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Persistence and Structure of the Fish Assemblage from the Ganga River (Kanpur to Varanasi section), India

Dwivedi AC[1*], Mishra AS[2], Mayank P[1] and Tiwari A[1]

[1]Regional Centre, Central Inland Fisheries Research Institute (ICAR), 24 Panna Lal Road Allahabad 211002, India
[2]Department of Zoology, Nehru Gram Bharti University, Allahabad, India

Abstract

Fish assemblages are an important component of aquatic ecosystems. Present investigation was undertaken to study the Persistence, structure and abundance of fishes from the Ganga river (site 1: Kanpur, site 2: Allahabad and site, 3: Varanasi section), India. The Ganga river is a back bone of Indian fishery. The samples were collected monthly during the period June 2011 to May 2013. Canonical correspondence analysis (CCA) indicated that axis 1 and 2 accounted for 67% and 33% variance for species and environmental relation, respectively. Structure of the fish assemblage of the Ganga at Kanupr to Varanasi harbors of 102 fish species belong to 8 orders and 28 families. 74, 89 and 82 fish species were recorded at Kanpur, Allahabad and Varanasi sites, respectively. Cypriniformes and Cyprinidae were the most rich fish species order and family in all sites. At total stretch, Cypriniformes order was shared 49 species, followed by Siluriformes 26 species and Perciformes 17 species. Orders Clupeiformes shared 5 species. Abundance was dominated by *Eutropiichthys vacha* compared to *Clupisoma garua* and *Sperata seenghala*. According to abundance, *Cyprinus carpio* var. *communis* (9.64%) and *Oreochromis niloticus* (9.19%) were powerfully invader in the Ganga river. Exotic species is alarming for indigenous species biodiversity. *C. carpio* var. *communis* and *O. niloticus* are frequently recorded in the Ganga river. Total hardness, alkalinity and dissolved oxygen were responsible for the presence of Catla *catla, Rita rita and Sperata aor*, while *Labeo calbasu*, *Cyprinus carpio* and *Cirrhinus mrigala* preferred nitrate, phosphate and total dissolved solid for their abundance. *Oreochromis niloticus* preferred high biological oxygen demand and lead while Zn and Sulphate were responsible for abundance of *L. rohita*. For conservation point of view *C. carpio* var. *communis* and *O. niloticus* species should be monitored in the Ganga river. Both species are very harmful for fish biodiversity in the Ganga river. Fish assemblage and their abundance know the health of ecosystem.

Keywords: Fish assemblage; Exotic fish species; Abundance; Ganga river; India

Introduction

Freshwater fishes are important and valued property for income, human food, sport and ornament. Overexploitation occurs around the world with the use of more and more refined fishing equipment, and the decrease of many fish stocks has been documented as a result of expanding fisheries [1,2]. Illegal fishing using dynamite, pesticides, electrofishing, etc. are also major threats to fish biodiversity all over the world [3].

Fish assemblages are recognized as responsive indicators of habitat degradation, natural condition degradation, environmental contamination, and overall ecosystem productivity. Freshwater fishes are the most imperiled vertebrate group with a projected extinction rate of five times that of terrestrial fauna and three times that of marine mammals [4-6]. The world natural fishery systems are collapsing as a direct result of overfishing and overcapacity of fishing fleets [7,8]. Biodiversity is essential for stabilization of ecosystem, protection of overall environmental quality for understanding intrinsic worth of all species on the earth [9]. Biodiversity of fishes are suffering day by day in 21th century. Main regions are availability of water in river/stream (for shelter), water abstraction, industries and private use [10,11], habitat destruction and defragmentation [12,13], pollution level [14], introduction of alien/exotic species [15] and impacts of global climate changes specially rainfall [16,17]. Distribution patterns of organisms are controlled by dispersal mechanism, historical factors (connecting pathways, dispersal barriers) and tolerance to environmental factors [18,19].

Biodiversity is the quantity, variety and distribution across biological scales ranging through genetics and life forms of populations, species, communities and ecosystems [20]. Biodiversity affects the capacity of living systems to respond to changes in the environment, underpins ecosystem function and provides the ecosystem goods and services that support human well-being (e.g., nutrient cycling, clean water) [21,22]. Fragmented information is available of the fish fauna in the Ganga river by Sinha et al., [23] Lakra et al., [12] Montana et al., [24] and Nautiyal et al., [25]. This section (Kanpur to Varanasi section) of the river is middle stretch which is most important for fisheries and human interference. But no information is available on Canonical Correspondence Analysis (CCA) in the Ganga river especially from Kanpur to Varanasi section, India (Map 1).

