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# Ichthyofaunal Diversity in Jia Bharali River of North bank Landscape of Assam in Eastern Himalaya, Northeast India

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**ABSTRACT**

Ichthyofaunal diversity in Jia Bharali River of Assam, Northeast India, has been carried out from September 2018 to March 2021. The study emphasized the documentation of fish faunal diversity in relation to water parameters of previously undocumented ecological pockets of Himalayan foothill zones of north-bank landscapes of Assam. Study revealed altogether 69 fish species belonging to 6 orders and 20 families in Jia Bharali River. Cypriniformes was the most dominant (42 species) order followed by Siluriformes (14 species), Perciformes (8 species), Synbranchiformes (3 species), whereas, Beloniformes and Clupeiformes support one species each. The highest species diversity was found in Site-1 (H′ = 3.76) whereas, in terms of seasons, the highest species diversity was found in retreating monsoon (H′ = 3.80). Among the 69 species of fish, 56 species (81.16%) were IUCN categorized as Least Concern, 6 were Not Evaluated (8.7%), two species were Near Threatened (2.90%), three were Data Deficient (4.34%), and one species each was Endangered (1.45%) and Vulnerable (1.45%) respectively. Analysis of the relationships between water parameters and ichthyofaunal diversity showed a positive correlation between increasing dissolved oxygen and species richness. Water temperature and pH showed a positive correlation with species abundance in the study area.

***Key words*** *: Ichthyofaunal diversity, Jia Bharali River, IUCN status, Species assemblages, Seasonal diversity, Water parameter.*

## Introduction

Fish assemblages are a crucial part of the aquatic ecosystem and are often used as a biological indicator for the assessment of the aquatic ecosystem (Karr, 1981). Freshwater fish constitute over 40 percent of the total recorded species of fish (Viswanath, 2010). In recent times, freshwater fish are one of the most threatened taxonomic groups (Darwall and Vie, 2005) owing to their sensitiveness to the qualita-

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tive and quantitative changes of aquatic habitats. Fish are very sensitive to changes in water chemistry due to various anthropogenic activities occurring in catchments. Fish assemblages have widely been used as an ecological indicator to assess and evaluate the level of degradation and health of water bodies at various spatial scales (Zampella *et al.,* 2006; Vijayalaxmi, *et al.*, 2010). The productivity of the freshwater community that determines the fish growth is regulated by the dynamics of its physicochemical parameters along with its biotic environment (Wetzel, 1983). The variation in the physical and chemical properties influenced the biotic communities of an aquatic ecosystem because the biological productivity of any water body is mostly influenced by water quality. So, the knowledge of the quality of water is very important for the ecological setup and productivity of fish species in an aquatic ecosystem.

India is one of the mega biodiversity countries in the world and occupies the ninth position in terms of freshwater biodiversity (Myers *et al*., 2000), represented by almost 2,500 fish species of which, 930 species are freshwater dwellings (Jayaram, 1999). Globally, altogether 450 families of freshwater fishes are reported, of which, about 40% are reported in India (Khodake, *et al*., 2014). Northeast India with unique topographic conditions sharing two biodiversity hotspots of the world, the Eastern Himalaya and Indo Burma, supports rich assemblages of ichthyofaunal diversity. Hora (1953) is one of the pioneer workers on ichthyological studies in this northeastern region of India. Pardhasaradhi (1986) recorded 199 species of fish from this region. Sinha (1994) had reported 230 species of fish from the northeastern region. Again 291 species of fishes had been recorded and reported from the NE region by Sen (2003) whereas Goswami *et al.* (2012) compiled a list of 422 fish species belonging to 133 genera and 38 families from northeast India. Sarma, Singh and Baruah (2018) havereported 138 endemic fish species belonging to 54 genera, 18 families, and 6 orders from this region. In Northeast India, Assam is one of the most important areas for freshwater fish fauna. Assam has been endowed with 1.02 lakhs ha. of natural lentic water bodies including swamps associated with the river Brahmaputra, Barak, and their tributaries (ENVIS, 2016). From Assam, 187 species of fish had been recorded by Sen (2003) and 217 species of fish recorded from the water bodies of Assam by Bhattacharjya, *et al*. (2003). A total of 112 species of fish were recorded from the lower Brahmaputra, Assam (Sudem, 2017). The river Brahmaputra has 42 important tributaries of which 27 are on the north bank and 15 are on the south bank of the main and its tributaries support rich ichthyofaunal diversity and offer livelihood and nutritional security (Bhattacharjya, *et al*., 2017). Among the various tributaries of the river Brahmaputra, the Jia Bharali is one of the major north bank tributaries that flow down from the lower Himalayas in Arunachal Pradesh and passes through the Sonitpur district of Assam, and finally reaches the Brahmaputra. From the ichthyofaunal point of view, the river Jia Bharali has been less studied. The river Jia Bharali is the transboundary river of Nameri National Park and tiger reserves of Assam, situated along the eastern Himalayan foothills of Assam and Arunachal Pradesh. Thus, the study area plays a pivotal role by providing habitat, food and shelter to diverged species of plants and animals. Considering all these backgrounds, a study was conducted to investigate the Ichthyofaunal Diversity and water parameters in Jia Bharali River of north-bank landscape of Assam in eastern himalaya, Northeast India.

## Materials and Methods

### Study area

Jia Bharali basin covers an area of 11,716 km$^2$ and lies between 26°37 ‘ N and 28$^o$0 N latitudes and 92°0’E and 93°25’E longitudes. The basin falls in between the states of Assam and Arunachal Pradesh accounting for 6.7% of the total catchment area of the Brahmaputra River System. Of the total basin area, 10,239.8 km$^2$ (87.4 %) lie in the hills of Arunachal Pradesh and 1,476.2 km$^2$ (12.6 %) in the plains of Assam. Jia Bharali river has a length of nearly 242 km. (Talukdar, 2011).

The river Jia Bharali is one of the important north-bank tributaries of the Brahmaputra River System in Northeast India. The river originates in the upper range of the Himalayas at an elevation of nearly 5400 m inthe state of Arunachal Pradesh (Talukdar, 2011) and flows through Doimara Reserve Forest, Pakke Wildlife Sanctuary and Eagle Nest Wildlife Sanctuary where it is known as Kameng river. It enters the state of Assam through the Sonitpur district at Bhalukpung and flows through Nameri National Park and Balipara Reserve Forest where it is

known as the Jia Bharali river. After that, it flows 56 km in the plains of Assam before joining the mighty river Brahmaputra near Tezpur (Khound and Bhattacharyya, 2018). The Nameri National Park which is one of the important national parks of India is bounded by the river Jia Bharali in the West anda significant stretch of one side of the river is covered by forests while the other side is covered with different habitats like forests and human habitation areas.

