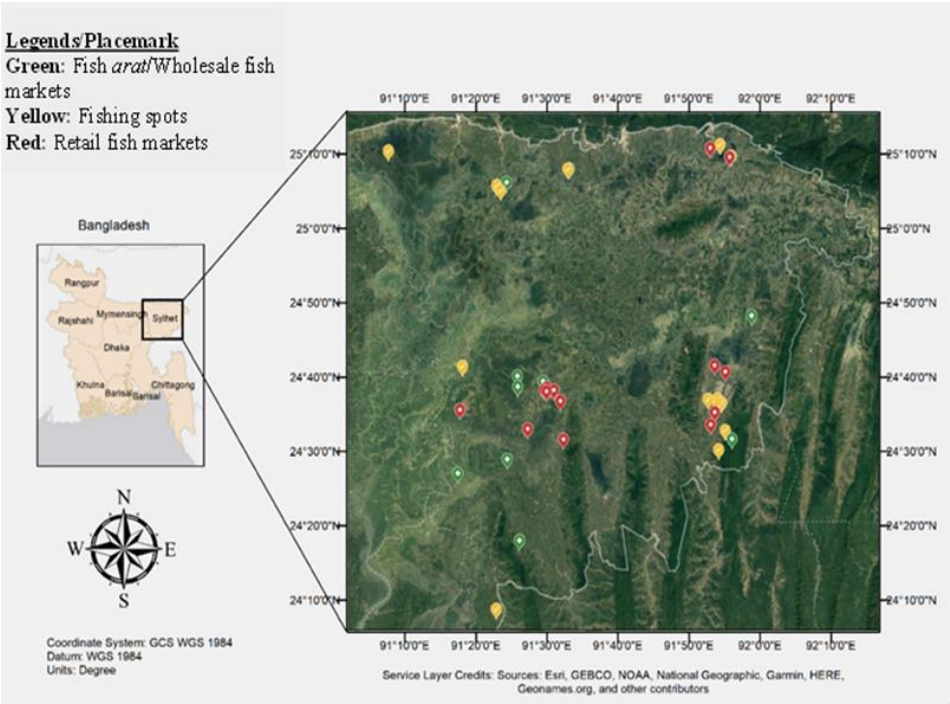

Figure 1. Sampling map and coordinates of sampling sites in Sylhet *haor* basin.

crushed ice before being transferred to the laboratory and identified up to the genus level using standard literature (Froese and Pauly, 2015; IUCN Bangladesh, 2015; Rahman, 2005).

The data on trophic categories (omnivores, carnivores, planktivorous, herbivorous, larvivores, and insectivorous), existing habitat (a dweller of riverine habitats as well as hill streams, migratory, estuaries, and floodplains) and population trends were studied by IUCN Bangladesh (2015), the Web-based database like *FishBase* (Froese and Pauly, 2015) and published articles (DoF, 2018; Pandit et al., 2021; Sarker et al., 2022; Lakra et al., 2010). The present status of SIS was classified into 4 groups namely abundantly available (AA); available throughout the year (species presence: 76–100%); commonly available (CA); frequently found in small numbers throughout the year (species presence: 51–75%); moderately available (MA); infrequently seen in the study area (species presence: 26–50%) and rarely available (RA); found intermittently in very limited number (species presence: 1–25%) were considered based on respondent's observations and species presence (%) (Jadhav et al., 2011; Myers, 1949). The commercial value of the species collected was determined by using criteria specific to their use as food (including adequate growth in unit time and reaching maximum size), sport (including angler preference), or ornamentation (including beautiful color, shape, and size, banding pattern, hardiness, transparent body, calm behavior, and adhesive suckers). The conservation status of species was recorded by following the IUCN Red List of Bangladesh (2015) and Global Red List of Threatened Species (IUCN, 2022). Primary (direct observations and conversations with respondents) and secondary sources were used to collect information on the threats to the small indigenous fish fauna.

Data Analysis

The contribution of orders, families, trophic category, habitat groups, commercial value, present status, national and global population trend and their present conservation status was calculated by the following equation: $F_0 = (N/n) \times 100$. Where, F_0 is the contribution of occurrence (%), N; the category to be determined (order, family, or conservation status) and n; total number of species.

RESULTS and DISCUSSION

Diversity of Fish Species

In total, 43 sampling sites comprised 140 small indigenous fish species classified into 89 genera, 35 families, and 12 orders (Table 1). Due to the paucity of studies on small native fish biodiversity in the floodplain-rich Sylhet belt of Bangladesh, it is difficult to compare the current results to prior studies. The role of SIS in aquaculture, nutritional value, biological importance, reproductive status, and conservation has received less consideration (Paul and Chanda, 2015). In comparison to other rivers of Bangladesh that have been studied by various authors (Joadder et al., 2015; Arefin et al., 2018; Islam et al., 2019; Gain et al., 2015), the current study found greater SIS species. The overabundance of fish species may have impacted the observed image of species diversity throughout the study period as a result of adequate sample area coverage and the use of several sampling techniques and activities. The interconnectedness of freshwater reservoirs, like streams, floodplains, *haor*s, and various landscape areas, as well as hydrographic conditions, climate patterns and suitable habitats play a major role in driving species abundance and SIS movement (Ray & Grassle, 1991; Saha et al., 2018).

