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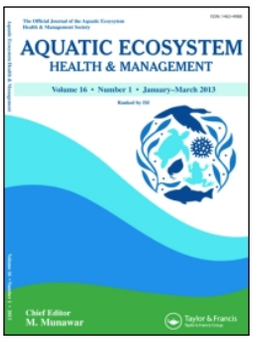

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Studies on ecology, fish diversity and fisheries of Ken–Betwa rivers (India): Proposed for inter-linking

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The Ken and Betwa rivers traversing through Central India are the major tributaries of the river Yamuna. Both rivers originate above 550 m above sea level in the Vindhya region. An interlinking project proposed for the rivers envisages diversion of water from Ken basin to the Betwa. The river sediment is alkaline and dominated by sand (78–89%) in both rivers. Oxygen-rich alkaline water and moderate values of chemical parameters show the pollution free and productive nature of both the rivers. There was no statistically significant difference in water quality between the Ken and Betwa rivers, except for total alkalinity. The biotic parameters were observed in similar ranges and moderate condition. A total of 61 planktonic forms were recorded from the rivers out of which 55 were phytoplankton. For the first time, 89 fish species belonging to 10 orders, 26 families, and 62 genera have been recorded in the river Ken, while 81 species classified under 10 orders, 24 families, and 55 genera were found in the Betwa. Exotic fish species were also observed in the downstream stretches of both rivers. Out of the total fish species, 77 were common to both rivers, 12 were found only in the Ken River, and 4 species were restricted to the Betwa. Analysis of relative abundance showed dominance of Labeo boggut *in the Ken and* Osteobrama cotio *in the Betwa River. On comparison of the Shannon–Wiener Diversity and Evenness Indices of fish diversity, these indicated slightly higher values in the Ken (3.76 and 0.842) than the Betwa (3.66 and 0.835). A total of nine near-threatened fish species was recorded in the rivers. Both rivers have already been obstructed by many developmental projects; the proposed interlinking would further negatively impact the ecology and fisheries.*

Keywords: sediment, water quality, biotic communities, impacts

Introduction

Rainfall is unequally distributed throughout different regions in India which receives about 4000 km^3 or an average of 1200 mm of water as precipitation annually (Ali, 2004; National Commission on Integrated Water Resource Development Plan [NCIWRDP], 1999). Owing to unequal precipitation pattern, some of the region faces severe flood conditions, while at the same time other areas face acute water shortages. To overcome the situation of unequal distribution of

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water, the National Water Development Agency (NWDA) has planned 30 inter-river-linking projects for redistribution of river water across the country. The Ken–Betwa link is one of these proposed projects (Misra et al., 2007). River interlinking has been done in many parts of the world but has raised environmental concerns (NWDA, 1982; Lakra et al., 2011). The Government of India has approved the country's first river-interlinking project for Ken–Betwa and a Memorandum of Understanding has been signed among the states of Uttar Pradesh, Madhya Pradesh, and the Union Government.

Most of the Indian rivers are excessively exploited to fulfill the ever-increasing demand from power, agricultural, industrial, and municipal sectors (Gopal, 2000; Gopal and Chauhan, 2003; Joshi and Mahanta, 2009; Mahanta et al., 2011). The massive hydroelectric projects, barrages, canals, influx of enormous silt load from eroded catchments, and the mining of river beds for boulders and sand have all drastically altered the pristine ecological conditions and flow regime of the rivers. Large-scale obstructions and water abstraction envisaged under inter-river-linking could further aggravate the situation. Therefore, detailed information on ecology and fishery aspects of the affected rivers is mandatory to infer possible impacts of interlinking.

The Ken–Betwa link project prepared by NWDA envisages diversion of surplus waters (1020 MCM annually^{-1}) from the Ken basin to the Betwa basin. The water flow in the Betwa River is depleting rapidly due to the cumulative effects of large scale modifications from the construction of dams/barrages at about seven sites on the main channel and two sites on tributaries, as well as prevailing drought conditions. The annual water discharge from the Parichha dam, constructed on the river Betwa near Jhansi, was estimated at 86,406.34 cubic meter sec^{-1} (cumecs) between 1983 and 1987, and reduced to 54,853.36 cumecs between 1993 and 1996. The discharge further reduced to 10,514.39 cumecs between 2001 and 2007 and 2367.79 cumecs in 2007 (NWDA, 1982). Keeping the above facts in mind, a dam is proposed on the Ken at Daudhan with an estimated submergence area of 8650–9000 ha. The water of the river Ken will be drained through a 231.45 km linking canal from the proposed Daudhan barrage to the Betwa River, near Barwa Sagar (NWDA, 1982).

The fish diversity and composition of a number of rivers and associated water bodies of Central India have been studied and documented by various researchers (Hora and Nair, 1941; Dubey and Mehra, 1959; Dubey and Verma, 1965; Motwani and David, 1957; Karmchandani et al., 1967; Karmakar and Dutta, 1988; Saxena and Srivastava, 1989; Desai et al., 1997; Joshi and Laal, 2007; Joshi et al., 2009). Exploratory surveys of fish diversity in the Ken and Betwa Rivers have also been undertaken (Srivastava et al., 1970; Joshi and Biswas, 2010; Johnson et al., 2012), but all these studies were fragmented in nature and generally covered only a single season. A recent study pertaining to fish diversity and management issues of the river Ken was also done (Sarkar et al., 2013). Fish diversity aspects of the Betwa River were investigated by Lakra et al. (2010). All the above studies conducted in the Ken and Betwa rivers mainly dealt with aspects of fish diversity. The present chapter comprises the results of very exhaustive investigations conducted for the first time on physicochemical, biological, and fishery parameters of these rivers, undertaken betwen 2007 and 2012, resulting in a preliminary assessment of the likely impacts of the proposed linking of the rivers.

