Fish communities and trophic metrics as measures of ecological degradation: a case study in the tributaries of the river Ganga basin, India

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Received 02-XII-2011. Corrected 06-X-2012. Accepted 06-XI-2012.

Abstract: Métricas tróficas y de comunidades de peces como medidas de la degradación ecológica: un estudio de caso en los afluentes de la cuenca del río Ganga, India. In India, freshwater aquatic resources are suffering from increasing human population, urbanization and shortage of all kind of natural resources like water. To mitigate this, all the major rivers have been planned for a river-interlinking through an interlinking canal system under a huge scheme; yet, the baseline information on ecological conditions of those tropical rivers and their fish communities is lacking at present. In view of that, the present study was undertaken to assess the ecological condition by comparing the trophic metrics of the fish community, conservation status and water chemistry of the two tropical rivers of the Ganga basin, from October 2007 to November 2009. The analysis of trophic niches of the available fish species indicated dominancy of carnivorous (19 species) in river Ken and omnivorous (23 species) in Betwa. The trophic level score of carnivorous species was recorded similar (33.33%) in both rivers, whereas omnivorous species were mostly found in Betwa (36.51%) than Ken (28.07%). Relatively undisturbed sites of Betwa (B1, B2 and B3) and Ken (K2, K3 and K5) were characterized by diverse fish fauna and high richness of threatened species. The higher mean trophic level scores were recorded at B4 of Betwa and K4 of Ken. The Bray-Curtis index for trophic level identified the carnivorous species (>0.32) as an indicator species for pollution. Anthropogenic exposure, reflected in water quality as well as in fish community structure, was found higher especially in the lower stretches of both rivers. Our results suggest the importance of trophic metrics on fish community, for ecological conditions evaluation, which enables predictions on the effect of future morphodynamic changes (in the post-interlinking phases), and provide a framework and reference condition to support restoration efforts of relatively altered fish habitats in tropical rivers of India. Rev. Biol. Trop. 61 (3): 1351-1363. Epub 2013 September 01.

Key words: fish community, trophic metrics, similarity index, threats, river interlinking, India.

Knowledge in trophic ecology of any given system is fundamental in understanding the ecosystem as a whole (Cruz-Escalona *et al*. 2000). Fishes are good indicators of freshwater ecosystems functioning, and of the ecological integrity of river systems, because their ability to occupy multiple trophic levels (Schlosser 1985, Schiemer & Spindler 1989, Copp *et al*. 1991). The responses of particular communities, especially fish, within the aquatic ecosystems may reflect the amount of degradation of that system (Wichert & Rapport 1998,). Because of the specific habitat requirements, fish species strongly depend on the water characteristics and its dynamics, as they have long been used to quantify the effects of disturbance in the environment (Magoulick 2004, Smol 2010).

In India, the tributaries of river Ganga basin, that support rich biodiversity and offer livelihood and nutritional security, has been less studied with regard to fish community and trophic ecology. Studies have been limited to scattered works on commercial fisheries based on catch data and have been largely restricted to the major river systems (Mishra & Moza 1997, Payne *et al*. 2004). To fulfill the water demand and mitigate flood and drought, the Indian Government has been planning a huge scheme encompassing the Himalayas and most of India, by linking all major rivers through interlinking canals systems and building several dams. Thirty river interlinks have been identified and among these, river Betwa and Ken have been approved for the country's first River interlinking (NDWA 2005). The Ken-Betwa interlink (KBI) involves building a dam on river Ken and diverting the water to Betwa through a link canal. Both the rivers are perennial tributaries of river Yamuna (tributary of river Ganga). River Betwa supports an exceedingly rich species spectrum of threatened, migratory and commercially important fishes with a wide distribution of species, families and genera (Lakra *et al*. 2010). The presence of threatened fishes of regional conservation concern in the river also makes it a high priority area for implementing urgent conservation and management measures to save them from further endangerment. Presently, the fish fauna of the River Betwa is highly threatened due to presence of dams and water diversions resulting in fragmentation of habitat, and have been subjected to extensive anthropogenic alterations (Lakra *et al*. 2010). On the other hand, in river Ken, the presence of a protected area (Panna National Park) on the upper stretch and forest cover on the mid stretch of the river, tends to have positive impacts on its aquatic habitat, and is known as one of the least polluted rivers in India (Dubey *et al.* 2012). However, as far as we know, no broad general synthesis of trophic metrics of the fish fauna following ecological assessment of these tropical rivers has yet been published to date.

Several studies have proved that changes in environmental conditions are reflected in corresponding alterations of aquatic community structure and ecosystem functioning (Strayer 2010, Turak & Linke 2011). Therefore, to appreciate the influence of the interlinking on the ecosystem of both rivers, studies are urgently needed to assess the existing (pre-interlinking) scenario. Analysis of fish community structure and trophic metrics in the existing conditions will provide the basic knowledge for evaluation of the ecological conditions of both rivers. The objective of this study was to describe the fish community of these two rivers, and to classify trophic attributes and evaluate the ecological condition by comparing the trophic metrics, and to develop an efficient approach to measure the ecological quality of the tropical rivers as a prerequisite to India's first river interlinking.