The objective of the present study was to give Canonical Correspondence Analysis (CCA) of the Ganga river at Kanpur to Varanasi section, aiming to contribute a better knowledge to structure of the fish assemblage and abundance of commercially important fishes from the Ganga river and a tool for conservation planning of aquatic environments in this region.

Material and Methods

The samples were collected monthly during the period August

***Corresponding author:** Dwivedi AC, Regional Centre, Central Inland Fisheries Research Institute (ICAR), 24 Panna Lal Road Allahabad 211002, India, Tel: +91-9450211911; E-mail: saajjjan@rediffmail.com

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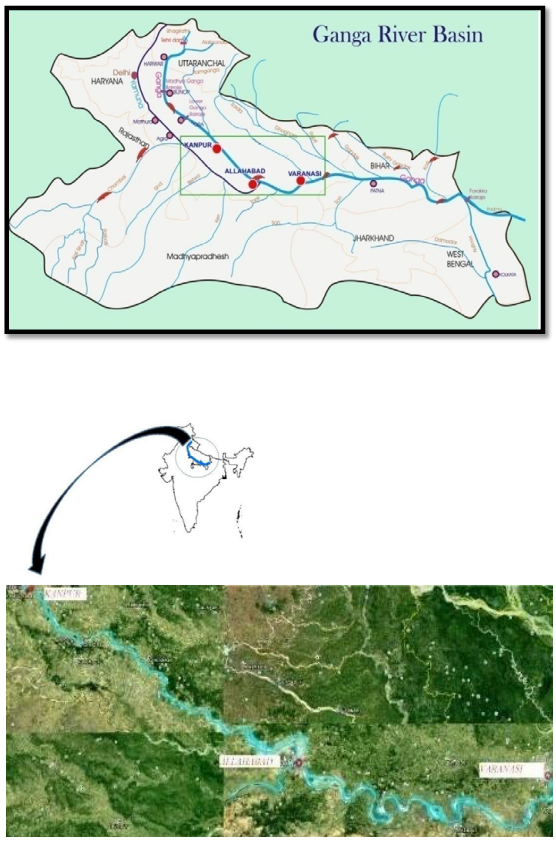

Map 1: Showing the sampling sites.

2012 to July 2013 from the three sites of the Ganga river namely Kanpur (Latitude- 26^0 27' 16" N, Longitude- 80^0 20, 58"), Allahabad (Latitude- 25^0 45' 27" N, Longitude- 81^0 59' 31") and Varanasi (Latitude- 25^0 19' 01" N, Longitude- 82^0 58' 15"). Present stretch is about 370 km. Human activities and industrial influent maximum reported in these sites of the river. The Ganga river is a holy river of India and has been declared as a national river by the government of India. The Ganga is a perennial river which originates as a stream called "Bhagirathi" from Gaumukh (Himalaya) in the Gangotri glacier at 30° 55' N, 79° 7' E, some 4100 m above mean sea level. Ganga river basin is the largest river basins in India and the fourth largest in the world, with a basin (catchment area) covering 8, 61,404 sq km. It has a total length of 2525 km with two countries (India and Bangladesh). It is backbone for irrigation, agriculture, industrials purpose and fisheries point of view.

Canonical correspondence analysis and related methodology has found wide-spread use in aquatic sciences. Canonical Correspondence Analysis (CCA version 4.5) was used to examine the factors response for the abundance of fish abundance [26].

The collected samples were preserved in 10% formalin and brought to the laboratory for further study. The fish was identified using Day [27], Talwar [28] and Jayaram [29] books and standard keys. The meristic and morphometric characters collected fishes were measured and counted and identified up to the species level.

The relative abundance was estimated only for commercially and economical important fishes, which preferred by consumer. The relative abundance of individual species was calculated by the following formula:

$$\frac{Number\ of\ sanmple\ of\ particular\ species}{Total\ Number\ of\ samples} 100$$

Axis variables	Correlation coefficient	
	1	2
Water Temperature(°C)	0.3391	0.9408*
pH	0.1879	-0.9822*
Total Dissolved Solid (mgl^{-1})	0.5334	-0.8459
SO_4 (mgl^{-1})	-0.6112	-0.7914
PO_4 (mgl^{-1})	0.9598*	-0.2806
Alkalinity (mgl^{-1})	-0.8865	0.4628
Total Hardness (mgl^{-1})	-0.9966*	0.0828
Nitrate (mgl^{-1})	0.9799*	-0.1994
Dissolved Oxygen (mgl^{-1})	-0.3241	0.9460*
Biological Oxygen Demand (mgl^{-1})	-0.8142	-0.5806
Cadmium (mgl^{-1})	-0.6368	-0.7710
Zink (mgl^{-1})	-0.4086	-0.9127*
Lead (mgl^{-1})	-0.8182	-0.5749

Table 1: Canonical correlation matrix with two axis of the environmental variables in the canonical correspondence analysis (CCA) for three sites in the river Ganga.