The present study revealed that 3 orders accounted for 83.57 % were found to be dominant. Cypriniformes (40 %), Siluriformes (27.85 %) and Perciformes (15.71 %) (Figure 2). Figure 3 summarized 5 families accounted for 56.43 % and documented as the leading families of the total family found. Cyprinidae was dominant with 39 species (27.85 %), followed by Sisoridae (8.57 %); Bagridae (7.85 %); Cobitidae (7.14 %) and Schibeidae (5 %). Other remaining families (21 families) were represented by 19.29 % species in total. Cypriniformes and Cyprinidae were the dominant common taxa of SIS community documented in different water bodies in Bangladesh (Chaki et al., 2014; Galib et al., 2010; Kostori et al., 2011; Hanif et al., 2016) similar to other Asian rivers (Baishya et al., 2016; Saha et al., 2018; Fu et al., 2003; De Silva, 2007). Rahman (2005) highlighted Cyprinidae under Cypriniformes as the most populous species-rich family among all freshwater fish families in Bangladesh. However, the proportion of dominant species in waterbodies may vary

Table 1. Small indigenous freshwater fish diversity in Sylhet Division.

Order	Family	Genera	Species
Perciformes	Anabantidae	1	1
	Ambassidae	3	5
	Badidae	1	1
	Gobiidae	3	3
	Nandidae	1	1
	Osphronemidae	4	6
	Sciaenidae	3	3
	Channidae	1	2
Siluriformes	Amblycipitidae	1	1
	Bagridae	5	11
	Chacidae	1	1
	Clariidae	1	1
	Erethistidae	1	1
	Heteropneustidae	1	1
	Olyridae	1	1
	Schilbeidae	5	7
	Siluridae	1	3
	Sisoridae	8	12
Anguilliformes	Moringuidae	1	1
	Ophichthidae	2	2
Cyprinodontiformes	Aplocheilidae	1	1
Beloniformes	Belonidae	1	1
	Hemiramphidae	2	2
	Adrianichthyidae	1	1
Pleuronectiformes	Soleidae	1	1
Cypriniformes	Cobitidae	6	10
	Balitoridae	4	6
	Cyprinidae	17	39
	Psilorhynchidae	1	1
Clupeiformes	Clupeidae	4	4
	Engraulidae	1	1
Osteoglossiformes	Notopteridae	1	1
Sygnathiformes	Sygnathidae	1	2
Synbranchiformes	Mastacembelidae	2	4
Tetraodontiformes	Tetraodontidae	1	2
Total: 12	35	89	140

depending on the physicochemical properties of aquatic water and geographic location.

Fishes were classified into 14 groups among them catfish, barb and minnows, perch and loach contributed 75.71 % (106 species) of the entire group found in the present study. The contribution of 6 groups *viz.* snakehead, flatfish, feather back, pipe fish, puffer fish and tooth carp were 7.14 % of the total catch (Figure 4). Islam & Hossain (2019) showed catfish contributed the most to the Sunamganj Dekar *haor*. Similarly, Haroon et al (2002) found that barbs and catfish were the leading groups (19 % and 18 % respectively) of the total groups in the Sylhet-Mymensingh basin. Catfish and minnows were the dominant SIS groups in Kishoreganj *haor* (Chaki et al., 2014) and River Gorai of Bangladesh (Hanif et al., 2016). Kostori et al (2011) noted that the Chalan *Beel* was an ideal habitat for SIS, particularly for barbs and minnows, and that it made the highest contribution.

Present Status of SIS in *Haor*

Figure 5a showed that 47 % (66 species) of SIS were moderately available, 29 % (41 species) commonly available, 14 % (20 species) rarely available, and the remaining 9 % abundantly available (13 species). The majority of Cypriniformes and Siluriformes species were classified as moderately available and rarely available, which corresponded to the findings of Sarker et al (2022). According to Kostori et al (2011), out of 82 small indigenous fish species in

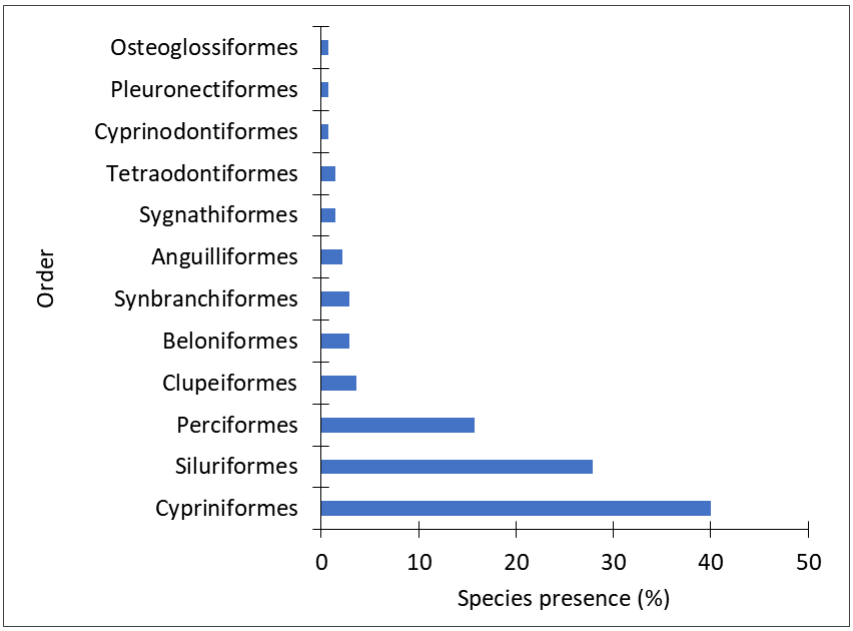

Figure 2. Relative abundance (%) of SIS in Sylhet division.