Study area

The Ken and Betwa rivers, two north-flowing tributaries of the river Yamuna and traversing through Central India, were studied during the period April 2007 to March 2012. The river Ken was studied at Daudhan and Banda centres, while the Betwa River was studied at Anjanighat and Badagaun (Figure 1).

The river Ken originates from the Ahirgawan village on the northwest slopes of the Kaimur hills in the Jabalpur district of Madhya Pradesh (M.P.) at an elevation of about 550 masl. The river traverses over a distance of 427 km and finally flows into the Yamuna River at Chilla (95 masl) in the Banda district of Uttar Pradesh (NWDA, 1982). Out of its total length, 292 km lies in Madhya Pradesh, 84 km in Uttar Pradesh, and 51 km along the common boundary between U.P. and M.P. The total catchment of the river is 28,058 km^2, with 24,472 km^2 in M.P. and the remaining 3586 km^2 in U.P. The major tributaries of the river are the

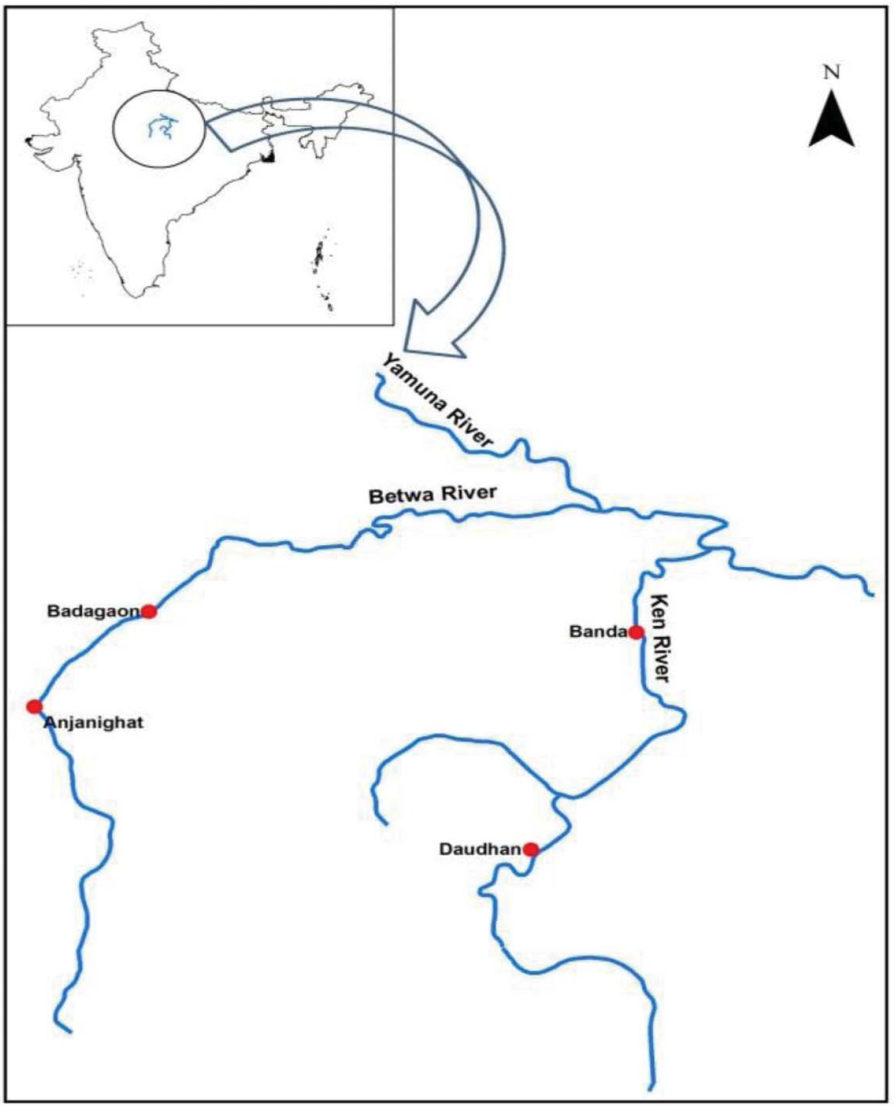

Figure 1. Map showing sampling centres on the Ken and Betwa rivers.

Chandrawal, Urmil, Shiam, Karoran, Kel, Banne, Kutni, Kail, Sonar, and Vearma.

The Betwa River originates from Barkhera village of the Raisen district of Madhya Pradesh in the Vindhya Plateau at an elevation of 576 masl. Total length of the river is 590 km, traversing 232 km in M.P. and 358 km in the territory of U. P. Betwa is a rainfed river with very high discharge during active monsoon and extremely low discharge during summer. The major tributaries of the river are Dhasan, Barwa, Parwaha, Jamini, and Paricha.

Methodology

The study on ecological, fish diversity, and fishery parameters of the Ken and Betwa rivers was conducted during three seasons (i.e. summer, monsoon, and winter) over five years. Two sampling centres (Table 1) were selected in each river for the study. The sampling for various parameters at each centre was conducted in a single day between 08.00 and 14.00 h. The sampling sites were selected on the basis of accessibility and maximum representation of the riverine habitats.

Table 1. Locations of sampling sites in Ken and Betwa rivers.