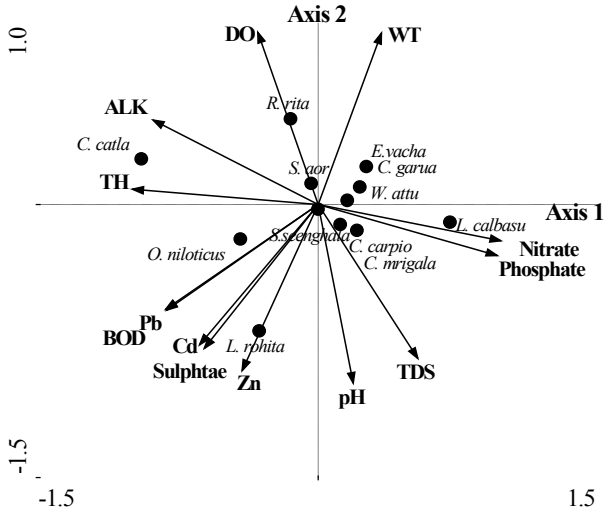

Figure 1: Canonical Correspondence Analysis (CCA). The multivariate analysis indicates the relationship between fish species and environmental variables in the River Ganga. Fish species and variables are indicated by filled circles and arrows, respectively.

Result and Discussion

Canonical correspondence analysis (CCA)

We analyze data in all three sites as a whole stretch because we estimated a comply results for all sites. A CCA diagram does not need to contain all the elements (species, sites, environmental variables). To avoid overcrowding of points, species and sites are often shown in separate diagrams that can, in principle, be overlain. Alternatively, selected points or variables are displayed. Canonical correspondence analysis (CCA) indicated that axis 1 and 2 accounted for 67% and 33% variance for species and environmental relation, respectively. The biplots metrics generated for all three stations by CCA, suggested that total hardness was most important factor at axis 1, while Nitrate and Phosphate were also important at the same axis. At axis 2, pH was most important factor followed by dissolved oxygen, water temperature and Zink metal (Table 1). These variables were correlated significantly (p=0.6660, F-value=0.67) for axis 1 and 2. Total hardness, alkalinity and dissolved oxygen were responsible for the presence of *Catla catla, Rita rita* and *Sperata aor*, while *Labeo calbasu*, *Cyprinus carpio* and

Cirrhinus mrigala preferred nitrate, phosphate and total dissolved solid for their abundance. *Oreochromis niloticus* preferred high biological oxygen demand and lead while Zn and Sulphate were responsible for abundance of *L. rohita* (Figure 1).

Ordination analysis revealed that environmental variables influence substantially the fish fauna in the Ganga river; total hardness, nitrate, phosphate, DO, pH and water temperature and Zn metal were most important variables for the abundance of *L. rohita, L. calbasu, C. catla, C. mrigala, R. rita* and *C. carpio*. *O. niloticus* was heavy metal preferred fish. Environmental conditions influence fish distributions, communities and seasonal movements. To minimize energy expended for survival, species typically favor areas that optimize their physiological processes [30]. Moyle et al. [31], Bain et al. [32], Lobb et al. [33] also reported water depth, current velocity and substratum as important factor for the abundance of *R. alburnoides* and *L. pyrenaicus* in the American rivers.

Structure of the fish assemblage

Fish assemblages in the Ganga river network are influenced by both restricted habitats and larger landscape patterns and water management system. Major local factors are 1) availability of different types of habitats condition, 2) availability of different types of food organisms and resources, and 3) interactions with other aquatic species (e.g., predation, competitive interactions). About half of Indian fishes are in the minnow family (Cyprinidae). During the study period different fish varieties have been recorded in the Ganga river at Kanpur, Allahabad and Varanasi sites, India. Human activities and industrial influent maximum reported in these sites of the river, so we have chosen these sites. The result showed that the area was rich in fish diversity. Fish biodiversity of the Ganga river from Kanupr to Varanasi harbors of 102 fish species (with variety) belong to 8 orders and 28 families (Table 2). Cypriniformes and Cyprinidae were the most rich species order and family. At total stretch, Cypriniformes order was shared 49 species (48.04%), followed by Siluriformes 26 species (25.49%) and Perciformes 17 species (16.67%). Orders Clupeiformes shared 5 species (4.90%) (Figure 2).