**Study design**

The study area encompasses 37.1 km of the Jia Bharali River covering the entire stretch from upstream to downstream (Fig. 1). For the convenience of the study, five sampling sites were selected along the entire river of Jia Bharali from Bhalukpung to the confluence of Bordikorai (Table 1). Among the selected sampling sites two are located upstream (Site-4 & Site-5), one in the midstream (Site-3) and two are in the downstream (Site-2 & Site-1) of the river. Sites were selected depending on the accessibility and similarity of physical habitat and as well as to maintain the same gap of nearly 9 km between each site and riparian zone vegetation structures. The locations of the study sites were taken using GPS (Garmin etrax-30). The fish sample collection and water parameters data were recorded from each sampling site in the morning session between 07:00 to 10:00 hours.

Regular monthly samplings of fishes were carried

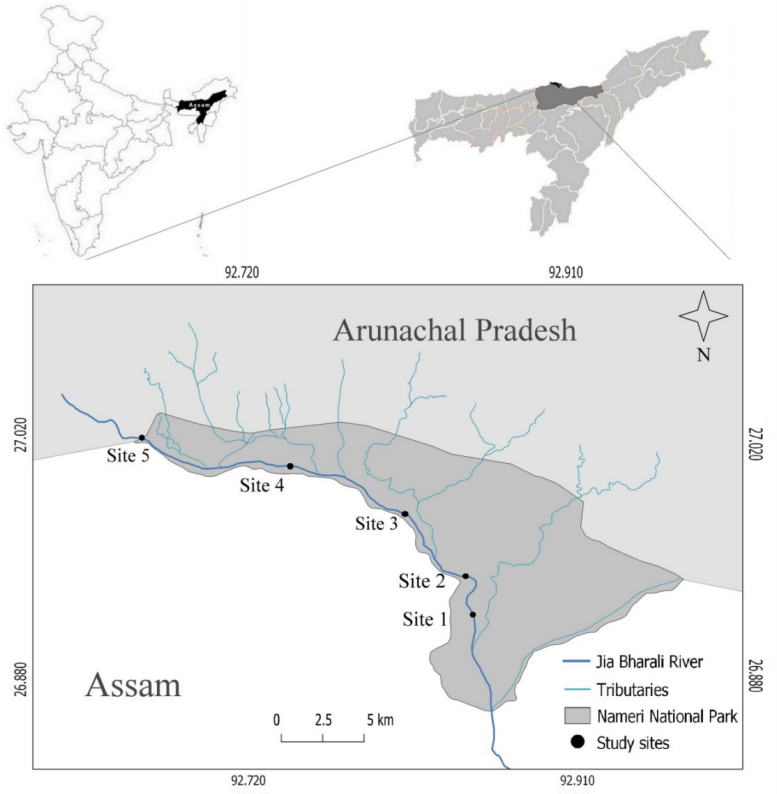


**Fig. 1.**Map of the study area with selected sampling sites.

**Table 1.** Selected sampling sites of Jia Bharali River, Assam

| Zonation | Sampling Sites (S) | Location | | Elevation(m) |
|---|---|---|---|---|
| | | Latitude (N) | Longitude(E) | |
| Downstream | Dharikati (S1) | 26.908 | 92.850 | 81.69 |
| Downstream | Potasali (S2) | 26.927 | 92.846 | 93.27 |
| Midstream | Kalabil (S3) | 26.971 | 92.811 | 114.91 |
| Upstream | Garami Loga (S4) | 26.998 | 92.741 | 116.74 |
| Upstream | Bhalukpung (S5) | 27.017 | 92.651 | 154.23 |

out from September 2018 to March 2021 covering four seasons of the year i.e., Retreating Monsoon (September to November), winter (December to February), Pre-Monsoon (March to May) and Monsoon (June to August) (Borthakur, 1986).

**Fish sampling**

Collection of fish was done on monthly basis from the studied river covering four seasons of the year. Experimental fishing was carried out in all the selected sampling sites with the help of local fishermen. Market survey at the nearest markets in and around the study sites and observation and interaction with local people and fisherman communities was also done so that no one species would be left out. The collection of fish was done following Jayaram (1999). Methods of collection of species are different depending on the size and habits. Different types of fishing gears including cast net and gill net of different mesh sizes and different traditional bamboo traps had been used. Each fishing gear was used at least five times at each sampling site. Maximum care was taken at the time of collection to keep the external morphology intake for further study. In each sampling site, fish samples were collected and immediately photographs were taken. After that fish samples were preserved in formalin solution and the fish specimens that are not needed for preservation were immediately sent back to the water. The collected specimens were preserved individually at 10% formalin solution following Walsh and Meador (1998) for proper identification of the species. To observe and record the colour in fresh, photographs of live and preserved specimens were taken by using a Digital SLR camera (Nikon D3500)

**Species identification**

The identification of the fishes was done following Talwar and Jhingran (1991), Jayaram (1999), Nath and Dey (2000), Vishwanath *et al.,* (2007), Viswanath *et al.* (2014). The confirmation of the valid scientific name and classification of each species was done with the help of Fishbase (Froese and Pauly, 2021) and Catalog of Fishes (Eschmeyer, *et al*., 2021). The threatened status of all the identified fish species was determined by following the IUCN Red List 2021 (IUCN, 2021).

**Water sampling**

For hydrological parameter analysis, water samples were collected during four seasons of the year i.e., retreating monsoon, winter, pre-monsoon and monsoon by following after Borthakur (1986). For the study and analysis of the water parameters of the river, random water samples were collected from each selected sampling sitein the morning session between 07:00 to 10:00 hours. At each sampling site, each water parameter had been measured at least five times and the result was recorded. Analysis of different water parameters was done at the sample collecting site itself. The parameters that were analyzed are water temperature, water pH, dissolved oxygen (DO) and water current. All the parameters were analyzed by using the method of APHA (2005).

**Water temperature:** Water temperature was analyzed by using a mercury-in-glass thermometer graduated in degree centigrade. The thermometer was immersed into the water for five to six minutes till it becomes stable and then the reading was recorded in the field notebook immediately.

**Water pH:** The value pH of sample water was recorded at the sample collection site by using a digital pH meter (Testo-206) immediately after the collection of the water sample. Data was recorded after the meter was stabilized.

**Dissolve oxygen (DO):** In each sampling site the dissolved oxygen (DO) content of water was recorded by using a digital DO meter (Lutron-5509). Data was recorded after the meter was stabilized.

**Water current:** Water current or surface water velocity was measured by using a measuring tape, float and a stopwatch. The float was weighted before the measurement to remove the wind effect. The particular distance covered by afloat at a particular time represents the velocity of the running water.