Rivers	Sampling site	Altitude (msl)	Coordinates	Substratum conditions
Ken	Daudhan, Dist. Chhatarpur, Madhya Pradesh (M.P.)	207	$80^0 00' 24.69''$ E $24^0 43' 58.17''$N	Boulders, pebbles, sand, silt
	Banda, Dist. Banda, Uttar Pradesh (U.P.)	101	$80^0 18' 46.15''$ E $25^0 28' 46.73''$N	Bedrocks, boulders, pebbles, sand, silt
Betwa	Anjanighat Dist. Jhansi (U.P.)	199	$78^0 39' 41.94''$ E $25^0 23' 21.55''$ N	Boulders, pebbles, sand, silt, clay
	Badagaon, Dist. Jhansi (U.P.)	189	$78^0 43' 51.13''$ E $25^0 28' 17.94''$ N	Pebbles, sand, silt, clay

Samples were collected from three sub-sites (both of the banks and the centre) for all the sampling sites. Locations of sites were recorded by using a global positioning system (GPS).

The sediment and water samples were collected and analyzed as per standard methods (Adoni, 1985; APHA, 2005). Specific conductance, pH, and total dissolved solids (TDS) were analyzed by portable EUTECH (Cyber scan series 600, Singapore). Plankton samples were collected by using plankton net made of bolting silk, net no. 25 (mesh size 0.3–0.4 mm). Each sample was collected by filtering 50 litres of sub-surface water. Periphyton samples were collected from the natural and artificial substratum, were brought to the lab after fixation in 4% formaline, and were analysed as per the standard procedure. Planktonic and periphytic taxa up to genera were identified at 400X magnification using standard texts (Ward and Whipple, 1992; Presscott, 1962). Three hauls of macro-benthic organisms were collected using an Ekman dredge (22.9 cm^2) at an average depth of 2 m up to 6 m at each centre. The samples were identified using standard methodologies (Ward and Whipple, 1992; Needham and Needham, 1962).

The information on piscine diversity was collected from the rivers through sampling conducted at the selected sites using cast (1.5 m diameter and 2.0 × 2.0 mm mesh) and gill nets (10–40 mm). Information was also collected from fishermen, market surveys at fish markets located at Gangau, Daudhan, Badagaon, and Jhansi, published data, and opinions of the active fishermen and experts. The fish were identified as per Talwar and Jhingran (1991). All species names adhere to Fish Base (Froese and Pauly, 2010).

The relative abundance of fish species, Shannon–Wiener Diversity and Equitability/Evenness Indices (Shannon and Wiener, 1963) were applied to describe the biotic communities and fish diversity of the rivers. Association of fish families with the sampling sites in the rivers were established by correspondence analysis (Greenacre, 1984) using the concept of chi-square and inertia of dimension with the help of SAS software.

Results and discussion

Sediment quality

The Ken and Betwa rivers traverse through varied catchments with forest land, agricultural fields, human settlements, and pasture lands. The substratum in the upper and midstream segments consist of bedrock and boulders; while gravels, sand, silt, and clay exist downstream. Due to minor differences in substratum characteristics, sediment was dominated by 89.0% sand in the river Ken in comparison to 78.3% in the river Betwa. Accordingly, higher values of silt (14.6%) were observed in the Betwa. The sediments were alkaline in reaction (pH: 7.2 and 7.6, respectively) in both the rivers. The values of conductance and free calcium carbonate were comparatively higher in the Betwa (244.0 μmhos cm^{-1} and 15.1%) than the river Ken (195.6 μmhos cm^{-1} and 1.4%). The nutrient status (Figure 2) in respect to available phosphorus (3.3 mg 100 g^{-1}) and organic carbon (0.36% and 0.49%) in the Ken and Betwa, respectively, showed a moderate productive nature of the rivers. As both the rivers traverse through similar catchments, there was no statistically significant differences in sediment quality parameters between the Ken and the Betwa rivers ($p > 0.05$).

Water quality

The common feature of the Ken and Betwa rivers were oxygen richness (6.1–9.1 mg l^{-1}), alkaline

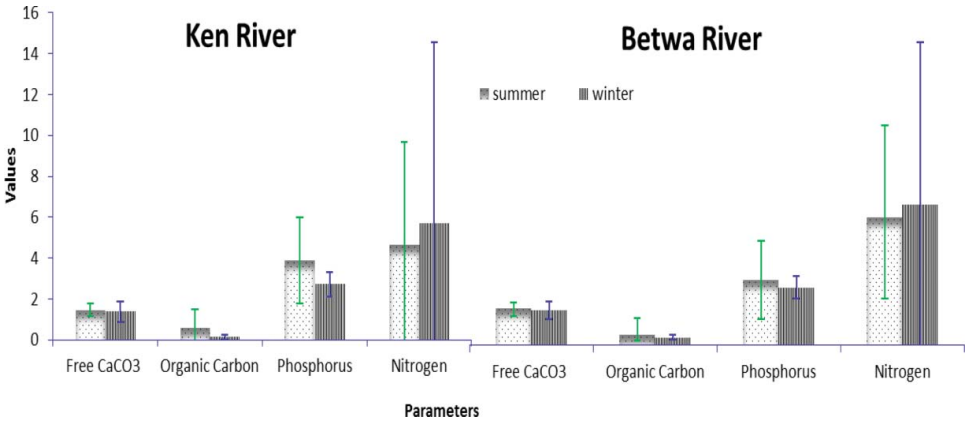

Figure 2. Average sediment quality parameters in Ken and Betwa rivers.

pH (7.26–7.66), and low nutrients (phosphate: 0.02 and 0.10 mg l^{-1}), although organic carbon was high (0.85 and 1.08 mg l^{-1}). The important chemical parameters—alkalinity, conductance, dissolved solids, hardness, and chloride (Figure 3)—were comparatively higher in the Ken (114.98 mg l^{-1}, 242.0 μmhos, 123.7 mg l^{-1}, 120.3 mgl^{-1}, 22.25 mgl^{-1}, respectively) than in the Betwa (93.89 m gl^{-1}, 212.0 μmhos, 110.71 mg l^{-1}, 109.33 mg l^{-1}, 19.29 mg l^{-1}, respectively). Comparatively higher conductance value in the sediment phase of the river Betwa could be attributed to deposition of organic load in absence of sufficient water discharge. There was no statistically significant difference in water quality parameters at 95% level of significance of the given data ($p > 0.05$) between the Ken and the Betwa rivers, except for the total alkalinity ($p = 0.0485$).