At Kanpur site, 74 fish species were recorded with 6 orders. Cypriniformes order was shared 32 species (43.24%) followed by Siluriformes 21 species (28.38%) and Perciformes 15 species (20.27%). Order Clupeiformes shared 3 species (4.05%) (Figure 3). At Allahabad site, 89 fish species were recorded with 8 orders. Cypriniformes order was shared 41 species (46.07%) followed by Siluriformes 25 species (28.09%) and Perciformes 14 species (15.73%). Order Clupeiformes and Osteoglossiformes shared 4 species (4.49%) and 2 species (2.25%),

S. N.	Order/Family/Genus/Species	Kanpur	Allahabad	Varanasi
	Order- Osteoglossiformes			
	Family: Notopteridae			
1	*Chitala chitala*	+	+	+
2	*Notopterus notopterus*	+	+	+
	Order- Anguilliformes			
	Family: Anguillidae			
3	*Anguilla bengalensis*		+	
	Order- Clupeiformes			
	Family: Clupeidae			
4	*Gudusia chapra*	+	+	+
5	*Goniolosa manmina*	+	+	
6	*Tenualosa (Hilsa) ilisha*			+
	Family: Pristigasteridae			
7	*Ilisha megaloptera*		+	
	Family: Engraulidae			
8	*Setipinna phasa*	+	+	+
	Order- Cypriniformes			
	Family: Cyprinidae			
9	*Catla catla*	+	+	+
10	*Chagunius chagunio*	+	+	+
11	*Cirrhinus mrigala*	+	+	+
12	*Cirrhinus reba*	+	+	+
13	*Ctenopharyngodon idella*	+	+	+
14	*Hypophthalmichthys molitrix*	+	+	+
15	*Cyprinus carpio communis*	+	+	+
16	*Cyprinus carpio specularis*	+	+	
17	*Aristhicthys nobilis*	+		+
18	*Labeo angra*		+	+
19	*Labeo calbasu*	+	+	+
20	*Labeo bata*	+	+	+
21	*Labeo boga*	+		
22	*Labeo rohita*	+	+	+
23	*Labeo gonius*		+	+
24	*Labeo pangusia*		+	
25	*Osteobrama belangeri*			+
26	*Osteobrama cotio cotio*	+	+	+

27	*Puntius chola*		+	+
28	*Puntius conchonius*			+
29	*Puntius sarana sarana*	+	+	+
30	*Puntius sophore*	+	+	+
31	*Puntius ticto*	+	+	+
32	*Chela laubuca*	+	+	+
33	*Chela sladonii*		+	+
34	*Chela cachius*		+	
35	*Salmostoma bacaila*	+	+	+
36	*Salmophasia phulo*	+	+	
37	*Amblypharyngodon mola*	+	+	+
38	*Aspidoparia jaya*	+	+	+
39	*Aspidoparia morar*	+	+	+
40	*Barilius barila*	+	+	+
41	*Barilius barna*		+	
42	*Barilius bendelisis*		+	+
43	*Barilius bola*	+	+	+
44	*Barilius vagra*		+	
45	*Esomus danricus*			yes
46	*Rasbora rasbora*	+	+	+
47	*Raiamas bola*		+	+
48	*Tor tor*		+	
49	*Securicula gora*	+	+	+
50	*Osteobrama cotio cotio*			+
51	*Crossocheilus latius latius*	+	+	+
	Family: Balitoridae			
52	*Nemacheilus botia*	+	+	+
53	*Aborichthys elongatus*		+	
	Family: Cobitidae			
54	*Botia almorhae*		+	+
55	*Botia lohachata*	+	+	+
56	*Botia dario*	+		+
57	*Lepidocephalus guntea*	+		
	Order- Siluriformes			
	Family:Bagridae			
58	*Sperata aor*	+	+	+
59	*Sperata seenghala*	+	+	+
60	*Mystus tengra*	+	+	+
61	*Mystus cavasius*	+	+	+
62	*Mystus vittatus*	+	+	+
63	*Mystus bleekeri*		+	
64	*Rita rita*	+	+	+
	Family: Siluridae			
65	*Ompok bimaculatus*		+	+
66	*Ompak pabda*	+	+	+
67	*Wallago attu*	+	+	+
	Family: Schilbeidae			
68	*Ailia coila*	+	+	+
69	*Clupisoma garua*	+	+	+
70	*Eutropiichthys vacha*	+	+	+
71	*Eutropiichthys murius*	+	+	+
72	*Silonia silondia*	+	+	+
	Family: Pangasiidae			
73	*Pangasius pangasius*		+	+
	Family: Sisoridae			
74	*Bagarius bagarius*	+	+	+
75	*Gagata cenia*	+	+	+
76	*Nangra nangra*			
77	*Nangra viridescens*	+	+	+
78	*Sisor rhabdophorus*	+	+	+
79	*Glyptothorax lineatus*		+	