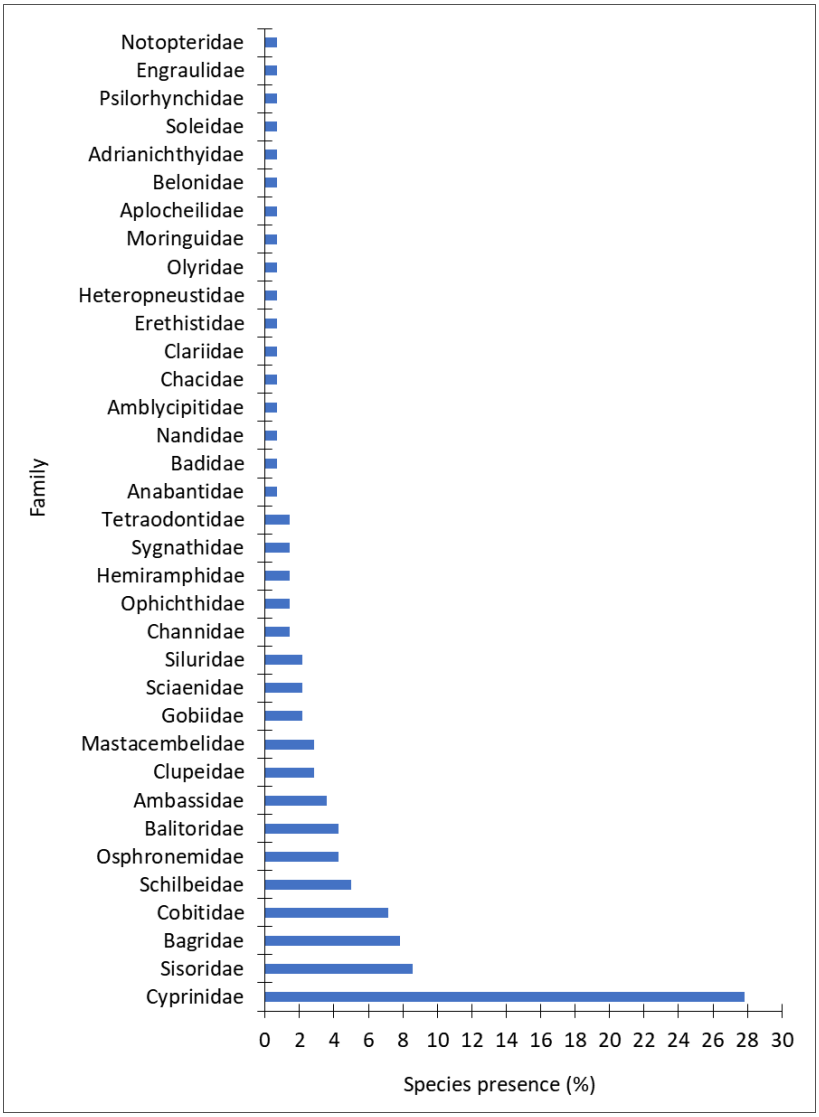

Figure 3. Relative abundance of SIS (based on family) in Sylhet division.

