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Fish Fauna Faces Anthropogenic Double Trouble: Erosion of Fish Diversity in Tropical Oxbow Lake of the Ganga River Basin in Eastern India

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Abstract

Fish diversity in Oxbow lake is adversely impacted due to diverse anthropogenic activities like over-exploitation, indiscriminate use of fine meshed fishing gears, jute retting etc. To quantify the impact of such anthropogenic activities on fish diversity and aquatic health, a survey with seasonal analysis of diversity indices, relative frequencies and abundance status of native fish populations was conducted from April 2013 to March 2014 in a semi closed Oxbow lake in Nadia district in eastern India. The level of $p<0.05$ was accepted as statistical significance. Of the 33 native fish species recorded 33% belonging to 8 orders and 17 families fell under vulnerable or endangered categories. Native species like *Amblypharyngodon mola*, *Chanda nama*, *Pethia ticto* and *Notopterus notopterus*, *Colisa fasciata*, *P. ticto*, were the most dominant and frequent fishes. Shannon-Weiner diversity index was decreased by 41% by precipitating impact of monsoonal anthropogenic activities during post-monsoon. Low native fish diversity indices are pointers to poor ecosystem health status owing to intense adverse activities like jute retting, indiscriminate fishing aggravated by influx of turbid water from the river Ganga following episodic flood events during monsoon. Regulation and prevention of such anthropogenic activities are urgently warranted for sustainable conservation and management of the Oxbow lake.

Keywords: Fish diversity; Ecosystem health; Oxbow lake; Jute retting; Overexploitation

Introduction

Fish forms highest species diversity among all vertebrates and their loss is one of the world's most pressing crises as human life and livelihood largely depend on the status of biological resources. The freshwater fish is one of the most threatened taxonomic groups due to their high sensitivity to the quantitative and qualitative alteration in aquatic habitats [1]. The fish diversity and community structure are regarded as a reliable indicator of environmental stress [2]. Top carnivore's bioaccumulate pollutants, so their presence is indicative of high ecosystem integrity. Proportion of omnivorous and insectivores can also be an indicator since there would be more omnivorous fish with increase in organic loading and gradual deterioration of environmental quality. Riverine and Oxbow lake ecosystems have suffered from intense human intervention resulting in habitat loss and degradation over the last century and as a consequence, many fish species have become highly endangered. Studies have been limited to scattered works on commercial fisheries [2-11], based on catch data of some major groups largely restricted to some of the major river systems [1,12]. Various fish diversity indices are reported in several studies [13-27].

There exists a paucity of information on the pattern of native fish species diversity and abundance in Oxbow lake, in general and the quantitative bio-assessment of native fish diversity in Oxbow lake in Nadia district, in particular. Hence the present study was adopted to assess the status of native fish community structure, abundance, diversity, richness of and threats to the fish species, to quantify the impact of anthropological activities on fish diversity and aquatic health of tropical Oxbow lake ecosystem of Ganga river basin so as to recommend sustainable conservation management measures.

Materials and Methods

Study area

The Chhariganga Oxbow Lake as abandoned, fractioned and derived from the river Ganga is selected at random and located in Nakashipara development block of Nadia district, West Bengal, India. It is situated at 23.5800°N, 88.3500°E, about 90 Km away from the Kalyani university campus, Nadia and nearly 40 km away from the line of tropic of cancer towards the north. It is fresh water and semi-closed type Oxbow lake and receives water from the river Ganga during monsoon through a narrow channel at the north east corner of a loop of the river. The Oxbow lake is spread over an area of 58.28 ha with an annual average depth of 2.6 m. It also stores rain water. The catchment area of the Oxbow lake is nearly 600 ha (Figure 1). There are three distinct annual seasons observed in changed climate of this region: The monsoon or rainy season generally from July to October when jute retting period lies normally during August-September, post-monsoon or winter from November to February and the pre-monsoon or dry season from March to June. There was an occasional inundation of the surrounding banks during the monsoon. The Oxbow lake is subjected to all forms of human activities including jute retting during monsoon, agriculture and fishing. It is the only source of irrigation water to the immediate agriculture communities.