	Family: Clariidae			
80	*Clarias batrachus*	+	+	+
81	*Clarias gariepinus*	+	+	+
	Family: Heteropneustidae			
82	*Heteropneustes fossilis*	+	+	+
	Family: Belonidae			
83	*Xenentodon cancila*	+	+	+
	Order-Synbranchiformes			
	Family: Synbranchidae			
84	*Monopterus cuchia*		+	+
	Order-Perciformes			
	Family: Ambassidae			
85	*Chanda nama*	+	+	+
86	*Chanda ranga*	+		+
87	*Pseudambassis ranga*			+
	Familty: Sciaenidae			
88	*Johnius coitor*	+	+	+
89	**Family: Mugilidae**			
90	*Rhinimugil corsula*	+	+	+
	Sicamugil cascasia	+	+	+
	Family: Gobiidae			
91	*Glossogobius giuris*	+	+	+
	Family: Anabaniitidae			
92	*Anabas testudineus*	+	+	+
	Family: Belontiidae			
93	*Colisa fasciatus*	+	+	
	Family: Channidae			
94	*Channa marulius*	+	+	+
95	*Channa punctatus*	+	+	+
96	*Channa striatus*	+	+	+
97	*Channa stewartii*	+		
	Family: Mastacembelidae			
98	*Macrognathus pancalus*	+	+	
99	*Mastacembelus armatus*	+	+	+
	Family: Nandidae			
100	*Nandus nandus*		+	
	Family: Cichlidae			
101	*Oreochromis niloticus*	+	+	+
	Order- Tetraodontiformes			
	Family: Tetraodontidae			
102	*Tetradon cutcutia*	+	+	+
Total	**102**	**74**	**89**	**82**

Table 2: Biodiversity of fishes from the Ganga River at Kanpur to Varanasi, India.

respectively (Figure 4). At Varanasi site, 82 fish species were recorded with 7 orders. Cypriniformes order was shared 39 species (47.56%) followed by Siluriformes 23 species (28.05%) and Perciformes 13 species (15.85%). Order Clupeiformes and Osteoglossiformes shared 3 species (3.66%) and 2 species (2.44%), respectively (Figure 5). *Cyprinus carpio* var. *communis* and *Oreochromis niloticus* are frequently recorded in the Ganga river. Both species had large dispersal capacity. Both species are exotic/alien fish species for India. For conservation point of view *C. carpio* var. *communis* and *O. niloticus* species should be monitored in the Ganga river. Both species are very harmful for fish biodiversity in any large water bodies as like rivers, lakes and reservoirs. Fishes are threatened by channelization of rivers/streams beds.

More species are needed to insure a stable supply of ecosystem goods and services as spatial and temporal variability increases, which typically occurs as longer time periods and larger areas are considered [21]. Each natural habitat has a variety of species, which differ in their relative abundance. No community consists of species of equal abundance. Some species are rare, others are common and still others may be abundant [34]. Nautiyal et al. [25] recorded 122 fish species from the Ganga river (Haridwar to Kanpur section). Menon [35] has listed 207 species of fish from the Gangetic plains which belong to 29 families and 82 genera. According to another estimate, the Gangetic system alone harbours not less than 265 species of fish [36]. Freshwater biodiversity has declined faster than either terrestrial or marine biodiversity over the past 30 years [37,38]. Introductions of non-indigenous fishes can reduce diversity and modify local community dynamics in freshwater systems [39]. The physical and biological characteristics of riverine systems have been shown to shape fish community [40].

Abundance of some important fishes

Abundance was recorded only commercially important fish species, which preferred by consumer and had high market price. Out of 102 species, species having higher economic value are *C. catla, L. rohita, C. mrigala, L. calbasu, S. aor, S. seenghala, W. attu, R. rita, E. vacha.*

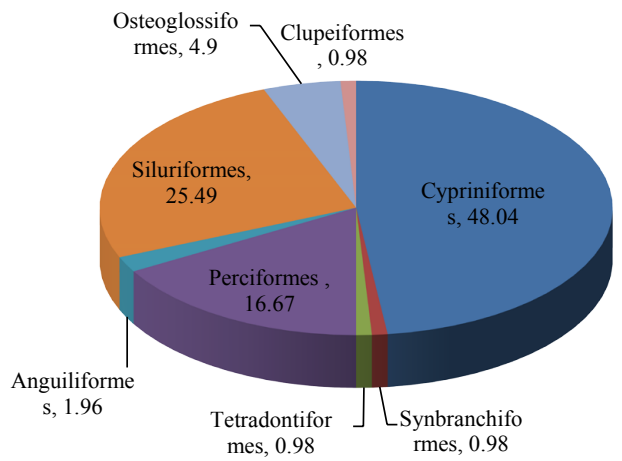

Figure 2: Contribution of different orders at Kanpur to Varanasi section.