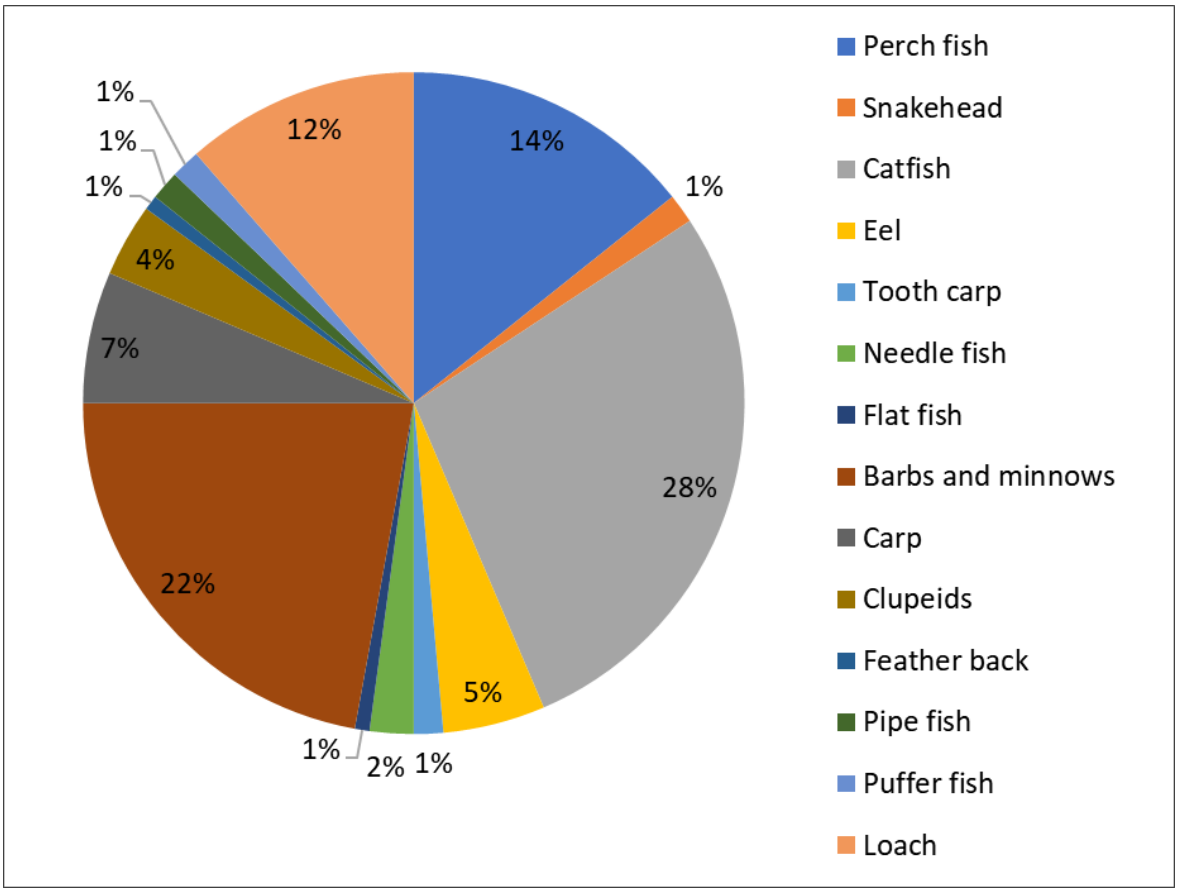

Figure 4. Major groups of SIS in the study area.

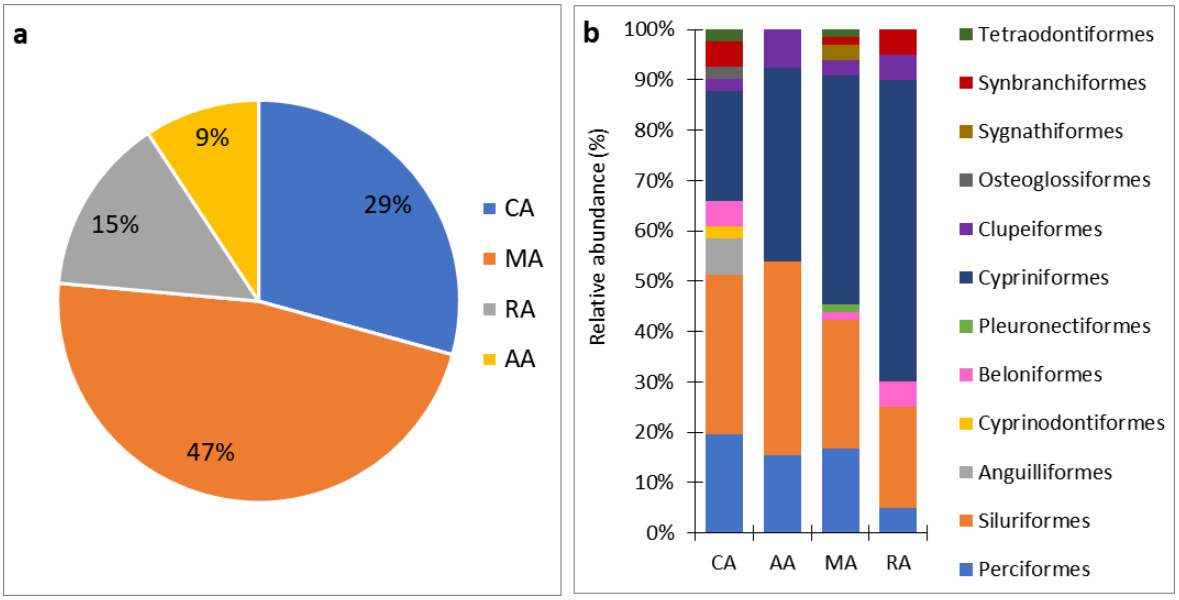

Figure 5. Present status of SIS in the study area.

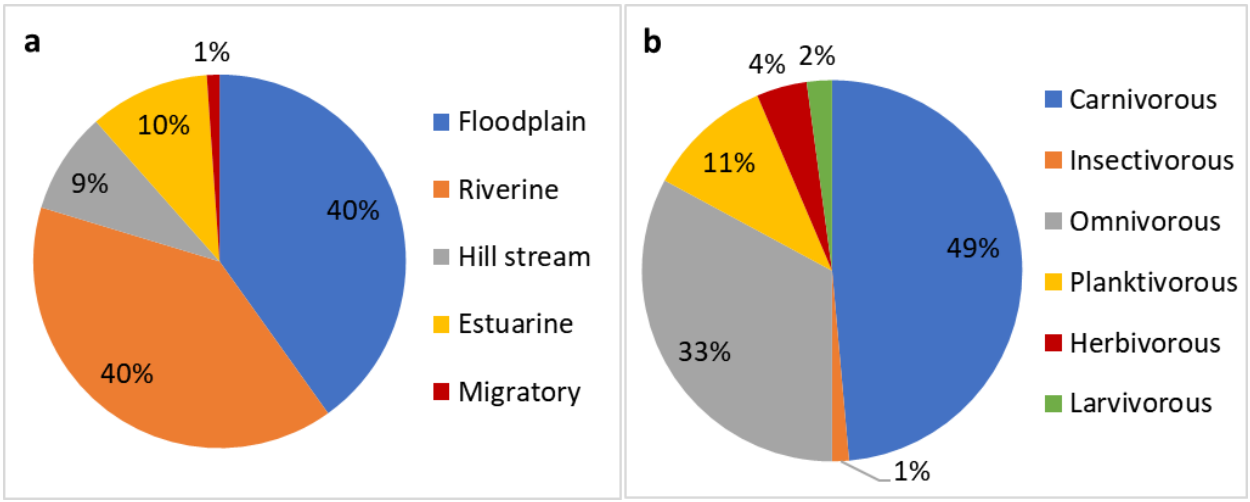

Figure 6. a) Habitat structure of SIS listed in the study area, **b)** Trophic group of SIS listed in the study area.