MATERIALS AND METHODS

Study area: The River Betwa (1 800º N - 77º34 E', 590km length and discharge of 10 000 million m^3) and the River Ken (24º41 N' - 079º54 E', 427km and 11 300 million m^3) are important perennial rivers of the Ganga basin (Fig. 1). The Betwa river is regulated by three large dams (Rajghat, Matatila and Paricha) and two small dam/weirs in the middle and upper stretch of the river. The topography and elevation (ranging from 700 to 300m above mean sea level) cause variation in land use, from flat open wheat and gram growing areas to steep forest-covered hills (Lakra *et al.* 2010). The Ken River is an interstate river between Uttar Pradesh and Madhya Pradesh, that has its origin from the Ahirgawan village, on the Northwest slopes of the Kaimur hills in the Jabalpur district of Madhya Pradesh (Dubey *et al*. 2012). Land cover of the river is largely composed of grasslands, mature forest, marshy lowlands and some small villages. The width of both river channels varies considerably with location, discharge, and the number of channels on a cross section. Both rivers experience similar times of drought and flood. The climate of the basin is mainly semi-arid to dry sub-humid. The basin area is mostly dry except in monsoon season, from June to October, when about 91.5% of the total annual rainfall occurs.

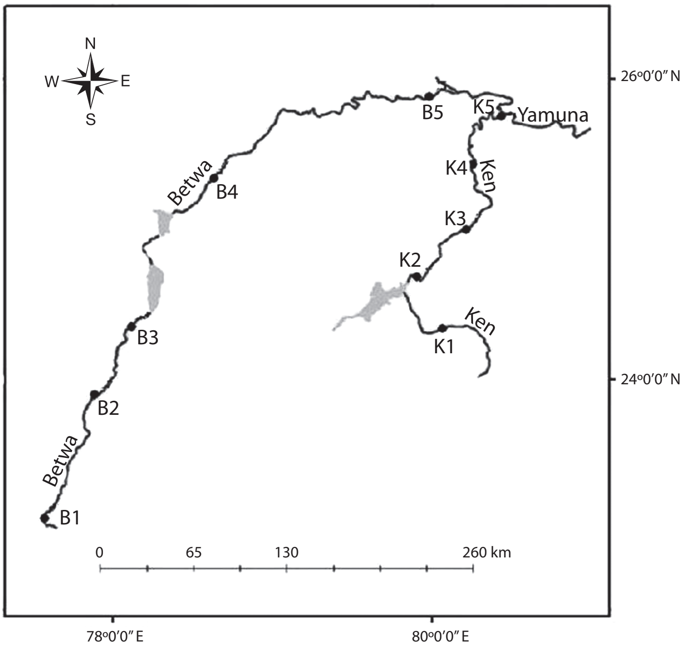

Fig. 1. Study area showing sampling sites in river Betwa and Ken.

Selection of sampling sites: The present study encompassed 590km of Betwa and 460km of River Ken. Based on the similarity of the physical habitat and distance coverage, each site (approximately 110km) in Betwa and Ken (approximately 90km) consisted of five sampling locations which were located starting from upstream to downstream section of both rivers: Bhojpur (B1), Ganjbasoda (B2), Rajghat (B3), Paricha (B4) and Hamirpur (B5) in river Betwa, and Amanganj (K1), Patan (K2), Mandala (K3), Banda (K4) and Chilla (K5) in river Ken. The study was carried out on a seasonal basis covering premonsoon (January to April), monsoon (May to August) and post monsoon (September to December) periods during October 2007 to November 2009.

Collection of water quality parameters: Physical and chemical water quality data was sampled systematically at each site across a transect spanning the river width. Samples were collected at a distance of every 10m at varying river width, and three replicates were collected for water quality at each sampling point. Water samples were collected in 500mL plastic containers and kept cooled in iceboxes in the field and transferred to the laboratory where they were deep frozen until analysis (4°C). The following physical and chemical parameters were studied: water depth (cm), water temperature (°C), Turbidity (NTU), water flow (cm/s), conductivity (µmhos/cm), total dissolved solids (ppm) and pH. Water temperature, conductivity, pH, TDS, DO were measured by a Cyber Scan Waterproof PC 300 multiparameter at the sampling locations. Water velocity was measured by a flow meter (JDC electronics SA; Switzerland). Alkalinity, nitrate, nitrite, orthophosphate, ammonia and turbidity were measured with a spectrophotometer (Spectroquant NOVA 60, Merck, Germany) within the next two days after their collection as per Eaton *et al.* (2005).

Fish community sampling: Fish samplings were undertaken in the same site where environmental variables were measured at varying depths. Fishing was carried out both by members of the project team as well as the expertise of local fisher folks. Fishes were collected using gill nets (mesh 2.5x2.5cm; 3x3cm; 7x7cm; length x breadth=50x1.3 m.; 50x1m.), cast nets (mesh 6x6mm.), drag nets (mesh 7x7mm, LxB=80x2.5m.) and other local contrivances, allowing us to sample a range of fish sizes and minimize the bias due to specific gears. Gill netting and cast netting was done by using a boat. At each site, four-gill nets were deployed overnight (17:00-07:00h). The cast nets ($5.5m^2$) were thrown 30 times per site, covering about $100m^2$ of river segments allowing 3-5 minutes settled times in each cast. Drag nets were used covering $175m^2$ area for 60min, whereas fry nets were used in the shoreline areas of the river for 20min twice per site (Lakra *et al.* 2010).

Representative specimens of all fish species were fixed in 10% formaldehyde, and transferred to the laboratory for study. They were also subsequently identified by following standard literature by Jayaram (1999) and Talwar & Jhingran (1991). Sets of indicators, i.e., weight, habitat orientation, trophic structure were examined. Data regarding threats faced by the fish fauna were obtained by direct observation, and also by interactions with local stakeholders and fishermen. The conservation status of fish was adapted from Lakra & Sarkar (2006).