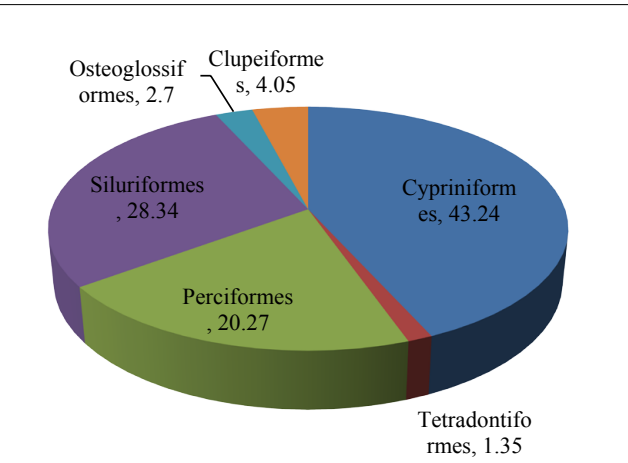

Figure 3: Contribution of different orders at Kanpur site.

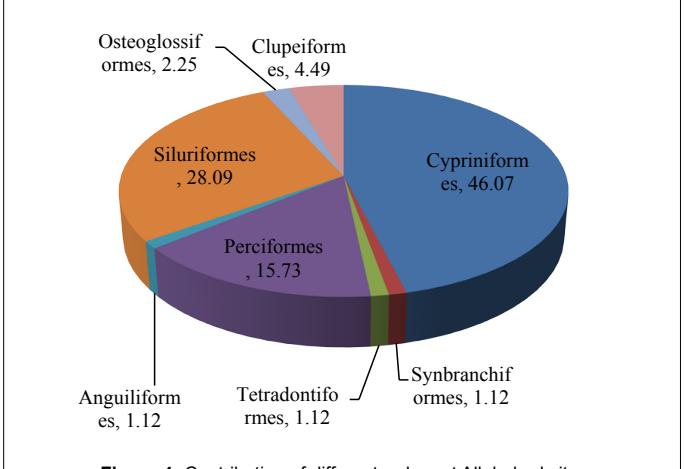

Figure 4: Contribution of different orders at Allahabad site.

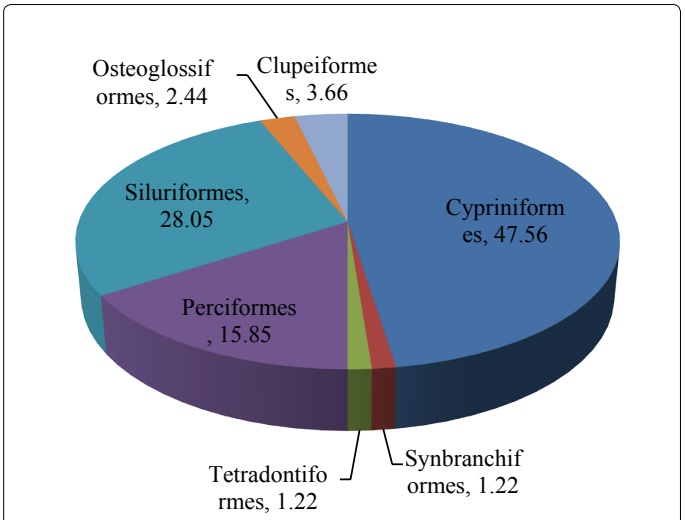

Figure 5: Contribution of different orders at Varanasi site.

Fishes	Kanpur		Allahabad		Varanasi		Total	
	Occurrence	%	Occurrence	%	Occurrence	%	Total number	%
Major carp								
Catlacatla	106	2.32	187	2.15	96	0.89	389	1.62
Labeorohita	163	3.56	137	1.57	179	1.67	479	1.99
Cirrhinusmrigala	208	4.55	311	3.57	463	4.32	982	4.08
Labeocalbasu	123	2.70	196	2.35	407	3.80	726	3.02
Catfishes								
Sperataaor	463	10.12	960	11.01	1007	9.39	2430	10.11
Sperataseenghala	721	15.76	1323	15.17	1602	14.94	3646	15.18
Wallagoattu	226	4.94	401	4.60	521	4.86	1148	4.78
Rira rita	183	4.00	486	5.57	372	3.47	1041	4.33
Eutropiichthysvacha	638	13.95	1630	18.69	2164	20.19	4432	18.46
Clupisomagarua	671	14.67	1482	17.00	2063	19.25	4216	17.62
Exotic fishes								
Cyprinuscarpio var *communis*	469	10.25	763	8.75	1082	10.09	2314	9.64
Oreochromisniloticus	603	13.18	843	9.67	763	7.12	2209	9.19
Total	**4574**		**8719**		**10719**		**24012**	

Table 3: Relative abundance of some commercially important fishes from the Ganga river.

