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

Ghosh D1 and Biswas JK1,2*
1Department of Ecological Studies, University of Kalyani, Kalyani, West Bengal, India
2International Centre for Ecological Engineering, University of Kalyani, Kalyani, West Bengal, India

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 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.

*Corresponding author: Jayanta Kumar Biswas, Department of Ecological Studies, University of Kalyani, Kalyani, West Bengal, 741235, India, Tel: +919434179945; Fax: 91-033-25828282; E-mail: biswajoy2000@yahoo.com

Received May 12, 2017; Accepted May 29, 2017; Published June 06, 2017

Citation: Ghosh D, Biswas JK (2017) Fish Fauna Faces Anthropogenic Double Trouble: Erosion of Fish Diversity in Tropical Oxbow Lake of the Ganga River Basin in Eastern India. J Biodivers Endanger Species 5: 188. doi: 10.4172/2332-2543.1000188

Copyright: © 2017 Biswas JK, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.
Fish Fauna Faces Anthropogenic Double Trouble: Erosion of Fish Diversity in Tropical Oxbow Lake of the Ganga River Basin in Eastern India

Citation: Ghosh D, Biswas JK (2017) Fish Fauna Faces Anthropogenic Double Trouble: Erosion of Fish Diversity in Tropical Oxbow Lake of the Ganga River Basin in Eastern India. J Biodivers Endanger Species 5: 188. doi: 10.4172/2332-2543.1000188

(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.

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

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 \( H = \text{SWI of species diversity} \) = Number of species; \( n = \text{Proportion of total sample belonging to the}^{i}\text{st species} \). 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, \( H' = \text{SWI}, \) and \( \log S = \text{Natural log of the total number of species} \) (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]:

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

D = Where \( n' \) is the proportion of individuals of the \( i^{th} \) species in the community. Simpson’s index gives relatively little weight to the rare species and more weight to the common species. It weights 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.
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%,
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 inverse 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 Labeo rohita, 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 Amblyphtyngodon 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 marilus (VU), Channa striatus (LRnt), Chitala chitala/ornare (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.
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

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

| Order       | Family      | Scientific name          | PRM | MON | POM | Year |
|-------------|-------------|--------------------------|-----|-----|-----|------|
| Beloniformes| Belonidae   | Xenentodon cancila       | 0.09| -   | -   | 0.02 |
| Clupeiformes| Clupeidae   | Gudusia chapra           | 0.09| 1.91| 0.17| 0.63 |
| Cobitidae   | Boleo dario |                          |     | 0.10|     | 0.05 |
| Cypriniformes| Cyprinidae | Amblyporgophidon mola   | 21.89| 31.18| 69.97| 47.83 |
|             |             | Aspidoparia morar        | 0.94| 1.10| -   | 0.53 |
|             |             | Callia catla             | -   | 0.29|     | 0.08 |
|             |             | Salmo phis bacailla      | 0.04| -   |     | 0.01 |
|             |             | Citrinus miragala        | -   | -   | 0.08| 0.04 |
|             |             | Labeo batra              | -   | 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| Notopterida | 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 | Anabas testudineus        | 2.17| -   | 0.42| 0.72 |
|             | Colisa fasciata |                      | 0.72| 8.84| 2.48| 3.82 |
| Channidae   | Channa marulues |                      | 0.77| 0.07| 0.35| 0.37 |
|             | Channa punctatus |                      | 0.43| 1.17| 0.17| 0.51 |
|             | Channa striaus |                      | 0.94| 0.07| 0.29| 0.38 |
| Gobiidae    | Glossosogibius 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 aur              | 0.17| 0.26| -   | 0.11 |
|             | Mystus vittatus |                      | 0.94| 1.61| 0.31| 0.82 |
| Claridae    | Claris batrachus |                      | 0.89| 1.36| 0.25| 0.21 |
| Heteropeustidae | Heteropeustes fossils | | 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 | Mastacembelida | Macrognathus aculeatus | - | - | 0.52| 0.25 |
|             | Mastacembelus pancerus |                  | 0.04| 0.04| 0.02| 0.03 |
|             | Mastacembelus 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 | Tetradon cutulata |                 | 3.19| -   | 1.04| 1.27 |

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

| Species Richness | PRM | MON | POM | Year | Seasonal Mean | SD  |
|------------------|-----|-----|-----|------|---------------|-----|
|                  | 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|
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.

**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.

![Figure 2: Seasonal fish species profile at the family level.](image-url)
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; ON: Monsoon; POM: Post-monsoon.

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

Authors acknowledge the research facilities and/or other help and cooperation extended by Department of Ecological Studies, University of Kalyani, Department of Fisheries, Government of West Bengal and Kulipara Fishermen Cooperative Society associated with Chhartaganga Oxbow Lake.

References

1. Sarkar UK, Pathak AK, Lakra WS (2008) Conservation of freshwater fish resources of India: new approaches, assessment and challenges. Biodivers Conserv 17: 2495-2511.