**Data analysis**

The analysis of the diversity was performed using Paleontological Statistics (PAST) Version 3.14. Species diversity was assessed using three different indices viz., Shannon Weiner Index (Shannon and Weiner, 1963), Buzas and Gibson's Evenness Index (Buzas and Gibson, 1969) and Dominance Index. The formula for assessing these diversity indices were as follows:

Shannon-Weiner Index (H'): The Shannon-Weiner Index is used for measuring diversity. It assumes that all species are represented in a sample and that the sample is obtained randomly.

$$H' = -\sum_{i=1}^{s} Pi \ln Pi$$

**Table 2.** Comprehensive list of fish faunal diversity of Jia Bharali river, Assam, India (S1: Dharikati, S2: Potasali, S3: Kalabil, S4: Garami Loga, S5: Bhalukpung; TRA: Total Relative Abundance; *DD:* Data Deficient, *LC:* Least Concern, *NE:* Not Evaluated, *NT:* Near Threatened, *VU:* Vulnerable, *EN:* Endangered)

| Species | Relative abundance in various Study Sites | | | | | TRA | IUCN red list status |
|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 | | |
| **Order: Beloniformes** | | | | | | | |
| **Belonidae** | | | | | | | |
| *Xenentodon cancila* (Hamilton, 1822) | 2.83 | 3.00 | 0.68 | 2.04 | 1.37 | 2.22 | LC |
| **Order: Clupeiformes** | | | | | | | |
| **Cluepidae** | | | | | | | |
| *Gudusia chapra* (Hamilton, 1822) | 0.44 | 0.00 | 0.00 | 0.38 | 0.00 | 0.21 | LC |
| **Order: Cypriniformes** | | | | | | | |
| **Balitoridae** | | | | | | | |
| *Schistura savona* (Hamilton, 1822) | 0.03 | 0.00 | 0.00 | 0.00 | 0.14 | 0.04 | LC |
| **Botiidae** | | | | | | | |
| *Botia dario* (Hamilton, 1822) | 0.63 | 1.25 | 0.00 | 1.12 | 0.77 | 0.78 | LC |
| **Cobitidae** | | | | | | | |
| *Canthophrys gongota* (Hamilton, 1822) | 0.07 | 0.40 | 0.00 | 0.00 | 0.57 | 0.22 | LC |
| *Lepidocephalichthys berdmorei* (Blyth, 1860) | 0.34 | 0.83 | 0.00 | 0.08 | 0.60 | 0.41 | LC |
| *Lepidocephalichthys guntea* (Hamilton, 1822) | 1.28 | 1.16 | 3.89 | 2.62 | 2.92 | 2.07 | LC |
| **Cyprinidae** | | | | | | | |
| *Bangana dero* (Hamilton, 1822) | 2.94 | 2.35 | 0.00 | 1.54 | 3.63 | 2.45 | LC |
| *Barilius barila* (Hamilton, 1822) | 0.44 | 1.93 | 0.00 | 1.00 | 0.43 | 0.76 | LC |
| *Barilius bendelisis* (Hamilton, 1807) | 2.48 | 1.07 | 0.00 | 3.53 | 4.23 | 2.47 | LC |
| *Barilius shacra* (Hamilton, 1822) | 2.02 | 1.68 | 0.00 | 1.85 | 3.32 | 1.98 | LC |
| *Chagunius chagunio* (Hamilton, 1822) | 1.95 | 2.17 | 0.00 | 2.12 | 3.23 | 2.08 | LC |
| *Cyprinion semiplotum* (McClelland, 1839) | 1.37 | 0.09 | 0.00 | 0.92 | 0.23 | 0.68 | VU |
| *Esomus danrica* (Hamilton, 1822) | 1.26 | 6.21 | 17.29 | 2.31 | 3.58 | 4.52 | LC |
| *Garra annandalei* (Hora, 1921) | 0.29 | 0.03 | 0.00 | 1.85 | 2.95 | 0.99 | LC |
| *Garra birostris* (Nebeswar and Viswanath, 2013) | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | NE |
| *Garra gotyla* (Gray, 1830) | 0.44 | 0.00 | 0.00 | 1.58 | 2.03 | 0.81 | LC |
| *Garra kalpangii* (Hamilton, 1822) | 0.91 | 0.00 | 0.00 | 1.35 | 0.83 | 0.69 | NE |
| *Garra quadratirostris* (Nebeswar and Viswanath, 2013) | 0.05 | 0.00 | 0.00 | 0.00 | 0.14 | 0.05 | NE |
| *Garra tamangi* (Gurumayum and Kosygin, 2016) | 0.61 | 0.00 | 0.00 | 0.04 | 0.23 | 0.26 | NE |
| *Labeo boga* (Hamilton, 1822) | 0.14 | 0.00 | 0.00 | 0.65 | 0.00 | 0.15 | LC |
| *Labeo calbasu* (Hamilton, 1822) | 3.23 | 0.18 | 0.00 | 1.81 | 0.54 | 1.54 | LC |
| *Labeo gonius* (Hamilton, 1822) | 3.23 | 0.95 | 0.00 | 0.69 | 2.32 | 1.88 | LC |
| *Pethia conchonius* (Hamilton, 1822) | 2.87 | 4.34 | 7.55 | 5.45 | 4.46 | 4.37 | LC |
| *Pethia guganio* (Hamilton, 1822) | 1.88 | 3.33 | 5.41 | 3.50 | 3.93 | 3.19 | LC |
| *Pethia ticto* (Hamilton, 1822) | 6.54 | 3.33 | 11.25 | 3.81 | 3.32 | 5.34 | LC |
| *Puntius chola* (Hamilton, 1822) | 1.31 | 0.79 | 1.80 | 2.85 | 0.92 | 1.42 | LC |
| *Puntius sophore* (Hamilton, 1822) | 6.20 | 4.04 | 6.19 | 4.31 | 3.92 | 5.02 | LC |
| *Tariqilabeo latius* (Hamilton, 1822) | 1.67 | 2.23 | 0.00 | 0.81 | 0.40 | 1.21 | LC |
| *Tor mosal* (Hamilton, 1822) | 0.43 | 0.49 | 0.00 | 2.15 | 1.83 | 0.95 | DD |
| *Tor putitora* (Hamilton, 1822) | 0.20 | 0.00 | 0.00 | 0.19 | 0.74 | 0.25 | EN |
| *Tor tor* (Hamilton, 1822) | 0.12 | 0.34 | 0.00 | 0.42 | 1.72 | 0.52 | DD |
| **Danionidae** | | | | | | | |
| *Amblypharyngodon mola* (Hamilton, 1822) | 2.99 | 3.85 | 6.25 | 3.31 | 0.00 | 2.93 | LC |
| *Cabdio morar* (Hamilton, 1822) | 2.10 | 2.26 | 0.00 | 2.50 | 3.00 | 2.16 | LC |
| *Danio rerio* (Hamilton, 1822) | 1.55 | 5.63 | 12.05 | 0.00 | 0.00 | 2.88 | LC |
| *Devario aequipinnatus* (McClelland. 1839) | 0.34 | 0.00 | 0.00 | 0.31 | 0.06 | 0.18 | LC |
| *Devario devario* (Hamilton, 1822) | 1.43 | 0.46 | 0.34 | 0.62 | 3.40 | 1.41 | LC |
| *Opsarius barna* (Hamilton, 1822) | 4.54 | 1.71 | 0.00 | 4.46 | 5.26 | 3.66 | LC |
| *Opsarius tileo* (Hamilton, 1822) | 2.85 | 0.00 | 0.00 | 2.54 | 2.35 | 1.85 | LC |
| *Raiamas bola* (Hamilton, 1822) | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | LC |