Trophic structure and score: Based on the feeding habitat, fishes were classified into various trophic groups (Karr *et al.* 1986, OPEA 1987). The gut contents of fishes were analyzed for both rivers and four types of trophic level of fishes were considered (planktivorous=PL, benthic feeder=BE, omnivorous=OM, carnivorous=CA) and recorded (Table 3). The trophic level score (Wichert & Rapport 1998, Gauch 1982, Das & Chakrabarty 2007) indicated the relative frequency of the fish using a particular trophic level among all the trophic levels available in that aquatic system. For example, there were 21 species of carnivorous fish in the Betwa river out of a total of 63 species. The score is thus 100×(21/63) or 33.33 (Table 3).

Habitat orientation and score: Based on the previous knowledge of feeding habits provided by FISHBASE (www.fishbase.org) and Jhingran (1997) fishes were classified into three general groups with respect to habitat orientation: pelagic (P), generalist (G) and benthic (B). Habitat orientation score denotes the relative frequency of the fish using a particular habitat among all the habitats available in that aquatic system (Wichert & Rapport 1998, Gauch 1982). For example, there were 14 species of benthic fish in the Betwa river out of a total of 63 species. The score was thus 100×(14/63) or 22.22 (Table 3). A *t*-test was performed for common fishes between the rivers to compare the results of the scores.

Similarity and dissimilarity indices to identify indicator species: Sorensen's coefficient (SC) (Sorensen 1948) developed an index called the similarity index, which measures similarity between two habitats (habitats A and B).

$$SC=\frac{2a}{2a+b+c}$$

Where, a=number of species common for two habitats, b=number of species present in habitat B but absent in habitat A, c=number of species present at site A, but absent in site B. The index value varies between 0 and 1. Zero indicates no similarity and 1 indicates maximum similarity. Calculated Sorensen's coefficients (SC) for the fish resources were calculated between the two rivers to identify the apparent pollution indicator species (Gauch 1982, Benson & Magnuson 1992, Odum & Barett 2005).

An additional composition attribute was Bray-Curtis dissimilarity (BCD), a coefficient shown to be a robust and ecologically interpretable index of changes in species composition (Legendre & Legendre 1998). BCD was calculated using the (n=67) taxa abundance data (standardized using log10 (X+1) transformation; Legendre & Legendre 1998).

The Bray-Curtis measure (B) is a measure of dissimilarity; hence 1-B is taken as a measure of similarity: where the values are in between 0 to 1.

$$B = \frac{\sum [X_{ij}-X_{jk}]}{\sum [X_{ij}+X_{jk}]}$$

Where, X_{ij}=number of individuals of ith species in sample or habitat or community j and X_{ik}=number of individuals of ith species in sample or habitat or community k.

All the calculations were performed using SPSS software (16.1).

RESULTS

Water quality: Aquatic habitat sampled in the river Betwa and Ken was common for the large river channels. The habitat structure was considerably different over the sites examined with water regulations. Several dams and reservoirs in the middle and upper stretch regulate the river habitat in Betwa and as a result, the channel is fragmented, and isolated pools and shallow water habitats can be found throughout the year, except during the wet season (July-August). The results on the various hydrobiological characteristics of the studied rivers were given in tables 1 and 2. The water temperature of the river fluctuated between 16.5-22.0ºC

TABLE 1
Mean and range values of hydrobiological characteristics (SD in parentheses) of river Betwa (B1-B5)

Parameters	B1	B2	B3	B4	B5
Depth (m)	0.35-5 2.8(±1.23)	2-5.2 3.47(±1.05)	4-15 9.4(±3.1)	0.25-7 2.7(±1.6)	3.5-15 9.1(±1.6)
Flow (m/sec)	0.1-0.8 0.28(±0.18)	0.1-0.45 0.26(±0.21)	0.11-1.8 0.57(±0.6)	0.1-3.5 1.4(±0.9)	0.1-0.3 0.2(±0.1)
Water temp.(°C)	19.2-23.1 22.2(±1.6)	19.6-26.5 23.7(±1.1)	17.8-26.6 22.2 (±1.2)	16.5-26.3 23.2.6(±3.9)	22-26.4 23.4(±4.4)
Turbidity (FNU)	10.2-25.4 17.8(±4.4)	18.1-39.6 26.56(±7.5)	3.2-19.5 10.4(±4.4)	23.4-39 31.6(±5.0)	22.4-98.9 46.5(±26.8)
TDS (mg/L)	76-171 135(±31.1)	172-295 249.1(±5.1)	164-225 183(±17.1)	270-564 401.1(±115.5)	335-489 389.1(±60.90)
pH	7.2-8.6 7.8(±0.45)	7.34-8.7 8.02(±0.4)	7.4-8.3 7.9(±0.26)	7.4-8.56 8.0(±0.3)	7.89-8.6 8.3(±0.3)
Conductivity (µS/cm)	166-678 374(±198.7)	362-582 469.23 (±91.8)	220-526 357.7(±76.9)	182-265 219.1(±34.5)	364-685 534.5(±156.2)
D.O (ppm)	4.2-6.9 5.18(±1.0)	4.32-8.2 6.75(±3.2)	3.1-6.9 5.4(±1.5)	3.5-6.8 4.51(±1.15)	5.2-6.8 5.3(±0.2)
Alkalinity (mg/L)	142-256 183.08(±35.7)	105-198 147.9(±30.5)	145-231 178.6(±25.5)	179-256 209.3(±26.30)	210-268 224.62(±18.1)
Total hardness (mg/L)	144-189 169.7(±11.46)	176-189 183.35(±5.7)	154-186 172.9(±10.2)	182-249 196.24(24.2)	135-186 174.9(±20.6)
Ammonia (mg/L)	0.01-0.87 0.17(±0.3)	0.14-0.74 0.4(±0.3)	0.3-0.86 0.42(±0.2)	0.47-0.99 0.72(±0.15)	0.35-0.98 0.6(±0.3)
Orthophosphate (mg/L)	0.01-0.18 0.1(±0.06)	00.01-0.03 0.02(±0.008)	0.01-0.12 0.02(±0.03)	0.02-0.17 0.079(±0.1)	0.2-0.3 0.22(±0.04)
NO_2 (mg/L)	0.01-0.07 0.03(±0.02)	0.01-0.07 0.03(±0.03)	0.01-0.04 0.02(±0.002)	0.01-0.1 0.05(±0.04)	0.01-0.02 0.011(±0.004)
NO_3 (mg/L)	1.3-4.1 2.8(±1.16)	0.9-3.9 2.89(±1.4)	0.69-2.6 2.05(±0.05)	0.12-4.6 3.46(±0.46)	3.7-4.4 4.2(±0.3)