Fish sampling and analysis

Sample fishing was carried out by using the expertise of local fisher folk using 8 different types of gears [28,29], on several occasions at random allowing us to sample a range of fish sizes and minimize the bias (sample size 24) due to specific gears. Each gear was operated for hours ranging from 4 to 24 in different sites of the Oxbow lake bringing the total mean efforts per day (65, 44, 77 and 95) with gear density

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Figure 1: Map showing study area (Modified after the map being downloaded from google.com on 12-05-2016).

(2565, 5161, 2957 and 10683); and total sampling gear efforts (3648, 5200, 3411 and 12259) respectively during pre-monsoon, monsoon, post-monsoon and the year for all the gears used in the sampling following the methods adopted earlier [28,29]. Species richness (S) was defined as the number of fish species encountered at least one time in the lake for this study. Local fish markets associated with the Oxbow lake system were also visited to monitor and look for the presence of any species which were not available during our sample fishing. The Relative Abundance (RA, equaling to percentage of catch) of fish across lake was worked out for those three seasons. RA of individual species was calculated by dividing the product of number of samples of particular species and 100 by total number of samples. The Relative Frequency (RF) of individual species was calculated by dividing the product of number of occurrences of a species and 100 by total number of occurrences of all species.

Fishes were subsequently identified as per standard literature [30-36]. The threat status of the fishes of Chhariganga Oxbow lake was divided into nine categories as adapted from [35-39], LRnt: Low Risk near Threatened; Lrlc: Low Risk Least Concern; LC: Least Concern; NE: Not Evaluated; DD: Data Deficient; EN: Endangered; NT: Near Threatened. VU: Vulnerable; NA: Not Assessed for the IUCN Red List. Fishes were sorted out by their numbers and weighed. Fish species compositions during pre-monsoon, monsoon and post-monsoon were calculated. Statistical analyses including mean, standard deviation and the degree of relationships were determined with the help of MS-Excel and then presented in textual, tabular and graphical forms. The level of $p<0.05$ was accepted as statistical significance. The indices were calculated for the number of individuals (not biomass) of each species. The species diversity was finally determined. Statistical analysis of fish indices, such as richness, evenness, Shannon-Wiener diversity and Simpson's dominance and diversity index was done by using the following diversity index formulas:

Shannon-wiener index (H'): This is a widely used method of calculating biotic diversity in aquatic and terrestrial ecosystems and is expressed as SWI [40]:

$$H' = \sum_{i=1}^{s} \frac{ni}{n} \log \frac{ni}{n}$$

Where H=SWI of species diversity s=Number of species; n_i=Proportion of total sample belonging to the ith species. This diversity index helps in calculating species relative abundance. A large H value indicates greater diversity, as influenced by a greater number and/or a more equitable distribution of species. The index values ranges between 0 and 5, where higher index values demonstrate higher diversity, while low index values are considered to indicate pollution. Diversity and anthropogenic disturbances are inversely related to each other. The SWI takes account of species richness as well as abundance. It is simply the information entropy of the distribution, treating species as symbols and their relative population sizes as the probability. The advantage of this index is that it takes into account the number of species and the evenness of the species. The index is increased either by having additional unique species, or by having greater evenness. Diversity is maximum when all species that made up the community are equally abundant (i.e., have a similar population sizes). The diversity is partly a function of the variety of habitats; the more varied habitats tend to be inhabited by a large number of species than less variable ones. Secondly the older habitats usually contain more species than younger ones.

Evenness index (E): This is relative distribution of individuals among taxonomic groups within a community and is expressed as [41]:

$$E = \frac{H'}{\log S}$$

Where, H'=SWI, and log S=Natural log of the total number of species (S defined as species richness) recorded. It is used for the degree to which the abundances are equal among the groups present in a sample or community.

Simpson's dominance index (D): The Simpson's Index (D) is calculated using the following equation [42]:

$$D = \frac{\sum_{i=1}^{s} ni\,(ni-1)}{n\,(n-1)}$$

D=Where 'n_i' is the proportion of individuals of the ith species in the community. Simpson's index gives relatively little weight to the rare species and more weight to the common species. It weighs towards the abundance of the most common species. It ranges in a value from 0 (low diversity) to a maximum of (1-1/s), where s is the number of species. In nature the value of d ranges between 0 and 1. With this, index 0 represents infinite diversity and 1, no diversity. The bigger the (D) value, the smaller the diversity.