**Table 2.** *Continued ...*

| Species | Relative abundance in various Study Sites | | | | | TRA | IUCN red list status |
|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 | | |
| *Salmostoma bacaila* (Hamilton, 1822) | 0.55 | 1.19 | 0.00 | 1.08 | 1.75 | 0.94 | LC |
| *Salmostoma phulo* (Hamilton, 1822) | 0.07 | 0.55 | 0.00 | 0.00 | 0.00 | 0.13 | LC |
| **Nemacheilidae** | | | | | | | |
| *Acanthocobitisbotia* (Hamilton, 1822) | 0.89 | 3.70 | 4.83 | 3.42 | 3.00 | 2.67 | LC |
| *Neonoemacheilus assamensis* (Menon, 1987) | 0.55 | 1.86 | 0.00 | 0.73 | 0.89 | 0.84 | NT |
| **Order: Perciformes** | | | | | | | |
| **Ambassidae** | | | | | | | |
| *Chanda nama* (Hamilton, 1822) | 4.47 | 3.45 | 1.41 | 4.50 | 2.06 | 3.47 | LC |
| *Parambassis ranga* (Hamilton, 1822) | 3.67 | 2.08 | 0.96 | 3.12 | 1.75 | 2.60 | LC |
| **Badidae** | | | | | | | |
| *Badis assamensis* (Ahl, 1937) | 2.58 | 2.02 | 2.65 | 1.42 | 1.32 | 2.04 | DD |
| *Badis badis* (Hamilton, 1822) | 1.23 | 2.23 | 1.63 | 1.12 | 2.06 | 1.62 | LC |
| **Gobiidae** | | | | | | | |
| *Glossogobius giuris* (Hamilton, 1822) | 2.72 | 1.19 | 3.04 | 0.00 | 0.00 | 1.48 | LC |
| **Nandidae** | | | | | | | |
| *Nandus nandus* (Hamilton, 1822) | 0.00 | 1.31 | 3.38 | 0.00 | 0.00 | 0.61 | LC |
| **Osphronemidae** | | | | | | | |
| *Trichogaster fasciata* (Bloch,1801) | 1.33 | 0.92 | 0.62 | 2.00 | 1.20 | 1.25 | LC |
| *Trichogaster lalius* (Hamilton, 1822) | 2.20 | 1.04 | 1.24 | 2.58 | 1.37 | 1.76 | LC |
| **Order: Siluriformes** | | | | | | | |
| **Ailiidae** | | | | | | | |
| *Ailia coila* (Hamilton, 1822) | 3.01 | 2.42 | 0.00 | 2.92 | 0.00 | 1.95 | NT |
| **Amblycipitidae** | | | | | | | |
| *Amblyceps laticeps* (McClelland, 1842) | 0.17 | 0.00 | 0.00 | 0.00 | 0.34 | 0.13 | LC |
| **Bagridae** | | | | | | | |
| *Batasio fasciolatus* (Ng, 2006) | 0.20 | 1.28 | 0.00 | 0.58 | 0.03 | 0.41 | LC |
| *Mystus cavasius* (Hamilton, 1822) | 0.26 | 3.03 | 0.00 | 0.46 | 2.20 | 1.19 | LC |
| *Mystus dibrugarensis* (Chaudhuri, 1913) | 1.30 | 1.01 | 0.00 | 0.00 | 0.23 | 0.69 | LC |
| *Mystus tengara* (Hamilton, 1822) | 2.73 | 4.80 | 1.69 | 3.95 | 4.49 | 3.57 | LC |
| *Mystus vittatus* (Bloch, 1794) | 3.43 | 3.18 | 4.27 | 4.26 | 2.99 | 3.51 | LC |
| *Olyra parviocula* (Kosygin, Shangningam & Gopi 2018) | 0.14 | 0.37 | 0.00 | 0.00 | 0.00 | 0.12 | NE |
| **Erethestidae** | | | | | | | |
| *Pseudolaguvia shawi* (Hora, 1921) | 0.10 | 0.43 | 0.00 | 0.15 | 0.34 | 0.21 | LC |
| **Schilbeidae** | | | | | | | |
| *Pachypterus atherinoides* (Bloch, 1794) | 0.17 | 1.86 | 0.00 | 0.19 | 0.49 | 0.55 | LC |
| **Sisoridae** | | | | | | | |
| *Gagatacenia* (Hamilton, 1822) | 0.14 | 0.52 | 0.00 | 0.00 | 0.03 | 0.15 | LC |
| *Glyptothorax dikrongensis* (Tamang & Chaudhry, 2011) | 0.14 | 0.00 | 0.00 | 0.00 | 0.40 | 0.13 | NE |
| *Glyptothorax telchitta* (Hamilton, 1822) | 0.17 | 0.00 | 0.00 | 0.00 | 0.60 | 0.18 | LC |
| *Nangra assamensis* (Sen and Biswas, 1994) | 0.15 | 0.00 | 0.00 | 0.35 | 0.37 | 0.18 | LC |
| **Order: Synbranchiformes** | | | | | | | |
| **Mastacembelidae** | | | | | | | |
| *Macrognathus morehensis* (Arun Kumar and Tombi Singh, 2000) | 0.79 | 0.00 | 0.62 | 0.00 | 1.23 | 0.59 | LC |
| *Macrognathus pancalus* (Hamilton, 1822) | 1.33 | 1.93 | 0.96 | 1.42 | 0.20 | 1.19 | LC |
| *Mastacembelus armatus* (La Cepede, 1800) | 1.17 | 1.53 | 0.00 | 1.04 | 1.29 | 1.12 | LC |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | |

Where Pi is the proportion of individuals found in the i$^{th}$ species and ln is the natural logarithm.