TABLE 2
Mean and range values of hydrobiological characteristics (SD in parentheses) of river Ken (K1-K5)

Parameters	K1	K2	K3	K4	K5
Depth (m)	0.12-3.2 1.5(±1.3)	0.86-5.2 2.80(±1.49)	1.5-8 4.3(±1.49)	2.3-15 6.7(±3.2)	3.6-15 7.6(±3.7)
Flow (m/sec)	0-1.3 0.17(±0.3)	0-0.50 0.2(±0.1)	0-0.50 0.19(±0.1)	0.01-0.8 0.38(±0.2)	0.1-0.6 0.2(±0.17)
Water temp. (°C)	16.2-26.8 22.9(±3.7)	19-26 23.3(±2.60)	17-26.3 21.6(±1.49)	19-26 26.3(±0.1)	18-26.8 24.9(±1.7)
Turbidity (FNU)	7.4-26.9 8.1(±0.7)	10.3-45.3 16.6(±5.63)	7.5-38.4 19.1(±12.2)	7.5-38.6 24.2(±12.3)	5.2-28.9 16.5(±6.4)
TDS (mg/L)	145-189 176.2(±14.2)	110-165 129.5(±20.2)	120-200 147.8(±30.7)	149-260 206.7(±30.2)	314-589 419.9(±93.7)
pH	7.1-7.9 7.5(±0.3)	7.1-8.8 7.9(±0.57)	7.1-9.09 8.0(±0.8)	7.4-8.8 7.8(±0.4)	7.2-8.2 7.9(±0.3)
Conductivity (µS/cm)	524-669 623.4(±45.6)	152-195 176.9(±10.50)	165-220 193.4(±19.7)	172-362 270.7(±69.6)	332-666 487(±150.7)
D.O (ppm)	6.8-10.5 7.4(±0.7)	3.2-6.4 5.8(±1.4)	4.1-8.2 6.5(±2.2)	4.1-6.2 4.6(±0.6)	4.2-6.8 5.1(±0.8)
Alkalinity (mg/L)	210-280 70.6(±14.4)	55-175 110.1(±55.9)	65-240 121.5(±61.4)	65-265 147(±69.8)	145-210 178(±23)
Total hardness (mg/L)	124-240 192.3(±39.2)	167-179 172.5(±4.7)	167-240 186.7(±21.1)	50-110 222.5(±23)	152-232 195.1(±28.2)
Ammonia (mg/L)	0.01-0.04 0.02(±3.7)	0.1-0.46 0.16(±0.08)	0.23-0.35 0.27(±0.05)	0.01-0.7 0.5(±.049)	0.05-0.8 0.4(±0.3)
Orthophosphate (mg/L)	0.01-0.07 0.06(±0.1)	0.01-0.09 0.03(±0.03)	0.01-0.05 0.03(±0.01)	0.04-0.24 0.14(±0.09)	0.01-0.08 0.07(±0.01)
NO_2 (mg/L)	0.01-0.04 0.03(±0.01)	0.015-0.07 0.04 (±0.02)	0.01-0.1 0.05(±0.05)	0.01-0.31 0.06(±0.07)	0.01-0.13 0.05(±0.05)
NO_3 (mg/L)	0.85-1.3 1.1(±0.2)	0.04-2.2 0.55(±0.64)	1.2-2.2 1.4(±0.5)	1.1-2.8 1.6(±0.6)	0.7-2.6 2.0(±0.7)