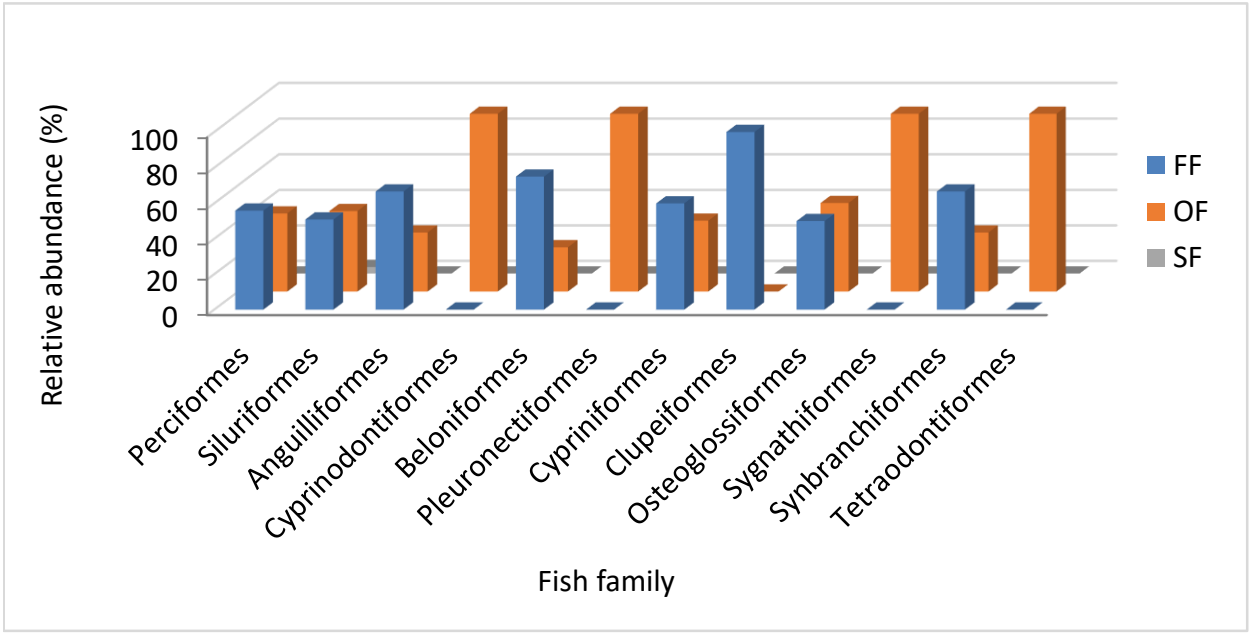

Figure 7. Relative abundance (%) of the commercial value of SIS.

Chalan *Beel*, 39 % were few, 23 % common, 15 % very common, 16 % rare and 7 % very rare. Baishya et al (2016) found that 23.08 % were listed as very rare, followed by 11.54 % in rare , 19.23 % in common and 46.15 % in very common category of river Brahmaputra in Assam. Recent research has revealed that a small number of species are available throughout the year, with more than half of the species having occasional and rare occurrences. The majority of the small native fishes found in *haor* are threatened by anthropogenic and natural causes, which may push moderately available species into the rare category and rare species into extinction in the near future.

Habitat and Trophic Status of SIS

Fish habitat classification is complicated because floodplain-resident species take refuge in neighboring perennial water bodies during the dry season (IUCN Bangladesh, 2015). Figure 6a revealed that 80% of the species were riverine and floodplain dwellers, 10% were estuarine, 1% were migratory, and 9% were found primarily in hilly locations, which is consistent with the prior findings (IUCN Bangladesh, 2015; Pandit et al., 2021). The findings revealed that carnivorous (49%) and omnivorous fish (33%) dominated the trophic group, accounting for 82% of the total feeding group found in Figure 6b. Similar

findings have been reported by Lakra et al (2010), Kundu et al (2020), Sarker et al (2010, 2022). According to Luz-Agostinho (2006), different fish species belong to multiple trophic groups based on environmental resources or prey availability. They spend most of their lives in rivers and/or floodplains, where they live significantly longer than in other freshwater ecosystems, as evidenced by their habitat choice.

Commercial Importance of SIS

The present study showed that 82.85 % (116 species) had food value (FF) and 45.71 % had ornamental value (OF) (64 species). About 17.14 % of SIS (24 species) had just ornamental value, whereas 1.4 % are considered sport fish (SF) (2 species). Species belonging to Clupeiformes had food value, whereas Tetraodontiformes, Sygnathiformes, Pleuronectiformes, and Cyprinodontiformes had ornamental value. In addition, species belonging to Beloniformes, Synbranchiformes, Anguilliformes, Cypriniformes, Perciformes, and Osteoglossiformes had food and ornamental value, where food value dominating (Figure 7). Dey et al (2015a, b) discovered an inverse pattern in the Indian state of West Bengal. It is difficult to build a checklist of the commercial worth of SIS due to a lack of appropriate data, but this study can be used as a reference to evaluate future management approaches.