C. garua and *C. carpio* var. *communis* and *O. niloticus* had moderate economic value. *C. catla, L. rohita, C. mrigala, L. calbasu* are herbivorous in feeding while *S. aor, S. seenghala, W. attu, R. rita, E. vacha. C. garua* are carnivorous in feeding. *C. carpio* var. *communis* and *O. niloticus* are omnivorous in feeding.

Canonical correspondence analysis confirmed statistically highly significant differences (P<0.0001) between fish abundance of the individual site. In total, 21.2% of fish assemblage variability is explained by this pattern, as it roughly summarises differences in environmental conditions of individual site. *C. carpio* var. *communis* and *O. niloticus* both species are invader species in the Ganga river. According to pooled abundance *E. vacha* was dominated fishes in the total stretch from the Ganga river. Indian major carp abundance was poor at present work. Catfishes were dominated in carp groups. Abundance of exotic species was also very high. At Kanpur site, *S. seenghala* (15.76%) was dominated compared to *C. garua* (14.67%) and *E. vacha* (13.95%). Its appeared 2.32%, 3.56% and 4.55% of *C. catla*, *L. rohita* and *C. mrigala*, respectively. *C. catla*, *L. rohita* and *C. mrigala* abundances were strongly correlated with temperature. At Allahabad site, *E. vacha* (18.69%) was dominated compared to *C. garua* (17.00%) and *S. seenghala* (15.17%). At Varanasi site, *E. vacha* (20.19%) was dominated compared to *C. garua* (19.09%) and *S. seenghala* (14.94%). Present study indicated that the *O. niloticus* strongly associated with high biological oxygen demand and lead. Lakra et al. [12] observed relative abundance 1.33, 2.75, 1.21 and 0.34 of *C. catla*, *L. rohita, C. mrigal* and *C. carpio* from the Betwa river. *O. niloticus* and *C. carpio* powerfully invaded in the Ganga river [15,41] and its largest tributary the Yamuna river [2]. Exotic species may become invasive and are capable of spreading exotic diseases, decreasing biodiversity through competition, predation and habitat degradation, genetic deterioration of wild populations through hybridization and gene introgression in short or long course of time [42,43].