Simpson's diversity index (1-D): It represents the probability that two individual organisms randomly selected from a sample will belong to different species. The value of this index also ranges between 0 and 1, the greater the value, the greater the sample diversity.

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Results

The study recorded 33 species of finfish belonging to 8 orders and 17 families. The season wise relative frequency (RF) of all the species have been shown in Table 1. *Perciformes*, *Siluriformes*, *Cypriniformes* and *Osteoglossiformes* are the orders with higher relative frequency round the year. In the present study, native fish species like *Chanda nama* (46.51%), *Amblypharyngodon mola* (21.89%), *Pethia ticto* (11.93%) during pre-monsoon, *A. mola* (31.18%), *P. ticto* (30.15%), *Colisa fasciata* (8.84%) during monsoon, *A. mola* (69.97%), *P. ticto* (12.07%), *C. nama* (8.38%) during post-monsoon and overall *A. mola* (47.83%), *C. nama* (17.33%), *P. ticto* (17.03%) throughout the year were observed to be most dominantly abundant in the Oxbow lake. In the study most frequent native fish species were *N. notopterus*, *C. fasciata*, *P. ticto*, *Mystus vittatus*, *Heteropneustes fossilis*, *A. mola*, *C. nama* which were observed throughout the year (Table 1).

Perciformes was the most dominant order, contributing 52.26% of fish species during pre-monsoon and second most abundant order contributing 18.86%, 12.38% and 23.65% of the total 8 orders observed during monsoon, post-monsoon and year, respectively in the Oxbow lake. *Cypriniformes* is the most abundant order contributing 69.22%,

Taxonomic status				Threat status			PRM	MON	POM	Year
Order	Family	Scientific name	Vernacular name	NBFGR [37]	IUCN [39]	IUCN [36]	RF %			
Beloniformes	Belonidae	*Xenentodon cancila*	Kankle	LRnt	LC	LC	0.54	-	-	0.17
Clupeiformes	Clupeidae	*Gudusia chapra*	Khoira	VU	LC	NA	0.54	4.30	1.92	2.33
Cypriniformes	Cobitidae	*Botia dario*	Bengal Loach	VU [38]		LC	-	-	1.20	0.42
	Cyprinidae	*Amblypharyngodon mola*	Mourala/Moya	-	LC	LC	3.53	6.21	9.13	6.40
		Aspidoparia morar	Morar	LRnt		NA	3.80	3.10	-	2.24
		Catla catla	Catla	VU	NE	NA	-	0.24	-	0.08
		Salmophasia bacaila	Chela	-		NA	0.27	-	-	0.08
		Cirrhinus mrigala	Mrigal	LRnt	LC	LC	-	-	0.48	0.17
		Labeo bata	Bata	LRnt	LC	LC	-	1.43	-	0.50
		Labeo calbasu	Calbaus	LRnt	LC	LC	0.54	0.48	0.24	0.42
		Labeo rohita	Rohu	LRlc	LC	LC	6.25	0.95	1.44	2.74
		Pethia ticto	Punti	LRnt	LC	LC	5.43	9.55	6.73	7.32
Subtotal Cypriniformes							19.84	21.96	19.23	20.37
Osteoglossiformes	Notopteridae	*Chitala chitala/ornate* [35]	Chital	EN	EN	LC	4.35	0.48	2.88	2.49
		Notopterus notopterus	Folui	EN	LC	LC	10.33	16.71	4.33	10.47
Subtotal Osteoglossiformes							14.67	17.18	7.21	12.97
Perciformes	Ambassidae	*Chanda nama*	Chanda	LRlc	LC	LC	5.98	3.82	9.13	6.32
	Anabantidae	*Anabus testudineus*	Koi	DD		NA	4.35	-	4.81	2.99
		Colisa fasciata	Khalse	LC	LC	NA	4.62	5.73	15.38	8.73
	Channidae	*Channa marulius*	Shaal/Gazar	VU	LC	LC	4.62	0.24	2.88	2.49
		Channa punctatus	Lyata	LRnt	LC	NA	2.72	4.77	1.92	3.16
		Channa striatus	Shol	LRnt	NE	NA	5.71	0.48	3.37	3.08
	Gobiidae	*Glossogobius giuris*	Bele	LRnt	LC	LC	0.27	-	-	0.08
	Nandidae	*Nandus nandus*	Nados/Nona/Bheda	LRnt	LC	LC	4.08	4.77	3.37	4.07
Subtotal Perciformes							32.34	19.81	40.87	30.92
Siluriformes	Bagridae	*Sperata aor*	Aar	VU [38]	VU	LC	1.09	0.48	-	0.50
		Mystus vittatus	Tangra	VU	LC	LC	5.98	10.50	3.61	6.73
	Clariidae	*Clarias batrachus*	Magur	LC	LC	LC	5.71	8.83	2.88	5.82
	Heteropneustidae	*Heteropneustes fossilis*	Singhi	VU [38]	LC	LC	4.89	11.22	3.13	6.48
	Siluridae	*Ompok pabda*	Pabda	EN/VU [38]		NA	0.82	-	2.40	1.08
		Wallago attu	Boal	LRnt	NT	NT	4.89	1.91	3.37	3.33