Dominance Index: D= $\sum_{i=1}^{n}\left(\frac{n_i}{N}\right)^2$

Where $n_i$ is the number of individuals of i$^{th}$ species and N is the total number of species.

Buzas and Gibson's Evenness Index (E): We have compared the actual value to the maximum possible diversity using the evenness index. The evenness index formulae used for analysis was as follows:

E= $\frac{H'}{Hmax}$ =$\frac{H'}{lnS}$

Where Hmax= lnS, H'= Shannon-Weiner Index and S= Total number of species in the sample.

SPSS version 16.0 software was used to perform One Way Analysis of Variance (ANOVA) to determine the variation of water parameters among the sampling sites at a significant level ($p$=0.01). Pearson Correlation was performed to determine the relationship between fish species assemblages and water parameters.

## Result

### Fish species assemblages

A total of 69 species of fish species belonging to 6 orders and 20 families were recorded in different study sites of the Jia Bharali River (Table 2). Of the total 69 species, 18 species were common in all the selected sampling sites. However, the species *Garra birostris* and *Raiamas bola* were found only at Dharikati (Site 1) during the study. *Garra birostris* was found in the Monsoon season and *Raiamas bola* in winter and Pre-monsoon season. Of all the species recorded in the study area, 68 species (98.55%) were recorded in Dharikati (Site-1), followed by 58 species (84.05%) in Garami Loga (Site-4), 53 species (76.81%) in Bhalukpong (Site-5), 51 species (73.91%) in Potasali (Site-2) and 24 species (34.78%) in Kalabil (Site-3). The analysis of the site-specific abundance of fish species showed that site-1 has the highest abundance downstream and lowest in site-3 of midstream location (Table 3). Season-wise analysis of species richness also showed variability with a maximum of 68 species recorded during Retreating Monsoon followed by 66 species in Pre-Monsoon, 60 species in Monsoon and 59 species in the winter season (Fig. 2). Among the six different orders of fish, the order Cypriniformes was found to be the most dominant with 60.87% (42 species) of the total species followed by Siluriformes (14 species), Perciformes (8 species), Synbranchiformes (3 species) and Beloniformes (1 species) and Clupeiformes (1 species). Out of the 19 families, Cyprinidae was the most dominant fish family, representing 25 species with 36.23% contribution of the total species fol-

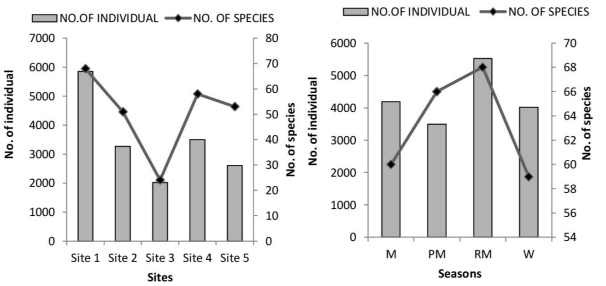


**Fig. 2.** Richness and Abundance of fish species recorded in different sampling sites of the study area and different seasons (M: Monsoon, PM: Pre-monsoon, RM: Retreating monsoon, W: Winter).

**Table 3.** Fish diversity and richness of Jia Bharali river among different sites and seasons

| Sites | Species richness | Species abundance | Dominance_D | Shannon_H (H´) | Evenness_ e^H/S(E) |
|---|---|---|---|---|---|
| Site 1 | 68 | 5853 | 0.029 | 3.764 | 0.634 |
| Site 2 | 51 | 3260 | 0.031 | 3.635 | 0.743 |
| Site 3 | 24 | 2018 | 0.083 | 2.750 | 0.652 |
| Site 4 | 58 | 3495 | 0.029 | 3.692 | 0.757 |
| Site 5 | 53 | 2600 | 0.029 | 3.705 | 0.701 |
| Seasons | Species richness | Species abundance | Dominance_D | Shannon_ H(H´) | Evenness_ e^H/S(E) |
| Monsoon | 60 | 4189 | 0.033 | 3.657 | 0.646 |
| Pre-monsoon | 66 | 3495 | 0.028 | 3.781 | 0.665 |
| Retreating monsoon | 68 | 5523 | 0.026 | 3.841 | 0.685 |
| Winter | 59 | 4019 | 0.028 | 3.76 | 0.728 |

lowed by Danionidae with 10 species (14.49%), Bagridae with 6 (8.70%) species, Sisoridae with 4 species (5.80%), Cobitidae and Mastacembelidae with 3 species (4.35%), Ambassidae, Badidae, Nemacheilidae and Osphronemidae with 2 species (2.90%) and Ailiidae, Amblycipitidae, Balitoridae, Belonidae, Botiidae, Clupeidae, Erethestidae, Gobiidae, Nandidae and Schilbeidae with only one species (1.45%) each (Fig. 3).

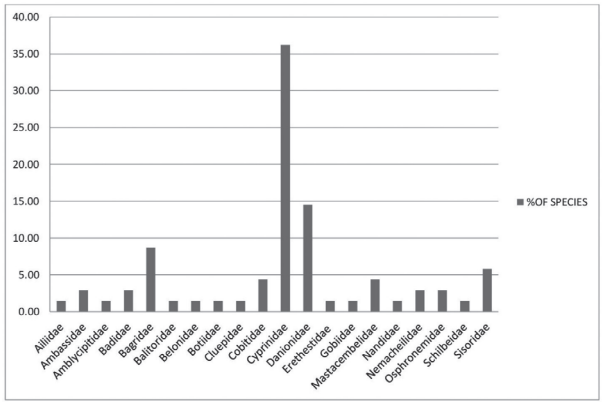


**Fig. 3.** Family-wise distribution of fish species percentage in the Jia Bharali River.

## Conservation status

As per the IUCN Red List category of 2021, the conservation status of all the recorded 69 species of ichthyofauna in the Jia Bharali River showed 56 species (81.16%) as Least Concern, 6 species (8.7%) as Not Evaluated, 3 species (4.34%) as Data Deficient, 2 species (2.90%) as Near Threatened and 1 species (1.45%) categorized as Vulnerable and Endangered status respectively. The present study recorded two Near Threatened species namely *Ailia coilia* and *Neonoemacheilus assamensis*, one Vulnerable species *Cyprinion semiplotum* and one Endangered species *Tor putitora* (Fig 4).