Plankton

Plankton population in the river Ken varied from 40 to 510 μl^{-1} (average 323 μl^{-1}) in different seasons. Maximum abundance was observed during summer, followed by winter, with the minimum seen during monsoon. Generally, phytoplankton formed the major constituent, and only 10.5% was contributed by zooplanktons at Banda during the post-monsoon season. Among various planktonic groups, Bacillariphyceae (54.2–100.0%) dominated during all the seasons and centres followed by Chlorophyceae (0.0–23.1%), Myxophyceae (0.0–18.7%), followed by minor amounts of others, as shown in Figure 4. A total of 61 forms were recorded from the Ken River, out of which 55 were phytoplankton and the rest zooplankton. Considerable inter-stretch variation was observed in abundance and composition of

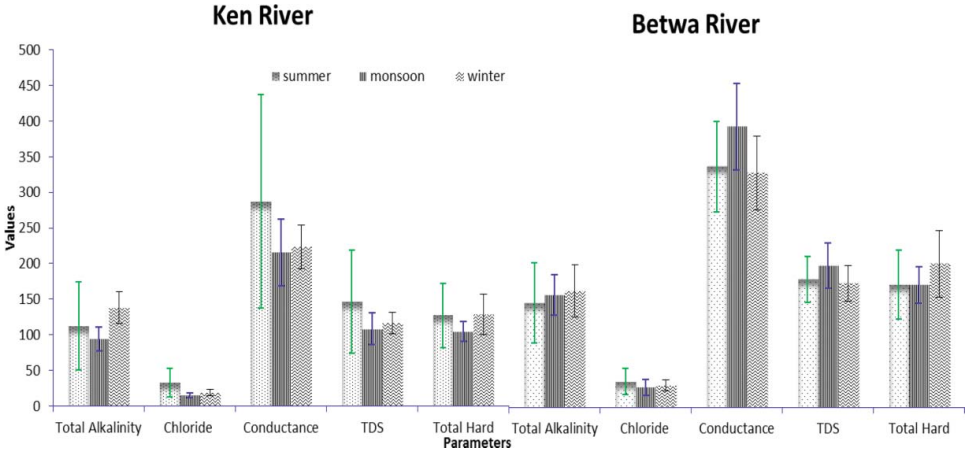

Figure 3. Average water quality parameters in Ken and Betwa rivers.

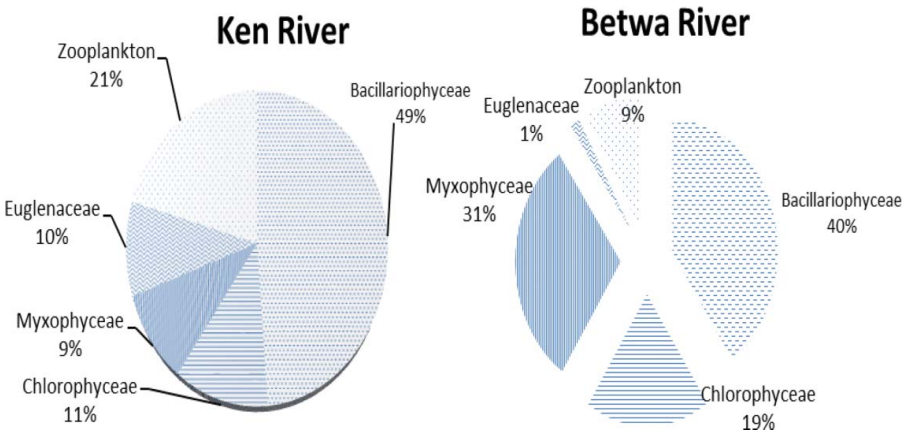

Figure 4. Percent composition of plankton groups in Ken and Betwa rivers.

various groups. Common genera encountered in the river Ken were *Navicula, Synedra, Fragillaria*, and *Meridion* among Bacillariophyceae; *Ankistrodesmus* and *Coelestrum* from Chlorophyceae; and *Phormedium* and *Lyngbya* among Myxophyceae. Among the zooplanktonic forms, *Diaptomus* sp. and *Bosmina* sp. were recorded amongst crustaceans.

The plankton population in the river Betwa was observed in the range of 30 to 670 μl^{-1}. Maximum abundance was found during summer, followed by winter, with minimum seen during monsoon. Phytoplankton contributed 66.7 to 100% of the plankton and the rest were zooplankton. A total of 41 genera were recorded from the river, out of which 33 were phytoplankton and the rest zooplankton. The common planktonic genera encountered in the river Betwa were *Synedra, Navicula*, and *Tabellaria* among Bacillariophyceae; *Ankistrodesmus* and *Microspora* among Chlorophyceae; and *Anabaena, Phormidium*, and *Lyngbya* among Myxophyceae. Among the zooplanktonic forms, *Diaptomus* dominates in crustaceans.

Shannon–Wiener diversity index in the Ken (1.37) and Betwa (1.31) rivers showed a marginal edge of plankton diversity in the river Ken over the Betwa. Likewise, the Evenness Index was slightly higher in the river Ken (0.854) than in the Betwa (0.816).