Taxonomic status				Threat status			PRM	MON	POM	Year
Order	Family	Scientific name	Vernacular name	NBFGR [37]	IUCN [39]	IUCN [36]	RF %			
Subtotal Siluriformes							23.37	32.94	15.38	23.94
Synbranchiformes	Mastacembelidae	*Macrognathus aculeatus*	Tora Ban		LC	NA	-	-	6.01	2.08
		Mastacembelus pancalus	Pankal/Guchi Ban	LRnt	NT	NA	0.27	0.24	0.24	0.25
		Mastcembelus armatus	Ban	VU	LC	NA	2.45	3.58	2.16	2.74
	Synbranchidae	*Monopterus cuchia*	Kuche	DD		LC	0.27	-	0.24	0.17
Subtotal Synbranchiformes							2.99	3.82	8.65	5.24
Tetraodontiformes	Tetraodontidae	*Tetradon cutcutia*	Potka/Tyapa	LRnt	NT	NA	5.71	-	6.73	4.07

Table 1: Diversity of fish species, threat status and relative frequency. LRnt: Low Risk near Threatened; Lrlc: Low Risk Least Concern; LC: Least Concern; NE: Not Evaluated; DD: Data Deficient; EN: Endangered; NT: Near Threatened; VU: Vulnerable; NA: Not Assessed for the IUCN Red List; RF: Relative Frequency; PRM=Pre-monsoon; MON; Monsoon; POM; Post-monsoon.

83.50% and 68.53% during two seasons and year except pre-monsoon when it is second (37.14%) most abundant order. The most abundant families of the native fish fauna encountered in numbers in the lake were Ambassidae (46.51%) followed by Cyprinidae (37.14%) and Tetraodontidae (3.19%) during pre-monsoon; Cyprinidae (69.22%) followed by Anabantidae (8.84%) and Ambassidae (7.96%) during monsoon; Cyprinidae (83.39%) followed by Ambassidae (8.38%) and Anabantidae (2.90%) during post-monsoon; and in total Cyprinidae (68.48%) followed by Ambassidae (17.33%) and Anabantidae (4.54%) during the year (Table 2).

The present study observed seasonal variations of range with mean ± SD values of species richness (23-28, 25.67 ± 2.52), Shannon-Wiener index (1.19-2.02, 1.68 ± 0.43), evenness index (0.36-0.64, 0.51 ± 0.14), Simpson's diversity index (0.49-0.79, 0.67 ± 0.16) of fish in the Oxbow lake (Table 3). During the study the species richness as found during pre-monsoon showed significant reduction (around 18%) during jute retting period during monsoon and recovered (13%) during post-monsoon when compared to monsoon. The SWI of the present study showed considerable variation. It indicated an increase (11%) during monsoon over pre-monsoon and overall sharp decrease (41%) during post-monsoon from monsoon which was inversed to the variations in overall species richness. Maximum Simpson's Diversity Index was observed in monsoon as compared to other two seasons. Post-monsoon showed the highest Simpson's dominance index with lowest Simpson's diversity index, SWI and species evenness. Most conspicuous (RA % in terms of catch in number) round the year species were like *A. mola*, *C. nama*, *P. ticto*, *C. fasciata*, *Labeo rohita*. *Cyprinidae*, *Channidae* and *Mastacembelidae* contributed the maximum species in each season (Figure 2).