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References

1. Allan JD, Abell R, Hogan Z, Revenga C, Taylor BW, et al. (2005) Overfishing of inland waters. Bioscience 55: 1041-1051.
2. Priyanka M, Dwivedi AC (2015) Biology of Cirrhinus mrigala and Oreochromis niloticus. LAP LAMBERT Academic Publishing, Germany.
3. Leveque CT, Oberdorff D, Paugy MLJ, Tedesco PA (2008) Global diversity of fish (Pisces) in freshwater. Hydrobiologia 595: 545-567.
4. Duncan JR, Lockwood JL (2001) Extinction in a field of bullets: a search for causes in the decline of the world's freshwater fishes. Biological Conservation 102: 97-105.
5. Argent DG, Bishop JA, Stauffer JR, Carline RF, Myers WL (2003) Predicting freshwater fish distributions using landscape-level variables. Fisheries Research 60: 17-32.
6. Cooke SJ, Bunt CM, Hamilton SJ (2005) Threats, conservation strategies, and prognosis for suckers (Catostomidae) in North America: insights from regional case studies of a diverse family of non-game species. Biological Conservation 121: 317-331.
7. Myers RA, Barrowman JA, Hutchinson, Rosenberg AA (1995) Population dynamics of exploited fish stocks at low population sizes. Science 269: 1106-1108.
8. Yakubu A, Li N, Conrad J, Zeeman ML (2011) Fish population dynamics and constant or periodic proportion harvesting policies. Math Bioscience 232: 66-77.
9. Ehrlich PR, Wilson EO (1991) Biodiversity studies science and policy. Science 253: 758-762.
10. Ricciardi A, Rasmussen JB (1999) Extinction rates of North American freshwater fauna. Conservation Biology 13: 1220-1222.
11. Nagy S (2004) international sediment initiative. Proceedings of the United Nations seminar, Netherlands.
12. 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 30: 306-319.
13. Dwivedi AC, Nautiyal P (2012) Stock assessment of fish species Labeo rohita, Tor tor and Labeo calbasu in the Rivers of Vindhyan region, India. Journal of Environmental Biology 33: 261-264.
14. Junior L, Cardone IB, Goitein R (2006) Fish assemblage structure and aquatic pollution in a Brazilian stream: some limitations of diversity indices and models for environmental impact studies. Ecology of Freshwater Fishes 15: 284-290.
15. Pathak RK, Gopesh A, Joshi KD (2013) Alien fish species, Cyprinus carpio var. communis (common carp) as a powerful invader in the Ganga River at Allahabad, India. Journal of the Kalash Science 1: 133-139.
16. Leveque C, Balian EV, Martens K (2005) An assessment of animal species diversity in continental waters. Hydrobiologia 542: 39-67.
17. Marti M, Berthou GE, Sabater S, Tomanova S, Monoz I (2010) Comparing fish assemblages and trophic ecology of permanent and intermittent researches in a Mediterranean stream. Hydrobiologia 215: 167-180.
18. Dwivedi AC, Nautiyal P (2010) Population dynamics of important fishes in the Vindhyan region, India. LAP Lambert Academic Publishing, Germany.
19. Pathak RK, Gopesh A, Dwivedi AC (2011) Alien fish species, Cyprinus carpio var. communis (common carp) as a powerful invader in the Yamuna River at Allahabad, India. National Academy of Science Letter 34: 367-373.
20. Mace G, Masundire H, Baillie J, Ricketts T, Brooks T (2005) Ecosystems and Human Well- Being: Current State and Trends. Biodiversity pp: 77-122.
21. Hooper DU, Chapin FS, Ewel JJ, Hector A, Inchausti P, et al. (2005) Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs 75: 3-35.
22. Diaz S, Fargione J, Chapin FS, Tilman D (2006) Biodiversity loss threatens human well-being. PLoS Biology 4: 1300-1305.
23. Sinha M, Khan MA (2001) Impact of environmental aberrations on fisheries of the Ganga (Ganges) River. Aquatic Ecosystem Health and Management Society 4: 493-504.
24. Mantana CG, Choudhary SK, Dey S, Winemiller KO (2011) Compositional trends of fisheries in the River Ganges, India. Fisheries Management and Ecology 18: 282-296.
25. Nautiyal P, Mishra AS, Singh KR, Singh U (2013) Longitudinal distribution of the fish fauna in the River Ganga from Gangotri to Kanpur. Journal Applied National Science 5: 63-68.
26. Braak T, Smilauer P (2002) CANOCO Reference Manual and Canodraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, USA.
27. Day F (1878) The Fishes of India. William Dawson and Sons Limited pp: 1-591.
28. Talwar PK, Jhingran AG (1991) Inland Fisheries of India and Adjacent Countries. Oxford and IBH Publication, Calcutta.
29. Jayaram KC (1981) The Freshwater Fishes of India Pakistan Bangladesh Burma and SriLanka A Handbook. Zoological Survey of India Culcutta pp: 475.
30. Matthews KR (1990) An experimental study of the habitat preferences and movement patterns of Copper, quillback, and brown rockfish. Environmental Biology Fishes 29:161-178.
31. Moyle PB, Vondracek B (1985) Persistence and structure of the fish assemblage in a small California stream. Ecology 66: 1-13.
32. Bain MB, Finn JT, Booke HE (1988) Streamflow regulation and fish community structure. Ecology 69: 382-392.
33. Lobb MD, Orth DJ (1991) Habitat use by an assemblage of fish in a large warm water stream. Transactions of the American Fisheries Society 120: 65-78.
34. Dwivedi AC, Tewari NP, Mayank P (2007) Biodiversity of fishes of Faizabad District. Flora and Fauna 13: 379-383.

35. Menon AGK (1974) A check list of fishes of Himalayan and Indo-Gangetic plains. Indian Fish Soc, pp: 136.

36. Yadav YS, Chandra R (1994) Some threatened carps and catfishes of Brahmputra Riverine fishes. Threatened fishes of India pp 45-65.

37. Jenkins M (2003) Prospects for biodiversity. Science 302: 1175-1177.

38. UNESCO (2003) Water for People, Water for life. TheUunited Nations World Water Development Report, Paris.

39. Minns CK, Cooley JM (2000) International introductions: Are the incalculable risks worth it? Non indigenous freshwater organisms. Lewis publishers, New York.

40. Barila TY, Williams RD, Stauffer JR (1981) The influence of stream order and selected stream bed parameters on fish diversity in Raystown Branch, susquehana River drainage, Pennsylvania. Journal of Applied Ecology 49: 193-198.

41. Dwivedi AC, Tiwari A, Mayank P (2015) Seasonal determination of heavy metals in muscle, gill and liver tissues of Nile tilapia, Oreochromis niloticus (Linnaeus, 1758) from the tributary of the Ganga River, India. Zoology and Ecology 25: 166-171.

42. Casal CMV (2006) Global documentation food fish introductions: the growing crisis and recommendations for action. Biological Invasions 8: 3-11.

43. Singh AK, Lakra WR (2006) Alien fish species in India: Impact and emerging scenario. Journal Ecophy Occup Heal 6: 165-174.