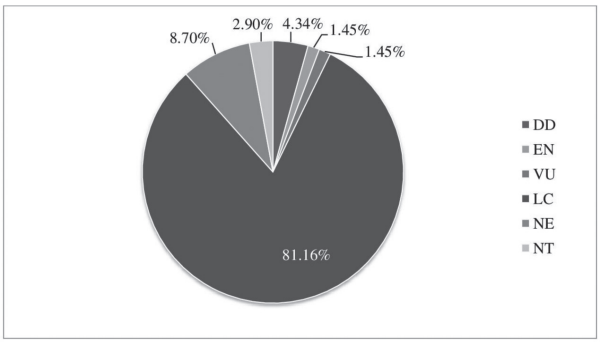


**Fig. 4.** Percentage composition of species under various threat categories as per IUCN status.

## Diversity Status

The diversity indices viz., Shannon Weiner index, Buza's and Gibson's Evenness index and Simpson's Dominance index were calculated according to sites and seasons. Among the sites, the highest species

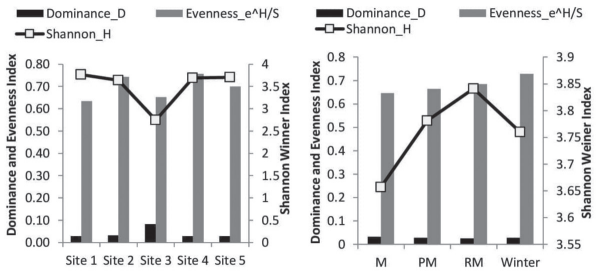


**Fig. 5.** Variation in species richness and species diversity indices among different sampling sites and seasons of Jia Bharali River (M: Monsoon, PM: Pre-monsoon, RM: Retreating monsoon, W: Winter).

**Table 4.** Variation of water parameters among sampling sites and seasons (PM= Pre-monsoon, M= monsoon, RM= Retreating monsoon, W=winter)

| Site code | N | Water current( m/s) | DO(mg/l) | Temperature(°C) | pH |
|---|---|---|---|---|---|
| S1 | 207 | 0.47 ± 0.01 | 9.20 ±0.04 | 21.23 ±0.13 | 8.10 ± 0.00 |
| S2 | 173 | 0.18 ± 0.00 | 5.35 ±0.06 | 20.08 ±0.18 | 7.07 ±0.03 |
| S3 | 58 | 0.17 ±0.00 | 5.08 ±0.13 | 22.82± 0.23 | 7.69± 0.03 |
| S4 | 174 | 0.42 ±0.02 | 6.35±0.05 | 21.95±0.14 | 8.49 ±0.04 |
| S5 | 194 | 0.55±0.01 | 7.16±0.06 | 23.43±0.16 | 8.84 ±0.01 |
| Season | N | Water current( m/s) | DO(mg/l) | Temperature(°C) | pH |
| M | 197 | 0.56 ± 0.02 | 6.31 ± 0.11 | 24.85 ± 0.10 | 8.04 ± 0.06 |
| PM | 210 | 0.30 ± 0.01 | 7.35 ± 0.10 | 21.42 ± 0.11 | 7.95 ± 0.04 |
| RM | 211 | 0.37 ± 0.01 | 6.51 ± 0.11 | 21.55 ± 0.06 | 8.16 ± 0.05 |
| W | 188 | 0.36 ± 0.01 | 7.78 ± 0.11 | 19.23 ± 0.10 | 8.30 ± 0.05 |

diversity (H'=3.764) was found in Site 1 and the lowest (H'=2.750) was found in Site 3. The Evenness index was highest (E =0.757) in Site 4 and the lowest (E=0.634) was found in Site 1. The dominance index was found highest (0.083) in site 3 (Table 3, Fig 5). Analysis of diversity indices among seasons indicates high species diversity in the retreating monsoon (H'=3.841) and the lowest in the monsoon season (H'=3.657). The highest Evenness index was found in winter (E=0.728) and the lowest was found in monsoon (E=0.646). The Dominance index (D) was found to be almost similar in the four seasons ranging from 0.026 in Retreating Monsoon to 0.033 in Monsoon season (Table 3, Fig 5).

**Water Parameters**

One way ANOVA was performed between sampling sites and water parameterswhere a significant difference was found in water current (F= 254.77, P< 0.01), Dissolve oxygen (F= 805.92, P < 0.01), Water temperature (F=67.23, P < 0.01) and pH (F= 837.96, P < 0.01) among the sampling sites. The water current was found to be highest in site 5 (0.55 m/s±0.01) and lowest in site 3 (0.17m/s ±0.00) (Table 4). Dissolve oxygen content was found to be highest in site 1 (19.20 mg/l ±0.04) and lowest in site 3 (5.08 mg/l ± 0.13). Water temperature was found to be highest in site 5 (23.43 °C ±0.16) compared to other sites and the lowest was found in site 2 (20.08 °C ± 0.18). pH value was found to be highest in site 5 (8.84 ± 0.01) and lowest in site 2 (7.07 ± 0.03) (Fig. 6).

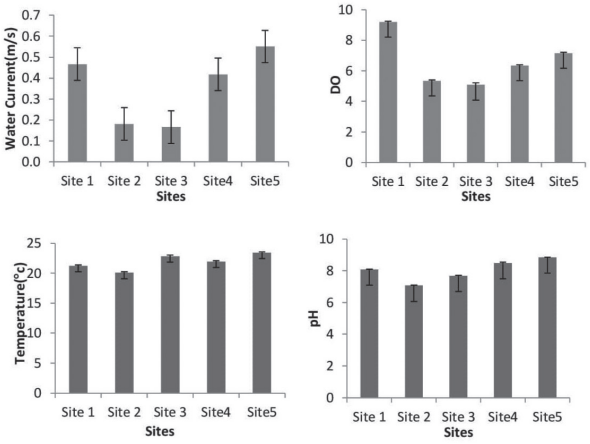


**Fig. 6.** Site-wise variation of different water parameters of river Jia Bharali (Mean ± S.E).

Moreover, among the seasons, water current was highest during monsoon (0.56m/s ±0.02) and lowest in the pre-monsoon (0.30m/s ±0.01) (Fig 7). Water temperature was found to be highest during monsoon (24.84 °C ±0.10) and found lowest in winter (19.23 °C ±0.10). Dissolved oxygen was found highest in winter (7.78 mg/l ±0.11) and was found lowest in monsoon (16.31mg/l ±0.11). pH value was found highest in winter (8.30±0.05) and lowest in the pre-monsoon season (7.95±0.04).