Discussion

Absence of exotic species of the present Oxbow lake indicated no threat to the native species [43]. However, the present study has lesser numbers of species recorded compared to the previous study [5], with similar type of fish species [2]. The present study also noticed the overall dominance of *Amblypharyngodon mola* among the 12 frequently available species throughout the year like other study [6]. Present findings on the catch composition, fish production, fish diversity, threats, etc. are in partial conformity with other studies on the floodplain wetlands ecosystems of the Gangetic basin in West Bengal [44]. In the present study, more than 80% relative abundance was contributed by only 3 fish species, 90% by only 8 species, whereas remaining 20 species make only 9.71% of individuals during pre-monsoon. More than 85% was contributed by six species, of which above 61% contributed by only two species, and remaining 17 make only 14.49% during monsoon whereas 3 species contribute more than 90%, 23 species make 9.59% during post-monsoon while 3 species make more than 82%, remaining 30 make only 17.82% during the year. Present findings are in full or partial agreement with other similar studies [7,18,22,24,26,45].

In the present study, 32 species was categorized in the following group: 9 as VU, 2 as EN and 21 as either LR or LC or others as the status of remaining 1 was not known due to data deficiency (DD). A seasonal variation in relative frequency was shown along with relative abundance of endangered and vulnerable native fish species in the Oxbow lake (Figures 3 and 4). One third of the fish species encountered in this study were either vulnerable or endangered with combined relative abundance of 5.45% in the year. Three species (*N. notopterus*, *Mystus vittatus* and *H. fossilis*) among the 11 vulnerable or endangered (4 species with moderate relative frequency), showed higher relative frequency and abundance throughout the year compared to *Catla catla* (the lowest), *Botia dario*, *Sperata aor* and *Ompok pabda*. The remarkable post-monsoon reduction in relative frequency of 14 species (half of VU and EN) and reduction in relative abundance of 15 species (40% VU and EN) like *Aspidoparia morar* (LRnt), *Labeo bata* (LRnt), *Sperata aor* (VU), *Catla catla* (VU), *N. notopterus* (EN), *H. fossilis* (VU) may be attributed to anthropogenic activities like overfishing or the their intolerance or less tolerance capability to organic pollution due to jute retting operations during monsoon in the lake. However, there were observed more relatively abundant 6 species (1/3rd of VU or EN) and frequent 9 species (more than 1/5th VU or EN) like *Channa marulius* (VU), *Channa striatus* (LRnt), *Chitala chitala*/ornate (EN), *Chanda nama* (LC), *Wallago attu* (NT) during the same period which indicated their hard tolerance to the pollution. The annual abundance of Labeo rohita was relatively higher compared to *Catla catla* and *Cirrhinus mrigala*. The present findings on relative abundance of vulnerable or endangered fish species were in partial agreement with other studies [18,23,26,27].

The SWI of the present study had shown maximum value during monsoon when all species are equally abundant with similar population