National and Global Population Trend of SIS

More than half (77 species) of SIS were unknown category (UN), such as Perciformes, Anguilliformes, Cyprinodontiformes, Beloniformes, Pleuronectiformes and Synbranchiformes; 44 % were declining (DE) such as Osteoglossiformes, Sygnathiformes, Cypriniformes and Siluriformes and the remaining 1 % were stable (ST) at the national level (Figure 8a, 8b).

Galib (2015), Galib et al (2016), Mohsin et al (2013) and Pandit et al (2021) found decreasing trends in the Brahmaputra River, Mahananda River, Padma River, and Dhanu River and its surrounding wetlands in Bangladesh, respectively. Based on the global population trend (Figure 8c, 8d), approximately three-fourths of the species (73 %) were in the unknown category, followed by 14 % and 13 % in the stable and declining categories. A stable trend was found in Perciformes, Siluriformes, Beloniformes, Cypriniformes, Osteoglossiformes, and Synbranchiformes. Species belong to Perciformes, Silurimormes and Clupeiformes show a decreasing trend. A similar trend was found in different water bodies and their surrounding wetlands (Joadder et al., 2015; Galib, 2015; Pandit et al., 2021; Chaki et al., 2014). This scenario is unsatisfactory for effective and sustainable aquatic resource management since knowledge of population trends is required to launch a successful management program (Galib et al., 2016).

National and Global Conservation Status of SIS in the Study Area

Figure 9a revealed that the majority of native small species were considered to be of least concern both at national (47.86 %) and global scale (85.71 %). Similar SIS trends were found by Chaki et al (2014) in the rivers and adjacent beels of Kishoreganj *haor* and Hanif et al (2016) in River Gorai. At the national level, 25.71 % of species were classified as threatened (CR - 4 species, EN - 18 species, and VU - 14 species), and at the global level, 2.86 % of species were classified as threatened (CR- 0 species; EN-2 species and VU-2 species). Similar to the present study, IUCN Bangladesh (2015) and Pandit et al (2021) listed 25.3 % and 26.4 % of species as endangered, indicating a decline in SIS abundance and diversity in Sylhet *haor* basin. The threatened species belong to 5 orders at national level of which Osteoglossiformes and Sygnathiformes account for 100 % under vulnerable category; Cypriniformes account for 23 species and 21.3 % of them were endangered, 16.06 % vulnerable and 3.57 % critically endangered (Figure 9b). Figure 9c showed the global threatened fish order: 25 % of Synbranchiformes and 2.56 % of Siluriformes are endangered, while 1 species each of Perciformes and Cypriniformes are vulnerable and account for 4.55 % and 1.79 %, respectively. The majority of Cypriniformes and Siluriformes species face a significant threat and are classified as endangered or critically endangered (IUCN Bangladesh, 2015; Hossain and Wahab, 2010; Sarker et al., 2022). It was observed that 9.29 % and 4.29 % of SIS were not evaluated nationally and globally, respectively. Globally endangered species such as *Mastacembelus oatesii* and *Rita rita* were classified as NE and LC, respectively,

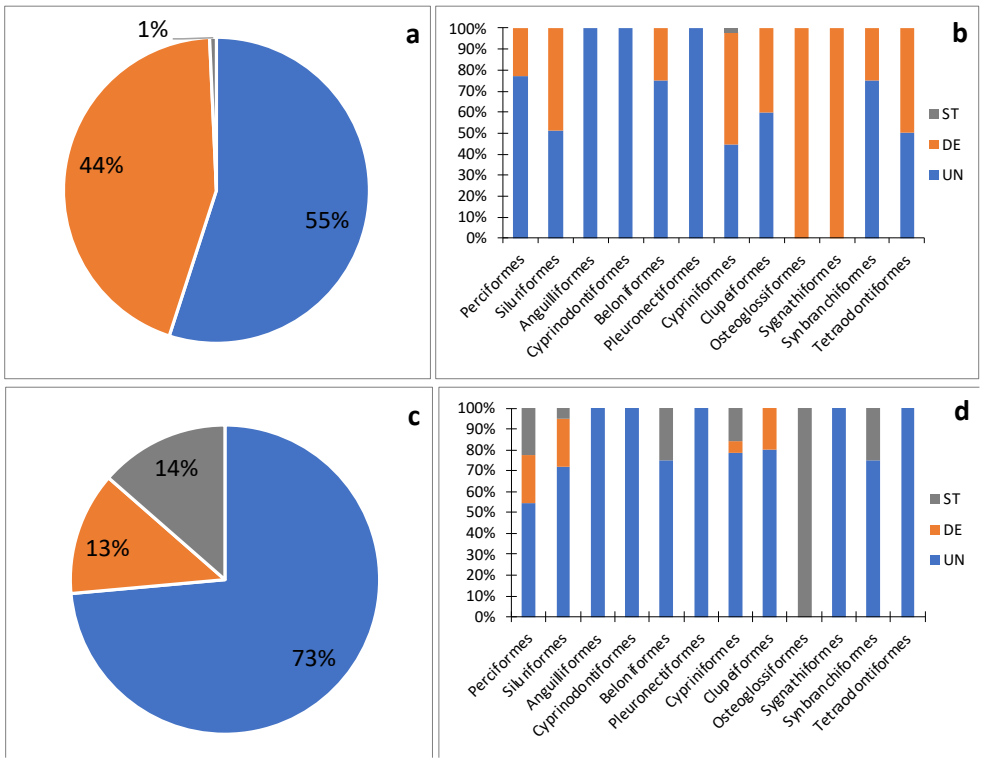

Figure 8. a,b) National population trend of SIS in study area, **c,d)** Global population trend of SIS in study area, . ST: Stable, DE: Decrease, UN: Unknown..