(winter) and 23.1-26.5ºC (summer) for Betwa and 17-19ºC (winter) and 24.4-26.8ºC (summer) for Ken. The maximum water flow was measured during June (3.5m/sec) at site B (IV) in Betwa and (1.3m/sec) at site K1 in Ken. During winter months, the water velocity ranged between 0-1m/sec in all the sampling sites of both the rivers. Turbidity was higher during peak monsoon periods (June-August) in both rivers (98.9 for Betwa & 45.3 for Ken), and it was considerably improved in Ken (5.2-10.3) and Betwa (3.2-22.4) during winter and premonsoon months. Water conductivity was relatively high with an average of 534.5µS/cm in Betwa downstream and 623.4µS/cm in Ken upstream, indicating higher concentration of dissolved materials. Total dissolved solids (TDS) and alkalinity showed similar trends of seasonal fluctuation in all the sampling sites studied for both rivers. The concentration of dissolved oxygen (DO) showed a range of 2.68-10.2 in Betwa and 3.2-10.5 in Ken. The total hardness varied from 189-249mg/L in Betwa and 110 to 240mg/L in Ken, and resulted higher in both rivers down streams. The mean level of annual concentration of NO_3 was higher in Betwa than Ken, and fluctuated between 0.12-4.2 in river Betwa and 0.04 to 2.8mg/L in river Ken. The average concentration of NO_2 was higher in Betwa and was negligible in Ken. The pH values showed definite seasonal trend, and it ranged between 7.2-8.7 in Betwa and 7.1-8.8 in Ken.

TABLE 3
Diversity, community indices, relative abundance (RA %) and threat status of the fishes in river Betwa and Ken

Family/ Species	Trophic level	Trophic level score		Habitat orientation nature	Habitat orientation score		Total relative abundance RA(%)		Threat status
		Betwa	Ken		Betwa	Ken	Betwa	Ken	
Notopteridae									
Chitala chitala	CA	33.33	33.33	P	44.44	42.11	0.3	0.13	EN
Notopterus notopterus	CA	33.33	33.33	P	44.44	42.11	0.2	1.21	EN
Clupeidae									
Gudusia chapra	PL	20.63	22.81	P	44.44	42.11	9.9	0.91	VU
Cyprinidae									
Aspidoparia morar	OM	36.51	NR	B	22.22	NR	0	0	LRnt
Barilius bendelisis	OM	36.51	28.07	P	44.44	42.11	0.08	0.02	LRnt
Catla catla	PL	20.63	22.81	P	44.44	42.11	1.33	0.22	VU
Chagunius chagunio	OM	36.51	28.07	P	44.44	42.11	0.07	0.55	DD
Cirrhinus mrigala	BE	9.52	15.79	B	22.22	24.56	1.21	1.07	LRnt
Cirrhinus reba	PL	20.63	22.81	G	33.33	33.33	0.23	1	LRnt
Cyprinus carpio	OM	36.51	28.07	B	22.22	24.56	0.34	0.09	
Crossocheilus latius latius	BE	NR	28.07	B	NR	24.56	NR	0.04	DD
Amblypharyngodon mola	PL	NR	22.81	P	NR	42.11	NR	0.56	DD
Garra gotyla gotyla	OM	36.51	28.07	B	22.22	24.56	1.82	0.38	VU
Labeo bata	PL	20.63	22.81	G	33.33	33.33	2.05	0.6	LRnt
Labeo boggut	BE	9.52	15.79	G	33.33	33.33	1.66	1.02	LRnt
Labeo calbasu	BE	9.52	15.79	B	22.22	24.56	1	1.51	LRnt
Labeo dyochilus	BE	9.52	15.79	B	22.22	24.56	0.17	0.43	VU
Labeo gonius	PL	20.63	22.81	G	33.33	33.33	1.33	1.25	LRnt
Labeo pangusia	BE	9.52	NR	G	33.33	NR	0.1	0	DD
Labeo rohita	BE	9.52	15.79	G	33.33	33.33	2.75	1.54	LRlc
Labeo fimbriatus	BE	NR	15.79	G	NR	33.33	NR	0.24	
Osteobrama cotio cotio	PL	20.63	22.81	P	44.44	42.11	6	2.45	LRnt
Puntius amphibious	OM	36.51	NR	P	44.44	NR	2.85	0	DD
Puntius chola	OM	36.51	28.07	P	44.44	42.11	2.45	0.06	VU
Puntius sarana sarana	PL	20.63	22.81	P	44.44	42.11	2.45	2.4	VU
Puntius sophore	PL	20.63	22.81	P	44.44	42.11	1.13	2.45	LRnt
Puntius ticto	PL	20.63	22.81	P	44.44	42.11	7.68	9.44	LRnt
Raiamas bola	OM	36.51	28.07	P	44.44	42.11	0.08	0.05	DD
Rasbora daniconius	OM	36.51	28.07	P	44.44	42.11	3.05	2.56	LRlc
Danio davario	PL	NR	22.81	P	NR	42.11	NR	0.22	LRnt
Salmostoma bacaila	OM	36.51	28.07	P	44.44	42.11	3.72	3.82	DD
Securicula gora	OM	36.51	NR	P	44.44	NR	0.48	0	DD
Tor tor	OM	36.51	28.07	G	33.33	33.33	0.05	0.67	EN
Balitoridae									
Acanthocobitis botia	OM	36.51	28.07	B	22.22	24.56	0.23	0.22	EN
Cobitidae									
Lepidocephalus guntea	PL	20.63	22.81	B	22.22	24.56	0.73	0.63	LRlc
Bagridae									
Sperata aor	CA	33.33	33.33	G	33.33	33.33	0.66	2.41	LRnt
Sperata seenghala	CA	33.33	33.33	G	33.33	33.33	0.54	2.91	LRnt
Mystus cavacius	CA	33.33	33.33	G	33.33	33.33	0.76	2.75	LRnt
Mystus tengara	CA	33.33	33.33	G	33.33	33.33	3.2	2.16	DD
Mystus vittatus	CA	33.33	33.33	G	33.33	33.33	0.73	2.77	VU
Rita rita	CA	33.33	33.33	B	22.22	24.56	3.71	5.23	EN
Siluridae									
Ompok bimaculatus	CA	33.33	33.33	G	33.33	33.33	1.66	1.78	EN