Taxonomic status			PRM	MON	POM	Year
Order	**Family**	**Scientific name**	**RA %**			
Beloniformes	Belonidae	*Xenentodon cancila*	0.09	-	-	0.02
Clupeiformes	Clupeidae	*Gudusia chapra*	0.09	1.91	0.17	0.63
Cypriniformes	Cobitidae	*Botia dario*	-	-	0.10	0.05
	Cyprinidae	*Amblypharyngodon mola*	21.89	31.18	69.97	47.83
		Aspidoparia morar	0.94	1.10	-	0.53
		Catla catla	-	0.29	-	0.08
		Salmophasia bacaila	0.04	-	-	0.01
		Cirrhinus mrigala	-	-	0.08	0.04
		Labeo bata	-	4.70	-	1.30
		Labeo calbasu	0.43	0.37	0.02	0.21
		Labeo rohita	1.92	1.43	1.25	1.46
		Pethia ticto	11.93	30.15	12.07	17.03
Cypriniformes			37.14	69.22	83.50	68.53
Osteoglossiformes	Notopteridae	*Chitala chitala/ornata*	0.68	0.22	0.25	0.34
		Notopterus notopterus	1.62	2.68	0.38	1.31
Osteoglossiformes			2.30	2.90	0.63	1.65
Perciformes	Ambassidae	*Chanda nama*	46.51	7.96	8.38	17.33
	Anabantidae	*Anabus testudineus*	2.17	-	0.42	0.72
		Colisa fasciata	0.72	8.84	2.48	3.82
	Channidae	*Channa marulius*	0.77	0.07	0.35	0.37
		Channa punctatus	0.43	1.17	0.17	0.51
		Channa striatus	0.94	0.07	0.29	0.38
	Gobiidae	*Glossogobius giuris*	0.04	-	-	0.01
	Nandidae	*Nandus nandus*	0.68	0.73	0.29	0.51
Perciformes			52.26	18.86	12.38	23.65
Siluriformes	Bagridae	*Sperata aor*	0.17	0.26	-	0.11
		Mystus vittatus	0.94	1.61	0.31	0.82
	Clariidae	*Clarias batrachus*	0.89	1.36	0.25	0.71
	Heteropneustidae	*Heteropneustes fossilis*	0.77	1.83	0.27	0.82
	Siluridae	*Ompok pabda*	0.47	-	0.21	0.21
		Wallago attu	1.06	0.29	0.50	0.58
Siluriformes			4.30	5.36	1.54	3.25
Synbranchiformes	Mastacembelidae	*Macrognathus aculeatus*	-	-	0.52	0.25
		Mastacembelus pancalus	0.04	0.04	0.02	0.03
		Mastcembelus armatus	0.55	1.72	0.19	0.70
	Synbranchidae	*Monopterus cuchia*	0.04	-	0.02	0.02
Synbranchiformes			0.64	1.76	0.75	1.00
Tetraodontiformes	Tetraodontidae	*Tetradon cutcutia*	3.19	-	1.04	1.27

Table 2: Seasonal variations in composition with relative abundance of fish species. RA: Relative Abundance (%); PRM: Pre-monsoon; MON: Monsoon; POM: Post-monsoon.

	PRM	MON	POM	Year	Seasonal Mean	SD
Species Richness	28	23	26	33	25.67	2.52
Shannon Index (SWI)	1.82	2.02	1.19	1.77	1.68	0.43
Species Evenness	0.54	0.64	0.36	0.51	0.51	0.14
Simpson's Dominance Index	0.28	0.21	0.51	0.29	0.33	0.16
Simpson's Diversity Index	0.72	0.79	0.49	0.71	0.67	0.16

Table 3: Seasonal variations in native fish diversity indices. PRM: Pre-monsoon; MON: Monsoon; POM: Post-monsoon; SD: Standard Deviation.

sizes. This is partly attributed to the variety of habitats of Oxbow lake with macrophyte conducive for breeding ground for several fishes during monsoon. The more varied habitats tend to be inhabited by a large number of species compared to less variable ones. However, sharp fall in the diversity during post-monsoon indicated lesser availability of fishes and/or their mortality perhaps due to jute retting and indiscriminate fishing operations of the monsoon season and higher level of diversity was subsequently noticed during pre-monsoon probably due to warmer temperatures, availability and stability of food compared to post-monsoon. Shannon-Weiner diversity index was decreased by 41% by precipitating impact of monsoonal anthropogenic activities during post-monsoon. Low native fish diversity indices are pointers to poor ecosystem health status owing to intense adverse activities like jute retting, indiscriminate fishing aggravated by influx of turbid water from the river Ganga following episodic flood events during monsoon. The present findings on fish SWI and Simpson