Periphyton

Periphytic population was in the range of 40–3440 ucm^{-2} (unit per square centimeter) in the river Ken. Bacillariophyceae (60.3–88.7%) dominates among the various periphytic groups, followed by Myxophyceae (6.2–36.7%), and Chlorophyceae (1.7–4.5%). In the river Betwa, periphytic assemblage varied from 140–2680 ucm^{-2}. Abundance of periphytons is also shown in Figure 5. The dominant group was Bacillariophyceae (54.8–66.8%), followed by Myxophyceae (37.6–24.8%) and Chlorophyceae (7.5–8.3%). Common genera encountered were *Synedra, Fragillaria, Navicula*, and *Meridion* among Bacillariophyceae; *Ankistrodesmus* and *Cosmarium* among Chlorophyceae; and *Phormedium* among Myxophyceae. Unlike the planktonic richness in the rivers, the Shannon-Wiener diversity index in the case of periphyton was slightly higher in the river Betwa (0.834) than in the Ken (0.775).

Benthos

Benthic population ranged from 47 to 187 n m^{-2} (number per square meter) in the river Ken and 30 to 95 n m^{-2} in the Betwa. Insects (*Gomphus* and *Chironomus* larvae) were dominant in the Ken during summer, and molluscs (*Bellamya bengalensis, Thiara tuberculata, Thiara lineata, Gyraulus labiatus, Lamellidens marginalis*, and *Parreysia flavidens*) dominated during post-monsoon months. In the Betwa, the annelids (*Nais* and *Tubifex)* were the dominant group, followed by the molluscs (*Bellamya bengalensis, Gyraulus labiatus*, and *Lamellidens corrianus*). A total of 14 taxa were observed in the entire stretch, of which 12 belong to Molluscs and one each to Dipterans and Annelids.

Fish and fisheries

Fish diversity in the river Ken

The altitudinal and geographical variation, vast and varied catchments, vegetation cover, and

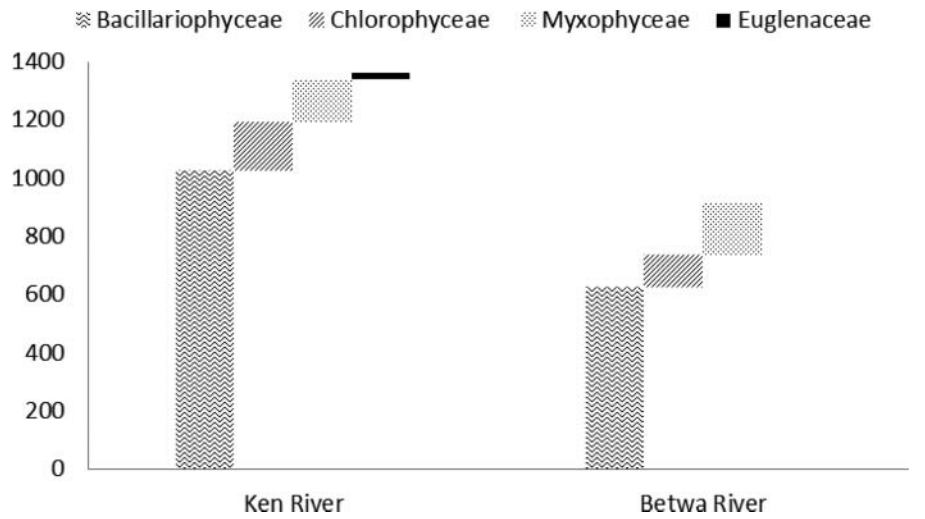

Figure 5. Average numerical abundance of periphyton groups in Ken and Betwa rivers.

influx of numerous tributaries have formed varying substratum and micro-habitats in the rivers. The variations are properly reflected in the form of diverse biotic assemblages and fish diversity. A total of 89 fish species belonging to 62 genera, 26 families, and 10 orders have been recorded for the first time from the river Ken (Table 2). Out of these, 85 species are native and 4 are exotic (*Cyprinus carpio, Oreochromis niloticus, Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*) (Table 3). As far as the number of fish species demonstrated from each family, the Cyprinidae (38 species) dominated among all, followed by Bagridae (7), Schilbeidae (5) and a variety of others. In the present investigations, out of a total of 89 species recorded from the river, 18 were observed for the first time. Research (Arrington and Winemiller, 2003; Postel and Richter, 2003; Welcomme and Halls, 2003) has revealed that the diversity of hydrological patterns appears to be central to the maintenance of habitat heterogeneity and species diversity. The Ken and Betwa rivers traverse through varied catchments, substratum, and flow regimes, hence the present findings also corroborate the above studies.

A total of 50 to 57 fish species were recorded from the river Ken in earlier studies (Srivastava et al., 1970; Joshi and Biswas, 2010; Johnson et al., 2012; Sarkar et al., 2013). But for the first time, the present investigation recorded 89 fish species This is most likely due to the fact that the study was conducted for longer a longer period of time (over five years from 2007 to 2012) with multiple efforts. Two Clupeids—*Corica soborna* and *Ilisha motius*— reported in studies conducted during the 1970s (Srivastava et al., 1970) were absent in the present study. Disappearance of the species could be attributed to large scale modifications in the riverine habitats due to construction of dams and barrages at two sites on the main channel and three sites on tributaries. Relative abundance (RA) of fish species in the river Ken showed dominance of *Labeo boggut* (7.551%) followed by *Osteobrama cotio* (5.310%), *Cirrhinus reba* (5.116%), *Securicula gora* (5.094%) and *Labeo bata* (4.675%). *Badis badis* (0.04%) showed the minimum abundance amongst the 89 species.