2. Das SK, Chakrabarty D (2008) The evaluation of ecological degradation in two tropical lakes of India in respect of fin fish community structure. In: Sengupta M and Dalwasi R (eds.) Proc Taal 2007: The 12th World Lake Conference pp: 2023-2030.

3. Dewan S, Uddin MJ, Hossain MMM, Das DR, Hossain MS (2002) Studies on production potentials of “Kua” fisheries of Raktodaha Beel, Bogra Bangladesh. Pak J Biol Sci 5: 221-224.

4. Ahmed N, Rahaman MM, Rahaman MM (2005) Fish catch assessment Maljhee Kangsa Flood plain in Bangladesh. Pak J Biol Sci 8: 396-400.

5. Kar D, Nagarathna AV, Ramachandra TV, Dey SC (2006) Fish diversity and conservation aspects in an aquatic ecosystem in north eastern India. Zoos Print J 21: 2308-2315.

6. Mondal DK, Kaviraj A (2009) Distribution of fish assemblage in two flood plain lakes of North 24-Parganas, West Bengal. J Fish Aquat Sci 4: 12-21.

7. Saha MK, Patra BC (2013) Present status of ichthyofaunal diversity of Damodar River at Burdwan District, West Bengal, India. J Int Sci Res Pub 3: 1-11.

8. Siddiq MA, Miah MI, Ahmed FS, Azaduljaman M (2013) Present status of fish, fishers and fisherries of Dogger Beel in Hajongir Upazila, Chandpur, Bangladesh. J Aquatic Sci 3: 19-45.

9. Viana AP, Lucena FF (2014) Ichthyofauna as bioindicator of environmental quality in an industrial district in the Amazon estuary, Brazil. Braz J Biol 74: 315-324.

10. Mukherjee S, Panighrahi AK, Mandal A (2015) Study on the effects of pollution on ichthyofaunal diversity of selected fresh water beets in Nadia District, West Bengal. Indian J Appl Res Zool 5: 558-561.

11. Rahaman M, Sayeed MA, Rasul MG, Mondal MN, Majumdar BC, et al. (2016) Impact of fishing gear on fish biodiversity of Hakaluki haor in Bangladesh. Int J Fisheries Aquatic Studies 4: 257-282.

12. Mishra DN, Moza U (1997) Changing scenario of fish and fisheries of River Yamuna-part II. In: Vass KK and Sinhha M (eds.) Changing perspectives of inland fisheries. Proceedings of the national seminar, March 16-17, 1997. Inland Fisheries Society of India, Barrack pore pp: 57-62.

13. Carvalho ED, Da Silva VFB, Fujihara CY, Henry R, Foresti F (1998) Diversity of fish species in the River Paranapanema-Juruñim Reservoir transition region (São Paulo, Brazil), Ital. J Zool 65: 325-330.

14. Henning J (2004) An Evaluation of Fish and Amphibian Use of Restored and Natural Floodplain Wetlands, Washington Department of Fish and Wildlife. Prepared for: Environmental Protection Agency.

15. Carvalho ED, Marcus LR, Foresti F, Silva VFB (2005) Fish assemblage attributes in a small Oxbow lake (Upper Paraná River Basin, São Paulo State, Brazil): species composition, diversity and ontogenetic stage. Acta Limnol Bras 17: 45-56.

16. Mustafa MG, Brooks AC (2009) A comparative study of two seasonal flood plain aquaculture systems in Bangladesh. Water Policy 1: 69-79.

17. Arthur RJ, Lorenzen K, Homekingeo P, Sidavong K, Sengvilaikhham B, et al. (2010) Assessing impacts of introduced aquaculture species on native fish communities: Nile tilapia and major carps in SE Asian freshwaters. Aquaculture 299: 81-88.

18. Lakra WS, Sarkar UK, Kumar RS, Pandey A, Dubey VK, et al. (2010) Fish diversity, habitat ecology and their conservation and management issues of a tropical River in Ganga basin, India. Environmentalist.

19. Juriapda P, Janac M, Valova Z, Streck G (2010) Fish community in the chronically polluted middle Elbe River. Folia Zool 59: 157-168.

20. Mondal DK, Kaviraj A, Saha S (2010) Water quality parameters and fish biodiversity indices as measures of ecological degradation: A case study in two floodplain lakes of India. J Wat Res Protect 2: 85-92.

21. Mwangi BM, Ombogo MA, Amadi J, Baker N, Mugalu D (2012) Fish species composition and diversity of small riverine ecosystems in the Lake Victoria Basin, Kenya. Int J Sci Tech 2: 675-680.

22. Murugan AS, Prabaharan C (2012) Fish diversity in relation to physico-chemical characteristics of Kamala Basin of Darbhanga District, Bihar, India. Int J Pharm Biol Sci 3: 2272-2730.