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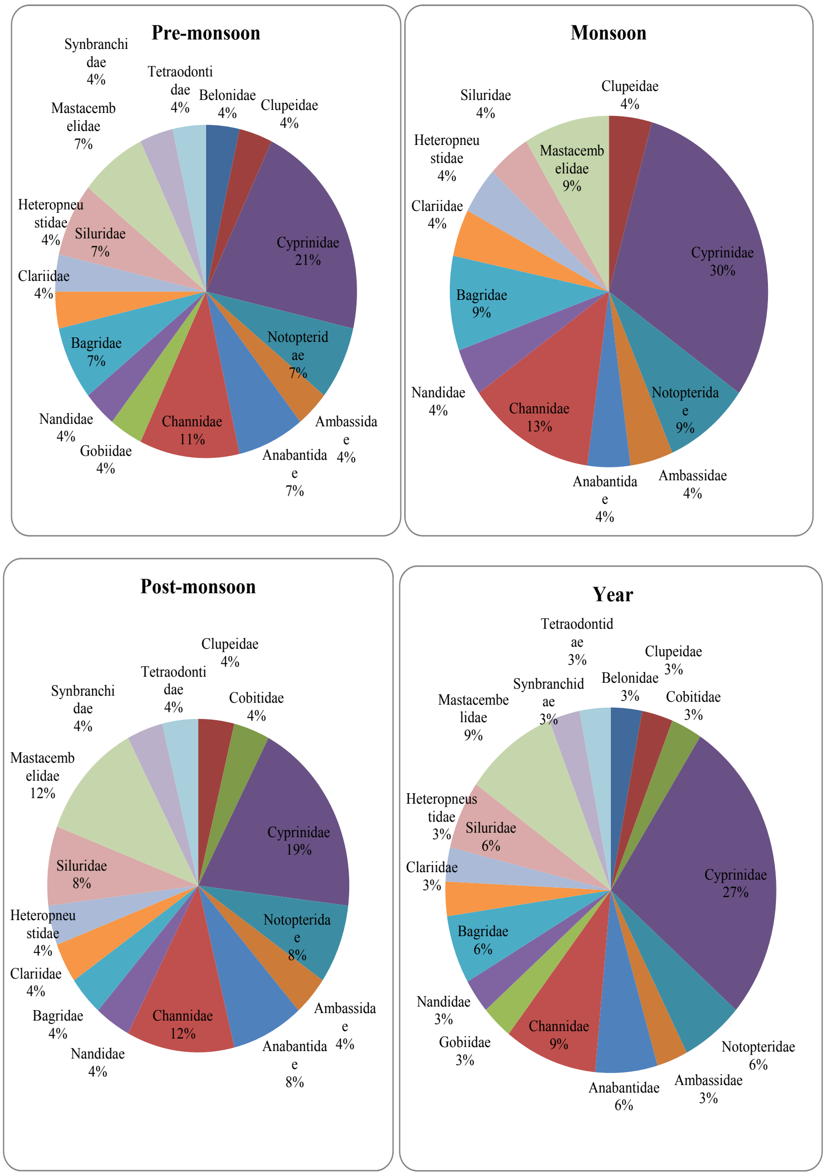

Figure 2: Seasonal fish species profile at the family level.

diversity values showed quite similarity with other studies [9,13-17,19,21,24,25,45], in contrast with other studies [18,20,22,23,26,27].

Fish diversity was therefore severely impacted by anthropogenic activities like jute retting and indiscriminate use of fishing gears of various mesh sizes as depicted in Figure 5. Shannon-Weiner diversity Index of native fish got sharply decreased by 41% during post-monsoon due to various anthropogenic activities during the monsoon in the present study. Lower fish diversity indices (values of SWI and Simpson diversity index) showed the bad to poor health status of the Oxbow lake and it was subjected to high anthropogenic pressure and pollution and was not suitable for fish growth. This pollution status concurred when assessed with diversity indices of rotifer [46], zooplankton [47], macroinvertebrates [48], macrophytes [49], phytoplankton [50], and fish diversity and productivity [28,29]. Due to lack of previous information on fish diversity from this Oxbow lake it is not possible to quantify the rate of decline in fish and since this Oxbow lake lacks earlier such database to compare the impact of pollution over the years, this first ever study of its kind conducted may serve the baseline data for quantitative and comparative bioassessment of native fin fish for the future studies in the years to come. The findings from the study will benefit the planning and management of sustainable fisheries and conservation of these natural resources at national level.

Conclusion

Shannon-Weiner diversity index was decreased by 41% by precipitating impact of monsoonal anthropogenic activities during post-monsoon. Low native fish diversity indices are pointers to poor ecosystem health status owing to intense adverse activities like jute retting, indiscriminate fishing aggravated by influx of turbid water from the river Ganga following episodic flood events during monsoon. Regulation and prevention of such anthropogenic activities are urgently warranted for sustainable conservation and management of the Oxbow lake.