Fish diversity in the river Betwa

A total of 81 fish species belonging to 55 genera, 24 families and 10 orders were recorded for the first time from the river Betwa (Table 2). Out of these, 79 species were native and 2 exotic (*Cyprinus carpio* and *Oreochromis niloticus*) (Table 3). A total of between 55 and 63 fish species were recorded from the river in earlier studies conducted during different periods (Adholia, 1977; Joshi et al., 2009; Lakra et al., 2010). As for the distribution of fish species, Cyprinidae (35 species) dominated among the various families, followed by Bagridae (7), Schilbediae (5) and various others. The present study was conducted for a longer duration than previous studies, and hence

Table 2. Relative abundance of fish species in the Ken and Betwa rivers.

Name of species	Common names	Relative Abundance	
		Ken	Betwa
Anguilla bengalensis bengalensis (Gray, 1831)	Indian Longfin Eel	0.154	0.210
Gudusia chapra (Hamilton, 1822)	Indian River Shad	3.541	6.437
Gonialosa manmina (Hamilton, 1822)	Ganges River Gizzard Fish	0.238	0.420
Setipinna phasa (Hamilton, 1822)	Gangetic Hairpin Anchovy	0.053	0.000
Catla catla (Hamilton, 1822)	Catla	0.440	0.285
**Cyprinus carpio* (Linnaeus, 1758)	Common Carp	0.194	0.285
Cirrhinus mrigala (Hamilton, 1822)	Mrigal	0.846	0.981
Cirrhinus reba (Hamilton, 1822)	Reba Carp	5.109	5.675
Chagunius chagunio (Hamilton, 1822)	Chaguni	0.696	0.836
Tor tor (Hamilton, 1822)	Deep Bodied Mahseer	0.207	0.210
Crossocheilus latius latius (Hamilton, 1822)	Gangetic Latia	1.788	1.611
Labeo rohita (Hamilton, 1822)	Rohu	0.344	0.262
Labeo calbasu (Hamilton, 1822)	Kalbasu, Black Rohu	0.062	0.103
Labeo gonius (Hamilton, 1822)	Kyria Labeo	0.198	0.383
Labeo angra (Hamilton, 1822)	Angra Labeo	0.106	0.023
Labeo fimbriatus (Bloch, 1795)	Fringed-Lipped Peninsula Carp	0.035	0.093
Labeo boggut (Sykes, 1839)	Boggut Labeo	7.540	3.830
Labeo pangusia (Hamilton, 1822)	Pangusia Labeo	0.709	0.640
Labeo dyocheilus (McClelland, 1839)	Brahmaputra Labeo	0.154	0.154
Labeo bata (Hamilton, 1822)	Bata Labeo	4.669	6.525
Garra *annandalei* (Hora, 1921)	Annadale Garra	0.115	0.000
Garra lamta (Hamilton, 1822)	Lamta Garra	0.075	0.000
Garra mullya (Sykes, 1839)	Mullya Garra	0.000	0.037
**Ctenopharyngodon idella* (Valenciennes, 1844)	Grass Carp	0.022	0.000
**Hypophthalmichthys molitrix* (Valenciennes, 1844)	Silver Carp	0.048	0.000
Puntius sophore (Hamilton, 1822)	Spot Fin Swamp Barb	3.493	3.078
Pethia conchonius (Hamilton, 1822)	Rosy Barb	3.523	3.130
Pethia ticto (Hamilton, 1822)	Ticto Barb	3.744	2.915
Puntius chola (Hamilton, 1822)	Swamp Barb	0.947	1.336
Systomus sarana sarana (Hamilton, 1822)	Olive Barb	0.943	0.836
Puntius amphibius (Valnciennes, 1842)	Scarlet-Banded Barb	0.128	0.210
Salmophasia bacaila (Hamilton, 1822)	—	3.061	1.822

(*continued on next page*)

Table 2. Relative abundance of fish species in the Ken and Betwa rivers. *(Continued)*

Name of species	Common names	Relative Abundance	
		Ken	Betwa
Amblypharyngodon mola (Hamilton, 1822)	Mola Carplet	0.612	1.130
Aspidoparia morar (Hamilton, 1822)	—	3.369	2.989
Rasbora daniconius (Hamilton, 1822)	Blackline Rasbora	0.414	0.589
Esomus danricus (Hamilton, 1822)	Flying Barb	0.330	0.238
Laubuca laubuca (Hamilton, 1822)	—	0.141	0.047
Raiamas bola (Hamilton, 1822)	Indian Trout	0.194	0.276
Barilius barila (Hamilton, 1822)	Bharred Baril	0.969	0.000
Barilius bendelisis (Hamilton, 1807)	Hamilton's Baril	0.225	0.135
Barilius barna	—	0.388	0.023
Securicula gora (Hamilton, 1822)	Gora Chela	5.087	4.601
Danio devario (Hamilton, 1822)	Devario	0.172	0.051
Osteobrama cotio cotio (Hamilton, 1822)	—	5.303	8.454
Osteobrama cotio peninsularis (Silas, 1952)	—	0.559	0.000
Lepodocephalichthys guntea (Hamilton, 1822)	Guntea Loach	0.132	0.037
Acanthocobitis botia (Hamilton, 1822)	—	0.075	0.019
Notopterus notopterus (Pallas, 1769)	Grey Feather Back	0.529	0.631
Chitala chitala (Hamilton, 1822)	Humped Feather Back	0.458	0.476
Bagarius bagarius (Hamilton, 1822)	Gangetic Goonchh	0.176	0.163
Nangra viridescens (Hamilton, 1822)	—	1.696	0.276
Gagata cenia (Hamilton, 1822)	—	0.352	0.635
Wallago attu (Bloch and Schneider, 1801)	Boal	0.969	0.733
Ompok bimaculatus (Bloch, 1794)	Indian Butter Catfish	0.775	0.659
Ompok pabda (Hamilton, 1822)	Pabdah Catfish	1.145	1.261
Sperata aor (Sykes, 1839)	Long Whiskered Catfish	0.255	0.299
Sperata seenghala (Hamilton, 1822)	Giant River Catfish	0.881	1.285
Mystus cavasius (Hamilton, 1822)	—	0.370	0.336
Mystus bleekeri (Day, 1877)	—	0.392	0.383
Mystus vittatus (Bloch, 1794)	Stripped Dwarf Catfish	2.370	2.508
Mystus tengara (Hamilton, 1822)	Tengra Mystus	0.440	0.037
Rita rita (Hamilton, 1822)	Rita	3.193	2.270
Clarias batrachus (Linnaeus, 1758)	Magur	0.044	0.037
Heteropneustes fossilis (Bloch, 1794)	String Catfish	0.255	0.285
Ailia coila (Hamilton, 1822)	Gangetic Ailia	0.339	0.280
Clupisoma garua (Hamilton, 1822)	Garua	1.550	1.355
Eutropiichthys vacha (Hamilton, 1822)	Batchwa Vacha	0.705	0.565