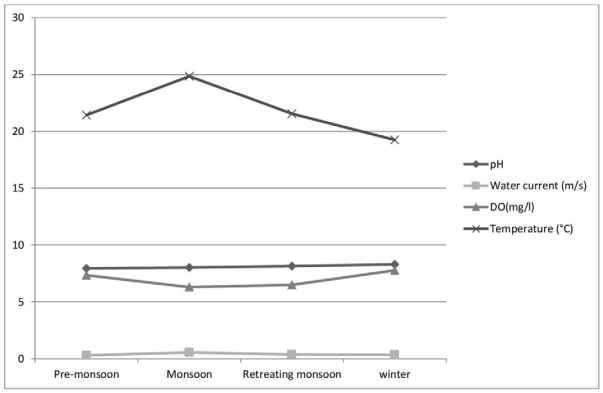


**Fig. 7.** Season-wise variation of some water parameters of river Jia Bharali.

To determine the relationship between fish species richness and abundance with the selected water parameters (water current, DO, temperature and pH) Pearson Correlation Analysis was performed and it showed a weak positive correlation between fish species richness and dissolved oxygen (DO) content in Jia Bharali river (r= 0.082, $p< .05$) but no significant correlation with water current, temperature and pH ($p>0.05$). In case of species abundance, a weak positive correlation was observed with water temperature (r= 0.116, $p<0.01$) and pH (r=0.104, $p<0.01$) but not significantly correlated to water current and DO ($p>0.05$) (Table 5).

**Table 5.** Correlation between fish species diversity and abundance and water parameters of Jia Bharali river

| Pearson Correlation | Water current | DO | Temperature | pH |
|---|---|---|---|---|
| Species richness | -0.005 | .082* | 0.071 | 0.019 |
| Species abundance | 0.0308 | 0.050 | 0.116** | 0.104** |

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

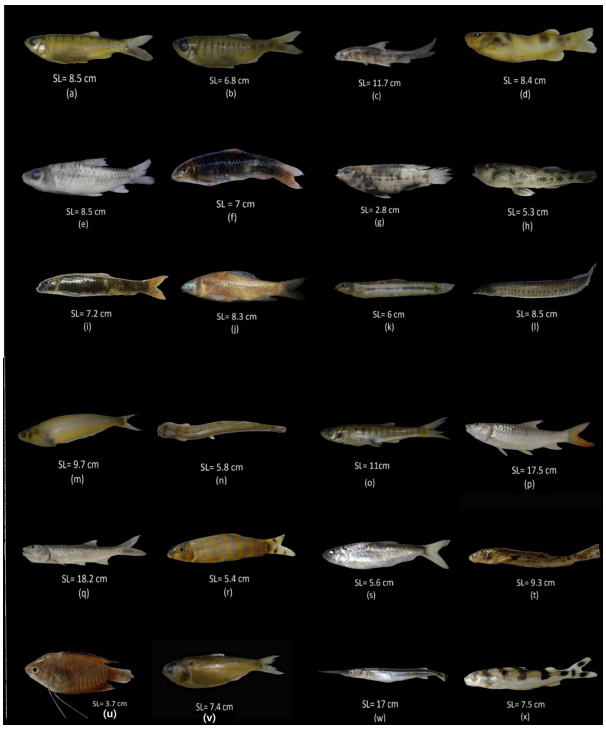


**Fig. 8.** Fish diversity recorded in Jia Bharali river during the study; (a) = *Barilius bendelensis*, (b)= *Barilius barila*, (c)= *Tariqilabeo latius*, (d)= *Batasiofasciolatus*, (e)= *Tor tor*, (f)= *Garragotyla*(g)= *Badis badis,* (h)= *Glossogobius giuris,* (i)= *Garra annandalei*, (j)= *Labeo calbasu*, (k)= *Lapedocephalichthys berdmorei*, (l)= *Macrognathus pancalus* (m)= *Ailia coila*, (n)= *Amblyceps laticeps*, (o)= *Barilius shacra* (p)= *Tor mosal*, (q)= *Raiamas bola*, (r)= *Botia Dario* (s)= *Cabdio morar,* (t)= *Canthophrys gongota,* (u)= *Trichogaster lalius*, (v)= *Gudusia chapra*, (w)= *Xenentodon cancila,* (x)= *Gagata cenia.*

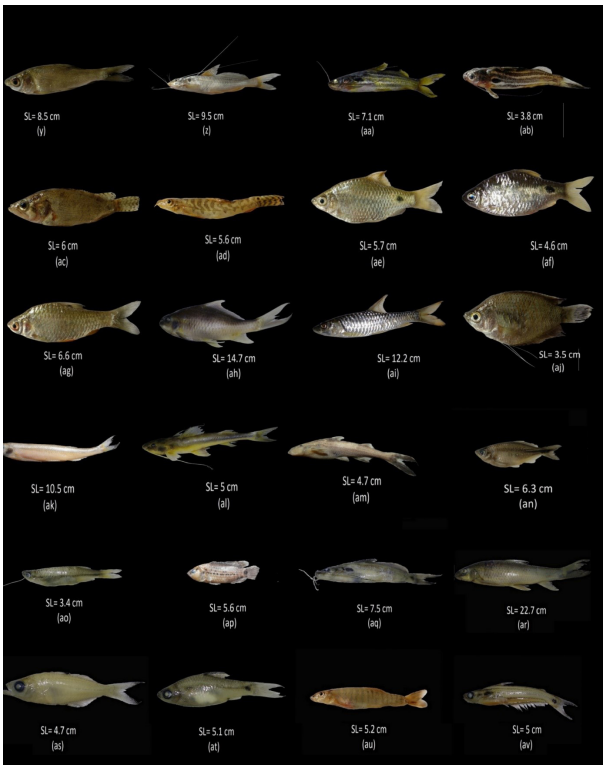


**Fig. 9.** Fish diversity recorded in Jia Bharali river during the study;(y)= *Labeo gonius*, (z)= *Mystus cavasius*, (aa)= *Mystus tengra,* (ab)= *Mystus vittatus*, (ac)= *Nandus nandus*, (ad)= *Acanthocobitis botia*(ae)= *Pethia ticto,* (af)= *Pethia conchinius*, (ag)= *Puntius sophore*, (ah)= *Cyprinion semiplotum*, (ai)= *Tor putitora*, (aj)= *Trichogaster fasciat a*(ak)= *Salmostomaba caila*, (al)= *Nangraas samensis*, (am)= *Glyptothorax telchitta*, (an)= *Devario devario*, (ao)= *Eosmas denricus*, (ap)= *Badis assamensis* (aq)= *Mystusdibrugarensis*, (ar)= *Chagunius chagunio*, (as)= *Chanda nama*, (at)= *Pethia guganio*, (au)= *Neonoemacheilus assamensis*, (av)= *Pachypterus atherinoides.*