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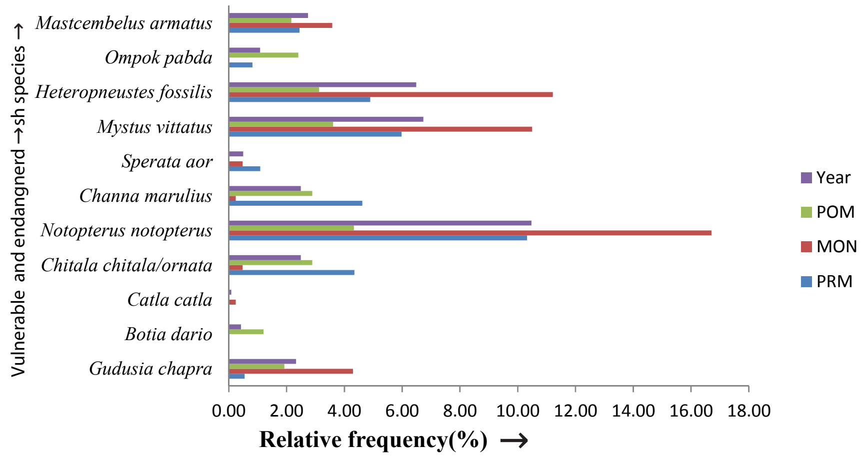

Figure 3: Seasonal variations in relative frequency (%) of vulnerable and endangered fish. PRM: Pre-monsoon; ON: Monsoon; POM: Post-monsoon.

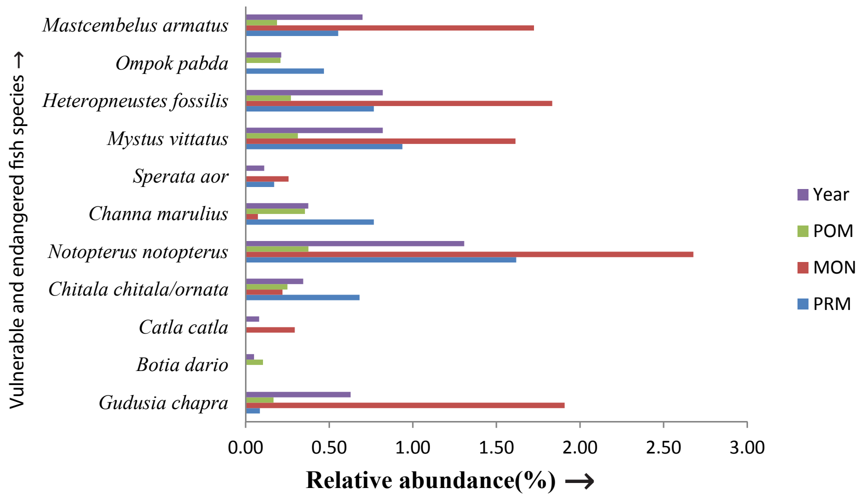

Figure 4: Seasonal variations in relative abundance (%) of vulnerable and endangered fish. PRM: Pre-monsoon; MON: Monsoon; POM: Post-monsoon.

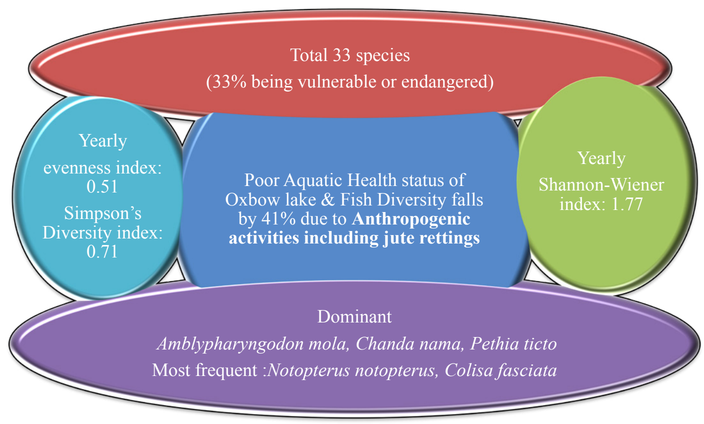

Figure 5: Fish diversity subjected to anthropogenic double jeopardy of jute retting and overexploitation using fine meshed fishing gears.

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