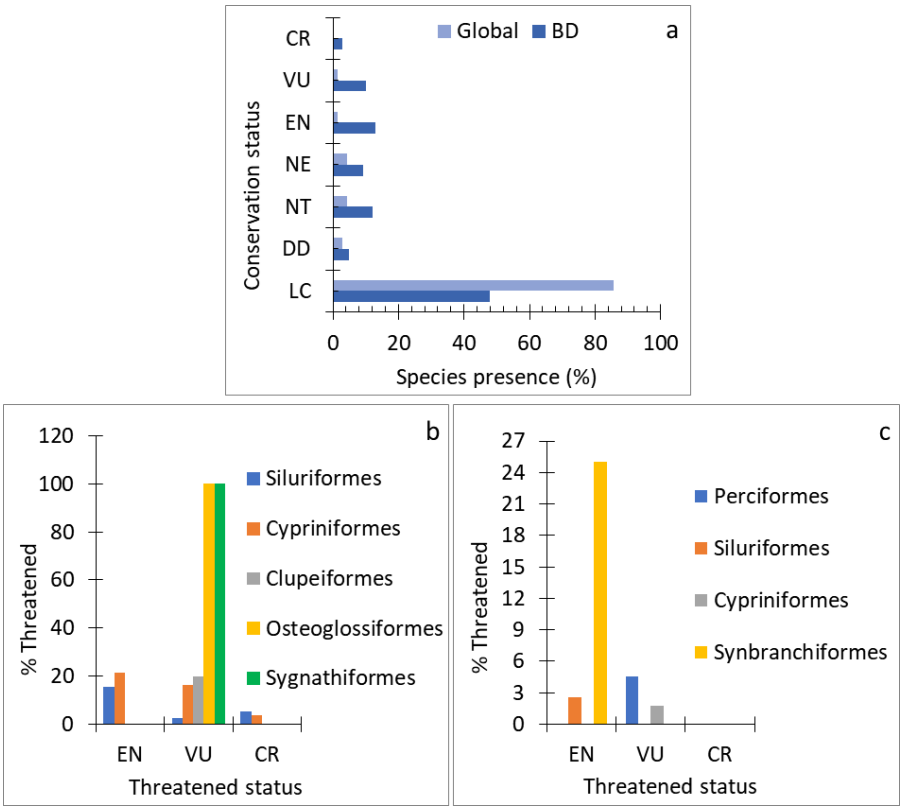

Figure 9. a) Species presence threatened status of SIS based on order, **b)** National threatened status of SIS based on order, **c)** Global threatened status of SIS based on order.