TABLE 3
Diversity, community indices, relative abundance (RA %) and threat status of the fishes in river Betwa and Ken

Family/ Species	Trophic level	Trophic level score		Habitat orientation nature	Habitat orientation score		Total relative abundance RA(%)		Threat status
		Betwa	Ken		Betwa	Ken	Betwa	Ken	
Ompok pabda	CA	33.33	33.33	G	33.33	33.33	0.8	0.65	EN
Walago attu	CA	33.33	33.33	G	33.33	33.33	0.7	2.38	LRnt
Schilbeidae									
Ailia coila	OM	36.51	NR	P	44.44	NR	0.2	0	VU
Eutropiichthys vacha	OM	36.51	28.07	P	44.44	42.11	3.91	2.58	EN
Clupisoma garua	CA	33.33	33.33	P	44.44	42.11	1.02	1.45	VU
Silonia silondia	CA	33.33	NR	G	33.33	NR	0.52	0	LRnt
Pangasidae									
Pangasius pangasius	CA	33.33	33.33	G	33.33	33.33	0.07	0.02	LRnt
Sisoridae									
Bagarius bagarius	CA	33.33	33.33	B	22.22	24.56	0.36	1.03	VU
Gagata cenia	OM	36.51	NR	P	44.44	NR	0.75	0	DD
Glyptothorax brevipinnis	OM	36.51	28.07	B	22.22	24.56	0.17	0.01	DD
Heteropnustidae									
Heteropneustes fossilis	OM	36.51	28.07	P	44.44	42.11	0.43	0.13	VU
Belonidae									
Xenentodon cancila	CA	33.33	33.33	P	44.44	42.11	0.59	5.98	LRnt
Ambissidae									
Chanda nama	CA	33.33	33.33	P	44.44	42.11	5.21	7.42	LRlc
Parambassis ranga	OM	36.51	NR	P	44.44	NR	5.31	0	LRlc
Sciaenidae									
Johinus coitor	CA	33.33	33.33	P	44.44	42.11	0.23	2.24	DD
Nandidae									
Nandus nandus	OM	36.51	28.07	G	33.33	33.33	0.77	0.77	LRnt
Cichlidae									
Oreochromis mossambicus	OM	36.51	28.07	B	22.22	24.56	0.66	0.02	
Mugilidae									
Rhinomugil corsula	OM	36.51	28.07	P	44.44	42.11	1.66	0.33	VU
Gobiidae									
Glossogobius giuris	PL	20.63	22.81	P	44.44	42.11	3.98	0.74	LRnt
Chandadae									
Channa marulius	CA	33.33	33.33	G	33.33	33.33	1.49	1.64	VU
Channa puntatus	CA	33.33	NR	G	33.33	NR	0.69	0	LRnt
Channa striatus	CA	33.33	33.33	G	33.33	33.33	1.76	0.88	LRnt
Mastacembelidae									
Macrognathus pancalus	BE	9.52	15.79	B	22.22	24.56	0.8	0.38	LRnt
Mastacembalus armatus	BE	9.52	15.79	B	22.22	24.56	1	1.68	VU
Tetraodontidae									
Tetraodon cutcutia	OM	36.51	NR	P	44.44	NR	0.78	0	LR-nt
Mean score		**29.25**	**26.9**		**35.8**	**34.87**			
Standard deviation (±)		9.34	6		8.8	7.06			
Coefficient of variation		88.60	35.96		77.42	49.84			

EN, endangered; VU, vulnerable; DD, data deficient; LRnt , lower risk near threatened; Lr lc, low risk least concern; NR, Not Recorded. PL, planktivores; BE, benthic feeder; OM, omnivore; CA, carnivore; P, pelagic; G, general; B, benthic.

Fish community and trophic indices: In the present study a total of 67 species representing 49 genera and 21 families were recorded from river Betwa and Ken (Table 3). River Betwa showed a higher richness with 63 species, 20 families and 45 genera, when compared to Ken, with 57 species, 20 families and 42 genera. The maximum species richness in river Betwa was recorded at site B2, followed by site B3 (46 species) and low species richness was recorded at site B4 in the lower stretch (Fig. 2). In river Ken, the maximum species richness (37 species) was recorded at K2 and the minimum from site K4, located in the lower stretches of the river channel. Assessment of the fish species threat status in both rivers showed eight species as endangered (EN), 14 species as vulnerable, 29 species under lower risk and data on 12 species were not available to categorize them under any threat category. Out of 22 threatened species (EN and VU) in Betwa and 19 species in Ken, the lowest abundance of threatened species was recorded at B4 of Betwa and K4 of river Ken (Fig. 2).

The analysis of trophic niches for the different sampling sites sampled in both rivers, indicated dominancy of carnivorous species (19) in river Ken and of omnivorous species (23) in Betwa (Table 4). For other groups like benthic feeder a total of (9) species were recorded in Ken whereas less were found in Betwa (six species). Data on species habitat orientation revealed the dominancy of pelagic fish species in both rivers (28 in Betwa and 24 species in Ken), and that these were followed by general and benthic ones.