(*continued on next page*)

Table 2. Relative abundance of fish species in the Ken and Betwa rivers. *(Continued)*

Name of species	Common names	Relative Abundance	
		Ken	Betwa
Eutropiichthys murius (Hamilton, 1822)	—	2.555	2.265
Silonia silondia (Hamilton, 1822)	—	0.066	0.033
Rhinomugil corsula (Hamilton, 1822)	Corsula Mullet	1.238	1.471
Sicamugil cascasia (Hamilton, 1822)	Yellow Tail Mullet	0.220	0.000
Xenentodon cancila (Hamilton, 1822)	Fresh Water Garfish	0.634	0.771
Chanda nama (Hamilton, 1822)	Elongate Glass Perchlet	5.351	5.773
Parambassis ranga (Hamilton, 1822)	Indian Glassy Fish	3.634	4.437
Parambassis lala (Hamilton, 1822)	Highfin Glassy Perchlet	0.000	0.056
Pseudambassis baculis (Hamilton, 1822)	Himalayan Glassy Perchlet	0.154	0.000
Johnius coitor (Hamilton, 1822)	—	0.198	0.117
Nandus nandus (Hamilton, 1822)	Mottled Nandus	0.137	0.201
Badis badis (Hamilton, 1822)	Dwarf Chameleon Fish	0.040	0.000
**Oreochromis niloticus niloticus* (Linnaeus, 1758)	Nile Tilapia	1.057	0.276
Anabas testudineus (Bloch, 1792)	Climbing Perch	0.220	0.000
Trichogaster fasciata (Bloch and Schneider, 1801)	Stripped Gourami	0.925	2.079
Trichogaster lalius (Hamilton, 1822)	Dwarf Gourami	0.000	0.318
Trichogaster chuna (Hamilton, 1822)	Sunset Gourami	0.000	0.056
Channa marulius (Hamilton, 1822)	Giant Snakehead	0.802	1.285
Channa striata (Bloch, 1793)	Stripped Snakehead	0.881	1.023
Channa punctata (Bloch, 1793)	Spotted Snakehead	0.440	0.458
Channa orientalis (Bloch and Schneider, 1801)	Asiatic Snakehead	0.066	0.000
Glossogobius giuris (Hamilton, 1822)	Tank Goby	1.872	1.962
Tetraodon cutcutia (Hamilton, 1822)	Ocellated Pufferfish	0.132	0.182
Mastacembelus armatus (Lacepede, 1800)	Tire-Track Spiny Eel	0.705	1.098
Macrognathus pancalus (Hamilton, 1822)	Stripped Spiny Eel	0.586	0.724
Monopterus cuchia (Hamilton, 1822)	Gangetic Mud Eel	0.044	0.023

*Exotic fishes.

recorded the maximum number of species ever collected and documented for this river. Out of the total 81species reported in the present study, 20 species were reported for the first time.

Unlike in the river Ken, the relative abundance (RA) in the river Betwa showed dominance of *Osteobrama cotio* (8.454%) followed by *Labeo bata* (6.525%), *Gudusia chapra* (6.437%), *Chanda nama* (5.773%), and *Cirrhinus reba* (5.675%). *Acanthocobitis botia* showed the least abundance (0.019%) of the 81 species found in the river Betwa. A comparison of the Shannon-Wiener Diversity and Evenness Indices of fish diversity in

Table 3. Distribution of fish species in Ken and Betwa rivers.

Characteristics	River Ken	River Betwa
Number of fish species present in the rivers	89	81
Native species	85	79
Exotic species	1. *Cyprinus carpio* 2. *Oreochromis niloticus* 3. *Hypophthalmichthys molitrix* 4. *Ctenopharyngodon idella*	1. *Cyprinus carpio* 2. *Oreochromis niloticus*
Common species in both the rivers	77	77
Species restricted to each river	1. *Setipinna phasa* 2. *Garraann andalei* 3. *Garra lamta* 4. *Ctenopharyngodon idella** 5. *Hypophthalmichthys molitrix** 6. *Barilius barila* 7. *Osteobrama cotio peninsularis* 8. *Sicamugil cascasia* 9. *Pseudambassis baculis* 10. *Badis badis* 11. *Anabas testudineus* 12. *Channa orientalis*	1. *Garra mullya* 2. *Parambassis lala* 3. *Trichogaster lalius* 4. *Trichogaster chuna*
Near-threatened species	1. *Tor tor* 2. *Labeo pangusia* 3. *Chitala chitala* 4. *Bagarius bagarius* 5. *Wallago attu* 6. *Ompok bimaculatus* 7. *Ompok pabda* *8. Ailia coila*	1. *Tor tor* 2. *Labeo pangusia* 3. *Chitala chitala* 4. *Bagarius bagarius* 5. *Wallago attu* 6. *Ompok bimaculatus* 7. *Ompok pabda* 8. *Ailia coila* 9. *Parambassis lala*

Ken and Betwa rivers, showed slightly higher values for the river Ken (3.76 and 0.842) than the Betwa (3.66 and 0.835).