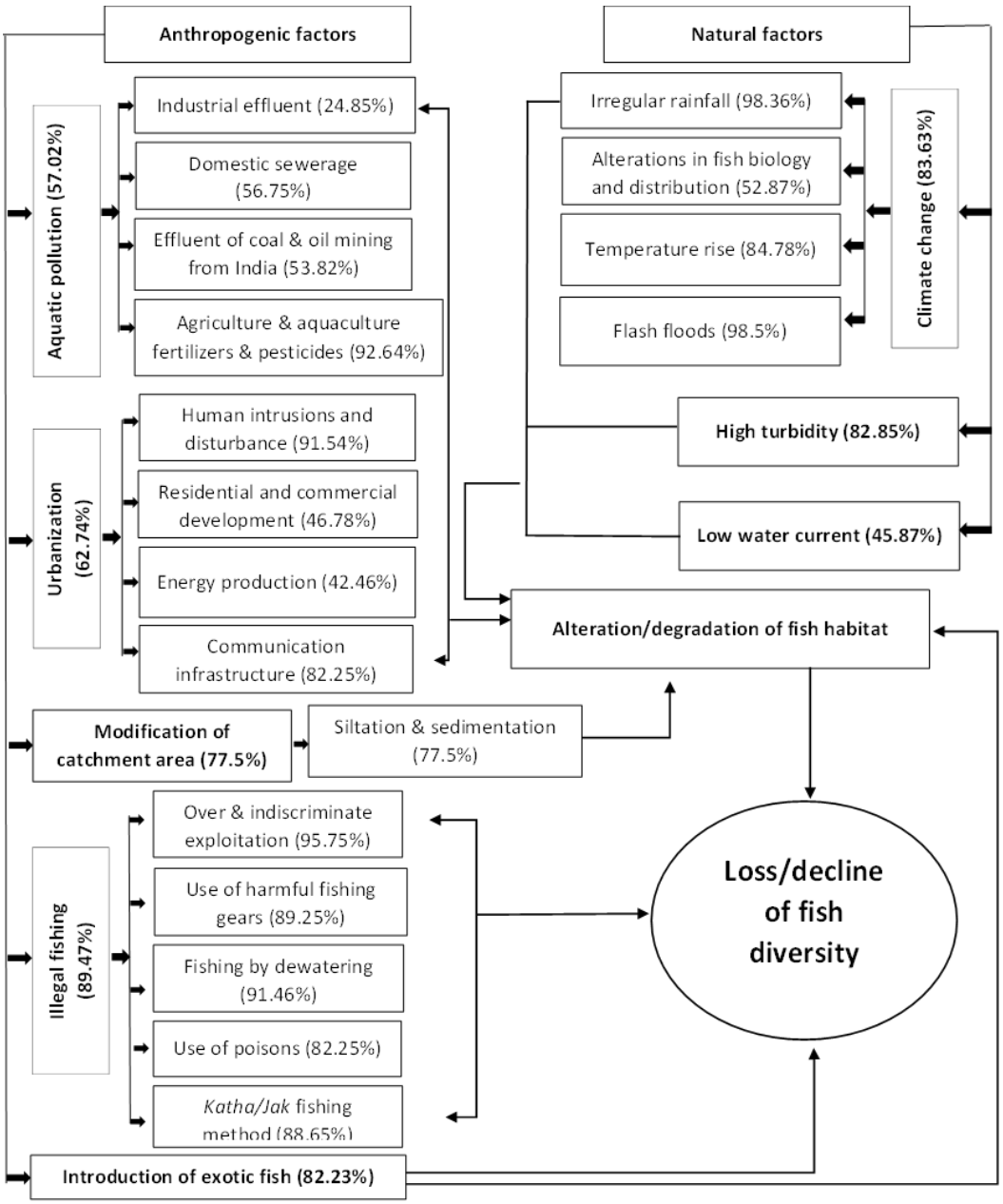

Figure 10. Anthropogenic and natural factors of SIS diversity loss on Sylhet *haor* basin.

while vulnerable species such as *Channa orientalis* and *Barilius dogarsinghi* were classified as LC and NE, respectively. Furthermore, the SIS listed in this study that are not threatened (17 species) or data deficient (7 species) should be investigated further at the regional and national levels.

Threats to SIS Diversity

Figure 10 summarizes the effects of natural and anthropogenic activities on fish diversity and habitat deterioration in the Sylhet *haor* basin. The diversity of fish is threatened by habitat loss and fragmentation, which has significantly impacted the diversity of fish as a whole. Illegal fishing, especially overfishing, the use of unlawful fishing gear, poisoning, katha fishing, and fishing by dewatering, is one of the leading anthropogenic causes of the decline in fish diversity. This approach generates short-term profits, leading to overfishing and population declines (Sarkar et al. 2010). The introduction of non-native fish species is also regarded as a serious threat to the alteration of fish habitat, resulting in a decrease in the *haor* basin's fish fauna. According to Strayer (2010) and Sheath et al (2015), invasive species pose a

serious threat to native species by modifying habitats, producing hybrid offspring, and spreading parasites and diseases. However, inquiries and interactions with respondents revealed that the SIS diversity of the Sylhet *haor* basin is threatened and causing large-scale fish mortality due to aquatic pollution such as pollutants from agriculture and aquaculture (92.64 %), domestic sewage (56.75 %), effluent from coal and oil extraction in India (53.82 %), and industrial waste (24.4 %). The effect of urbanization (62.74 %) and modification of catchment area (77.5 %) also led to high levels of habitat degradation and threats to SIS biodiversity. Similar types of anthropogenic factors were identified by various researchers for the decline of species in the various inland waterbodies of Bangladesh (Flowra et al., 2013; Pandit et al., 2015, 2021; Islam et al., 2019; Arefin et al., 2018; Talukder et al., 2022).

Climate change (83.63 %) and high turbidity (82.85 %) were the leading natural factors that altered fish habitat in the Sylhet region. Irregular rainfall, flash floods, and temperature rise have all been identified as key climatic factors that have reduced the number of SIS species. Irregular rainfall and temperature changes have a major effect on fish spawning and species diversity, which alter the freshwater environmental parameters and adversely affect the SIS population (Chowdhury et al., 2010).

CONCLUSION

A comprehensive investigation was conducted to determine the current diversity, availability, population trend, conservation and threat status of small indigenous fish species at floodplain-rich *haor* areas in Sylhet basin, Bangladesh. This study recorded 140 native species, 89 genera, 35 families of 12 orders. Cypriniformes was the leading order, with 40 % of the species found to be moderately available. According to IUCN Bangladesh (2015), 25.71 % and 2.86 % of species are threatened at the national and global levels, respectively. The findings revealed that the population status of approximately half of the recorded fish is now declining. Species belonging to Silurimormes, Perciformes and Clupeiformes were more vulnerable. According to this study, anthropogenic activities (aquatic pollution, catchment area modification, urbanization, and illegal fishing) and natural factors (mostly unpredictable climatic conditions) are implicated in the decline of SIS diversity in Sylhet *haor*. Furthermore, SIS are facing a reduction in number in the Sylhet division and a stock decline across the country. To conserve SISs diversity, governments and non-governmental organizations should implement consistent and coordinated mitigation measures such as community-based fisheries management programs, sophisticated conservation planning, eco-friendly modern fishing tools, and the *beel* nursery concept.

ACKNOWLEDGEMENTS

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HIGHLIGHTS

• In total, 140 morpho-species belonging to 89 genera, 35 families, and 12 orders were found in *Haor*-based floodplain dominated Sylhet Division in Bangladesh.
• This system is spatially consistent with a good indication of fish biodiversity especially small indigenous species.
• A good number of species were synthesized which were not assessed by IUCN evaluation.
• A long-term conservation strategy and sustainable management programs need to be developed to protect fish biodiversity in *Haor*-based Sylhet belt.

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