The trophic level score of carnivorous species was recorded similar (33.33%) in both rivers, whereas it was higher for omnivorous species in Betwa (36.51%) than Ken (28.07%). The relative abundance of top carnivore species in river Ken like *N. notopterus* (1.21%), *S. aor* (2.41%), *S. seenghala* (2.91%), *M. tengara* (2.16%), *R. rita* (5.23%) and *X. cancilla* (5.9%) showed higher abundances than for Betwa. On the other hand, the relative abundance of omnivorous species like *P. ranga* (5.31%), *R. daniconius* (3.05%), *P. amphibious* (2.85%), *P. chola* (2.45%) and *R. corsula* (1.66%) were recorded higher in Betwa than river Ken (Table 3). The mean score for habitat orientation was 35.8 (±8.8) for Betwa and 34.87 (±7.06) for Ken showed no major differences between the two rivers, but the mean trophic level score of river Betwa (29.25%±9.34) was recorded

TABLE 4
Number of species at different trophic level and habitat orientation and their similarity (Sorensen's coefficient) and dissimilarity (Bray-Curtis) indices between Betwa and Ken rivers

Ecological characteristics	Trophic level		Habitat orientation	
	Betwa	Ken	Betwa	Ken
Occurrence of fish species	PL=13 BE=6 OM=23 CA=21	PL=13 BE=9 OM=16 CA=19	P=28 G=21 B=14	P=24 G=14 B=19
Total No. of species	57	63	57	63
Similarity index	PL=0.08 BE=0.99 OM=0.94 CA=0.68		P=0.99 G=0.85 B=0.93	
Dissimilarity index	PL=0.19 BE=0 OM=0.06 CA=0.32		P=0.005 G=0.14 B=0.06	

PL, planktivores; BE, benthic feeder; OM, omnivore; CA, carnivore; P, pelagic; G, general; B, benthic.

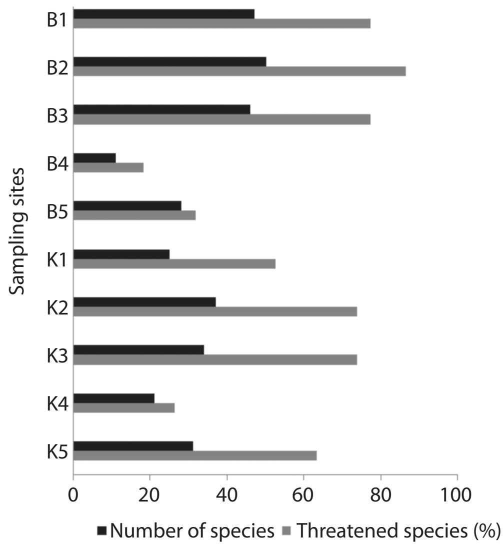

Fig. 2. Number of species and % of threatened species in river Betwa (B1-B5) and Ken (K1-K5).

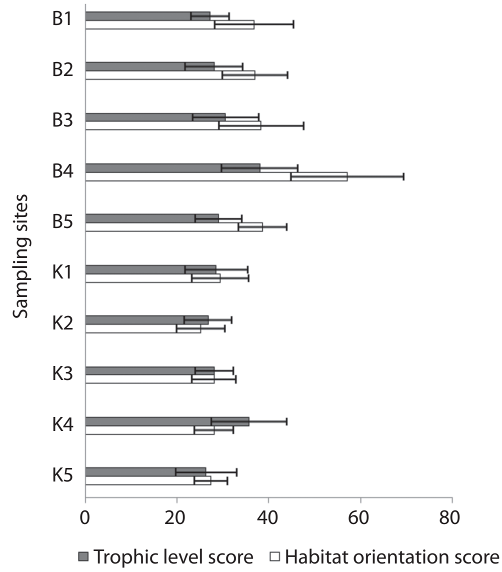

Fig. 3. Comparison of mean (±SD) trophic level and mean (±SD) habitat orientation scores at different sampling sites in river Betwa (B1-B5) and Ken (K1-K5).

higher than Ken (26.9%±6). The biodiversity of the fishes, present in the two rivers was comparatively different as river Ken has 1.1 times fewer fish species than the Betwa.

In both rivers, variations in the trophic and habitat metrics were also recorded among the sampling sites. The mean habitat orientation score in Betwa was recorded higher at site B4 (57.03±12.3) and lower at B1 (36.7±8.6), whereas in river Ken, no major differences were recorded among the sampling sites (Fig. 3). The mean trophic level score was recorded higher at B4 (38±8.3) and lower at B1 (27.2±4.2) in river Betwa, whereas in Ken, it was higher at K4 (35.5±8.2) and lower at K2 (26.7±5.2). The data for similarity index (Sorensen's coefficient) showed its least value (0.68) and dissimilarity index (Bray-Curtis) showed its maximum value (0.32) for carnivore species among four types of trophic level fishes (Table 4). The similarity showed its higher values among habitat orientation of fishes. The Bray-Curtis index for trophic level identified the carnivore species (>0.32) as an indicator for pollution.

DISCUSSION

Alterations in water quality or other habitat conditions, including land use pattern in the watershed, commonly result in shifting availabilities of many food resources and changes in the fish community that can then be measured (Karr 1981). In our study, the downstream area (B4 and B5, especially in Betwa) was expected to be a cause of concern, due to the possible effects caused by the discharges from the thermal power plant and several dams, that have resulted in a fragmented channel and the formation of isolated pools and shallow water habitats. The excess of nitrite, total hardness, and turbidity in these sites of Betwa were the main causes of pollution and loss of biodiversity. The degraded conditions of the lower stretches in river Betwa have also been confirmed, in a recent study by Lakra *et al.* (2010). On the other hand, in river Ken, the water quality was improved as compared to Betwa, although the shallow water depth in the upper stretch, and dams and weirs located up to the middle stretches, were the cause of habitat modification.