23. Galib SM, Abu Naser SM, Mohsin ABM, Chaki N, Fahad FH (2013) Fish diversity of the River Choto Jamuna, Bangladesh: Present status and conservation needs. Int J Biodivers Conserv 5: 389-395.

24. Vyas V, Vishwakarma KS (2013) Fish diversity in two tributaries of River Narmada, Central India. J Chem Biol Phys Sci 3: 2722-2730.

25. Sweke EA, Assam JM, Matsuishi T, Chande AI (2013) Fish diversity and abundance of Lake Tanganyika: Comparison between protected area (Mahale Mountains National Park) and Unprotected Areas. Int J Biodivers.

26. Basavaraaya D, Narayana J, Kiran BR, Puttiaah ET (2014) Fish diversity and abundance in relation to water quality of Anjanapura reservoir, Karnataka, India. Int J Curr Microbiol App Sci 3: 747-757.

27. Ghosh D, Biswas JK (2015) Impact of jute retting on native fish diversity and aquatic health of roadside transitory water bodies: An assessment in Eastern India. J Ecol Eng 16: 14-21.

28. Ghosh D, Biswas JK (2017) Erosion of Fish Diversity: Ranking Degree of Dangers of unsustainable Fishing gears in a Tropical Oxbow lake in eastern India. IUCB Research Paper 3: 1-17.

29. Ghosh D, Biswas JK (2017) Fish productivity: Assessing sustainability in a tropical Oxbow lake of Nadia district, West Bengal, India. Arch Agric Environ Sci 2: 6-20.

30. Jayaram KC (1981) Freshwater Fishes of India-Hand book. Zoological Survey of India, Calculutta.

31. Jayaram KC (1999) The Freshwater Fishes of the Indian Region. Narendra Publishing House, Delhi, India 27: 551.

32. Talwar PK, Jhingran AG (1991) Inland fishes of India and adjacent countries, Oxford and IBH Co. Pvt. Ltd., New Delhi, India p: 1158.

33. Dutta MJS, Srivastava MP (1988) Natural history of fishes and systematics of freshwater fishes in India, Narendra Publishing House, New Delhi, India p: 421.

34. Froese R, Pauly D (2015) Fishbase. World Wide Web electronic publication.

35. Vidhathyannon C (2012) Chitala ornata. The IUCN Red List of Threatened Species.

36. IUCN (2015) IUCN Red List of Threatened Species.

37. Lakra WS, Sarkar UK (2007) Freshwater fish diversity of central India. National Bureau of Fish Genetic Resources, Lucknow p: 183.

38. Lakra WS, Sarkar UK, Gopalakrishnan A, Kathirvelpandian A (2010) Threatened Fresh water Fishes of India, published by National Bureau of Fish Genetic Resources (NBFRG), Lucknow, India pp: 1-20.

39. IUCN (2011) IUCN red list of threatened species.

40. Shannon CE, Wiener W (1963) The mathematical theory of communication. University of Illinois press, Urbana, USA p: 117.

41. Pelou EC (1966) An Introduction to Mathematical Ecology. John Wiley and Sons, NY, USA.

42. Simpson EH (1949) Measurement of diversity. Nature pp: 163-188.

43. Sarkar UK, Gupta BK, Lakra WS (2010) Biodiversity, Ecolhydrology, threat status and conservation priority of freshwater fishes of River Gomali, a tributary of River Ganga (India). Environmentalist 30: 3-17.

44. Bhaumik U, Paria T, Saha S (2006) Fisheries status of floodplain wetlands of the Gangetic basin in West Bengal. In: AEHMS conference proceedings of The Majestic River Ganga: Health, Integrity, and Management, Patna, India.

45. Khodake SP, Rajendra PB, Petare RK (2014) Ichthyofaunal diversity in Jamkhedi reservoir in Dhule District, Maharashtra, India. J Environ Res Dev 9: 177-183.
46. Ghosh D, Biswas JK (2014) Rotifera diversity indices: Assessment of aquatic health of an Oxbow lake ecosystem in West Bengal. Int J Curr Res 6: 10554-10557.

47. Ghosh D, Biswas JK (2015) Zooplankton diversity indices: Assessment of an Oxbow lake ecosystem for sustainable management in West Bengal. Int J Adv Biotechnol Res 6: 37-43.

48. Ghosh D, Biswas JK (2015) Macroinvertebrates’ diversity indices: Quantitative bio-assessment of ecological health status of an ox-bow lake in eastern India. J Adv Environ Hlth Res 3: 78-90.

49. Ghosh D, Biswas JK (2015) Biomonitoring macrophytes and abundance for rating aquatic health of an Oxbow lake ecosystem in Ganga River basin. Am J Phytother 3: 602-621.

50. Ghosh D, Biswas JK (2015) Impact of jute retting on phytoplankton diversity and aquatic health: Biomonitoring in a tropical Oxbow lake. J Ecol Eng 16: 15-25.