## Discussion

The widespread distribution of cyprinids species in all the sampling sites of the Jia Bharalu River indicates the dominance of the family group in the study area. The dominance of the family Cyprinidae is in conformation with many other studies in India (Singh and Agarwal, 2013; Basavaraja *et al*., 2014) in general and northeast Indian rivers or wetlands in particular (Deori, Abujam and Biswas, 2015; Nath *et al*., 2015; Bagra *et al*., 2009; Bakalial *et al*., 2014; and Sudem, 2017). It has been stated that the order Cypriniformes has a high tolerance capacity to a wide range of environmental variables (Arunachalam *et al*., 2003). That might be led to the findings of 60.87% of the total fish species recorded (42 species) in the study area. In addition, species like *Amblyceps laticeps, Glyptothorax dikrongensis*, *Glyptothorax telchitta*, *Labeo boga, Gudusia chapra, Nandus nandus* and *Olyra perviocula* are recorded as rare in occurrences. Furthermore, the occurrence and abundance of torrential species like *Garra* spp., *Glyptothorax* spp., and *Schistura savonais* are significant in the study area due to the hillstream nature of the Jia Bharali river. Jia Bharali originates from the hills of Arunachal Pradesh and flows through Nameri National Park showing the hill stream characteristics. The hillstream nature of the river with its

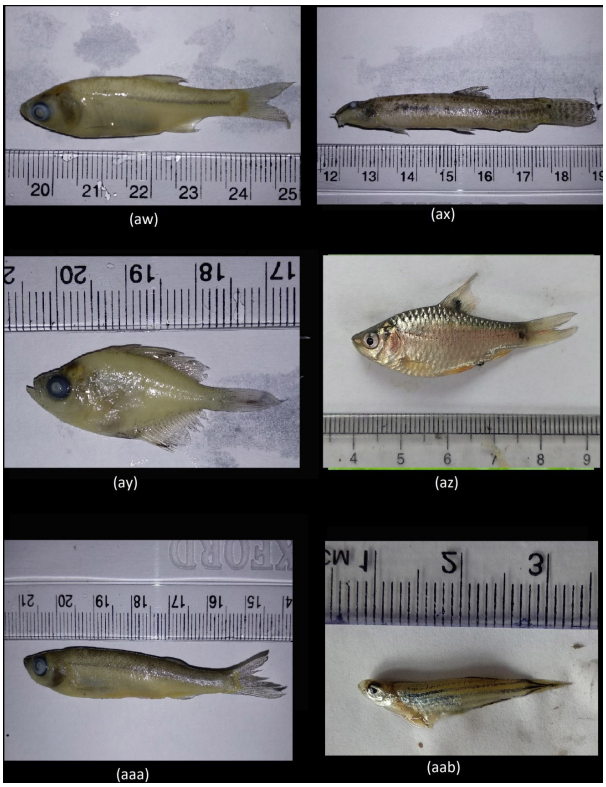


**Fig. 10.** Fish diversity recorded in Jia Bharali river during study; (aw) =*Amblyopharyngodon mola*, (ax)= *Lapidocephalichthys guntea*, (ay)= *Parambasis ranga*, (az)= *Puntius chola*, (aaa)= *Salmostoma phulo*, (aab)= *Danio rerio.*

pebbly and rocky and unconsolidated riverbed and the course of the river through the National Park offer habitat and breeding grounds for many species of hill stream and non-stream species in the study area. Certain semi-torrential species are also found during the study period in the study area. Ao, Dey and Sarmah (2008) also suggested that semi-torrential species were adapted in this type of environment with some structural modifications. Species like *Amblyceps laticeps*, *Olyra perviocula*, etc., with poor structural modification, were recorded from under rock and boulders. Overall, the species recorded from the Jia Bharali riverare found to be similar to those species recorded in Arunachal Pradesh to some extent as per Bagra *et al.* (2009).

In the present study, the diversity and abundance of fish species downstream are found to be high and low in midstream which is contrasting with the fact that fish community typically follow a pattern of increasing species richness, diversity and abundance from upstream to downstream in the riverine system (Welcomme, 1985; Bayley and Li, 1996). This may be due to the excessive degradation of riverbank forests in the midstream area. High species diversity in Site 1 indicates that the site provides a better environment for the survival of the fish species as compared to the other sites. While species diversity was highest in Site 1, the species were less evenly distributed in same (E=0.63) as compared to other sites. However, the evenest distribution was found in upstream Site 4. Moreover, the seasonal pattern of diversity showed minimal variations. The lower species diversity during winter was evident in the present study which is can be due tothe shrinkage of water in the river in winter decreases the availability of habitat and food resources of the fishes and eventually contributed to the low abundance of fish species (Welcomme, 1985). The high species diversity during retreating monsoon may be due to the higher temperature and moderate volume of water in the river.

The water parameters of Jia-Bharali river such as water current, dissolved oxygen, water temperature, and water pH showed significant variation among the study sampling sites depicting the potential of finding diverse fish fauna in different sampling sites. However, the ideal ranges of the above-mentioned parameters (Bhatnagar and Devi, 2013) were met in the present study as well. Water temperature and pH showed a weak positive correlation with species abundance in the present study. Water parameters have less influence on the diversity and abundance of fish fauna as most species have different tolerance levels and ecological needs (Huang *et al.*, 2019). A positive correlation between fish species richness and dissolved oxygen (DO) content was found in the present study. The dissolved oxygen (DO) content in water is an important environmental parameter for the survival of aquatic life as DO content is essential for respiration also plays an important role in regulating various metabolic as well as physiological processes (Rand *et al.*, 1995). It is important to note that a significant positive correlation of fish species assemblages with the dissolved oxygen (DO) content was also reported by Negi and Mamgain (2013). Further, the higher value of DO content during the winter and a lower value of DO during the monsoon season in the present study are supported by the finding of Bose *et al.* (2019). A higher value of DO (7.78±0.11) during the winter season compared to warmer days may be due to lower temperature in colder months as the solubility

of oxygen is increased with decreasing temperature (Odum and Gray, 2005).

The study provided valuable insights regarding the ichthyofaunal diversity of Jia Bharali River along with its water parameters. From the study, it can be concluded that the assemblages of different fish species depend not only on the habitat but also on the water parameters in the river system. It is noteworthy that a relatively high abundance of introduced species or exotic species indicates a great threat to the other local species in the river. The establishment of exotic species makes it difficult to conserve the local species. However, to conserve the threatened species recorded in the present study (endangered *Tor putitora*, vulnerable *Cyprinion semiplotum*, Near Threatened *Ailia coila* and *Neonoemacheilus assamensis*) needs urgent attention in terms of habitat management. Further study can be conducted to assess the ecosystem health of the river throughout its course which will be necessary for formulating future conservation strategies.

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