Variations in species composition among the different sampling sites in both rivers indicated that altered habitats support less biological communities (Arunachalam 2000). Relatively undisturbed sites of Betwa (B1, B2 and B3) and Ken (K2, K3 and K5) were characterized by a diverse fish fauna, which included high richness of threatened species in a variety of habitats. The mean trophic level score was recorded higher at B4 of Betwa and K4 of river Ken. This indicated that the fishes of those sites were likely responding to ecosystem stress (Rapport 1995), resulting in degradation of fish community structure compared to other sites in both rivers. In contrast, high diversity of fish species, in B2 and K2 represents a variety of suitable habitats and food types, to support many different species (Growns *et al.* 2003, Raghavan *et al.* 2008, Dubey *et al.* 2012).

It is evident that, in a changing ecosystem, omnivorous are able to consume food from a variety of sources (Wichert & Rapport 1998), and this could be a possible reason that the diversity and abundance of omnivorous species in Betwa was recorded higher than in river Ken. Furthermore, the higher abundance of omnivorous species in Betwa indicated that they are more able to tolerate the degraded habitats of the river than other groups. A recent study by Das & Chakrabarty (2007) also indicated that in a least disturbed system, a higher proportion of species present would belong to the benthic feeders and carnivorous groups than at heavily degraded sites. As degradation intensifies, those species at the top of the trophic structure, i.e., the carnivorous, would disappear first, followed in sequence by benthic insectivorous, general insectivorous, planktivorous and omnivorous (Wichert & Rapport 1998).

In conclusion, it appears that due to habitat regulation by several dams, fragmented water channel and pollution, the structural properties of fish communities in the lower stretches (B4 of Betwa and K4 of Ken) of both rivers were affected; as a result, low species richness and lower abundance of threatened species were recorded. On the other hand, the data on the utilization of trophic ecology showed dominancy of omnivorous fishes in Betwa and more precisely in the lower stretches indicating that our metrics may be useful for assessing altered as well as less altered fish habitat of both rivers, and also for other tropical rivers in an Indian river system. In this study, the habitat orientation score did not appear to be a useful indicator of ecosystem stress. It is in agreement with Rapport (1995) as the habitat orientation score is not an indicator for ecosystem stress in lotic environments.

Our results presented herein provided for the first time an assessment of the trophic metrics of fish community in rivers Betwa and Ken, Central India. Evidently, this can be used to prioritize sites and to guide protection and management activities, and support restoration efforts of relatively altered fish habitats of both the rivers. The present investigation on the trophic structure of the fishes serves as a basis to plan management strategies for the rivers premeditated for the India's first interlinking in which morphodynamics changes will have catastrophic effect on the fish community in near future (in the post interlinking phases). However, further detailed studies are required to quantify the changes to predict a future action plan to check further loss of aquatic biodiversity.

ACKNOWLEDGMENTS

The authors are grateful to Director, NBFGR for providing necessary facilities and the Department of Biotechnology (DBT), Govt. of India for financial support.

RESUMEN

En la India, los recursos acuáticos de agua dulce están sufriendo debido a la creciente población humana, la urbanización y la escasez de todo tipo de recursos naturales como el agua. Para mitigar esto, se ha planificado bajo un amplio esquema que todos los grandes ríos estén interconectados a través de un sistema de canales, sin embargo, la información básica sobre las condiciones ecológicas de los ríos tropicales y sus comunidades de peces es escasa en la actualidad. En vista de ello, el presente estudio se realizó para evaluar el estado ecológico, mediante la comparación de los parámetros tróficos de la comunidad de peces, estado de conservación y el agua de los dos ríos tropicales de la cuenca del Ganges, de octubre 2007 a noviembre 2009. El análisis de los nichos tróficos de las especies de peces disponibles indican dominancia de carnívoros (19 especies) en el río Ken y omnívoros (23 especies) en Betwa. El nivel trófico de las especies carnívoras fue similar en ambos ríos (33.33%), mientras que las especies omnívoras fueron mayores en Betwa (36.51%) que en Ken (28.07%). Sitios relativamente inalterados de Betwa (B1, B2 y B3) y Ken (K2, K3 y K5) se caracterizaron por la alta diversidad y riqueza de especies de peces amenazadas. Los puntajes medios más altos del nivel trófico se registraron en B4 de Betwa y K4 de Ken. El índice de Bray-Curtis para el nivel trófico identificó las especies carnívoras (>0.32) como indicadoras de contaminación. Exposición antropogénica, reflejada en la calidad del agua, así como en la estructura de la comunidad de peces, fue más alta, especialmente en los tramos inferiores de ambos ríos. Nuestros resultados sugieren la importancia de métricas tróficas en la comunidad de peces, para la evaluación de las condiciones ecológicas, lo que permite hacer predicciones sobre el efecto de futuros cambios morfodinámicos (en las fases de post-interconexión), y proporcionar un marco y condición de referencia para apoyar los esfuerzos de restauración de hábitat de peces relativamente alterados en los ríos tropicales de la India.

Palabras clave: comunidad de peces, métricas tróficas, índice de similitud, amenazas, interconexión de ríos, India.

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