Correspondence analysis of the 26 families recorded in both rivers has been done at different sites to show the degree of association (Figure 6) between the rivers. In this comparison, the first two dimensions explain 95.13% of the inertia of the given data. Therefore, dimension-I (75.25% inertia) and dimension-II (19.89% inertia) of the plot have been utilized for interpreting the family-wise distribution (Table 4). The families plotted on the right side of dimension-I show their association with the river Betwa and those on the left the association with the river Ken.

Families Engraulidae, Cichlidae, and Anabantidae (numbered as 3, 19, and 20) show more representation in the river Ken in comparison to the river Betwa. Likewise, the families Claridae, Osphronemidae, and Synbranchidae (numbered as 11, 21, and 26) show more association of species with the river Betwa. Serial numbers of 26 families represented in the analysis are shown in Table 5.

The Ken and Betwa rivers traverse through diverse habitats, including rapids, falls, and deep pools; likewise the river substratum comprises bedrocks, boulders, gravels, sand, silt, and clay in different stretches. Owing to these diverse characteristics, both rivers hold rich piscine diversity as well as a moderate fishery. Indian major Carps

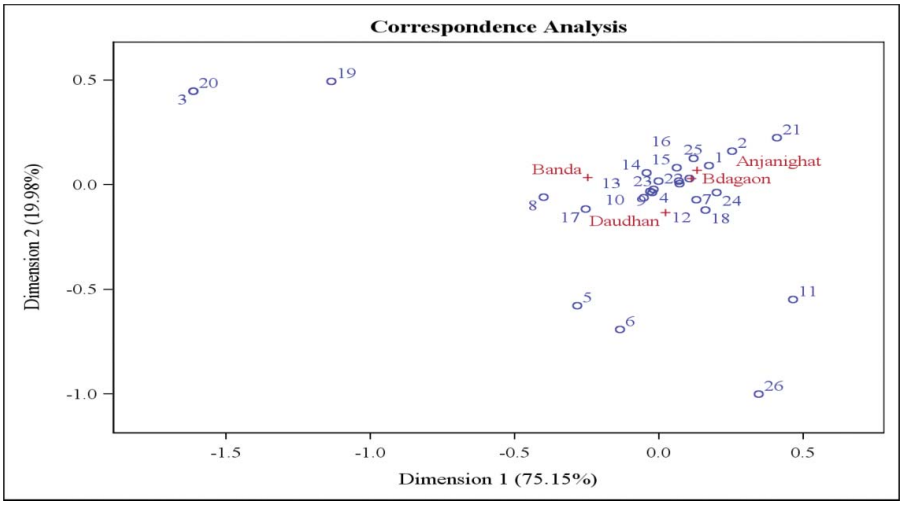

Figure 6. Correspondence analysis showing degree of association of fishes in Ken and Betwa rivers with different locations. The number shows the serial number of fish families.

(IMC), large Catfish, Murrels, Featherbacks, Mahseer and miscellaneous fish form the major fishery groups in the rivers. Deep pools situated in the course of the rivers hold some large specimens of *Labeo rohita, Catla catla, Labeo calbasu, Sperata aor, Sperata seenghala, Bagarius bagarius, Wallago attu, Chitala chitala, Tor tor* and *Ophiocephalus marulius*, which occasionally appear in the catches. Among the fish diversity recorded from the rivers, *Tor tor* is a migratory species, which moves to upstream segments for breeding. *Anguilla bengalensis bengalensis* and *Bagarius bagarius* also migrate up and downstream of the rivers for feeding and breeding purposes. Construction of barrages and related river modifications are catastrophic to these migratory species. Among the fish recorded from the rivers, the majority (59.13%) were food fishes, followed by species with ornamental (33.34%) and sport (7.53%) value. Some people residing along the river's catchment consume *Anguilla bengalensis bengalensis* for its immense importance in traditional medicines.

Threatened fish species

Both the rivers harbor certain threatened species categorized as Near Threatened as per the IUCN Red List 2013 (IUCN, 2013), in which eight were in the river Ken and nine in the Betwa (Table 3). Beside these, a few stray specimens of *Anguilla bengalensis bengalensis* were also observed in the river Ken (RA 0.154%) and the Betwa River (RA 0.210%), while this catadromous fish is very rare in the main Yamuna River.

Table 4. Inertia and chi-square decomposition in analysis.

	Principal Inertia	Chi-Square	Percent	Cumulative Percent	15 30 45 60 75
	0.02340	1032.43	75.15	75.15	**********
	0.00622	274.54	19.98	95.13	*******
	0.00152	66.85	4.87	100.00	**
Total	0.03114	1373.82	100.00		

Degrees of Freedom = 75

Table 5. Serial number and name of the families used in correspondence analysis.

Sl. No.	Family	Sl. No.	Family	Sl. No.	Family
1	Anguillidae	10	Bagridae	19	Cichlidae
2	Clupeidae	11	Claridae	20	Anabantidae
3	Engraulidae	12	Heteropneustidae	21	Osphronemidae
4	Cyprinidae	13	Schilbeidae	22	Channidae
5	Cobitidae	14	Mugilidae	23	Gobiidae
6	Balitoridae	15	Belonidae	24	Tetraodontidae
7	Notopteridae	16	Ambassidae	25	Mastacembelidae
8	Sisoridae	17	Sciaenidae	26	Synbranchidae
9	Siluridae	18	Nandidae		

Likely impacts of proposed inter-river-linking on the Ken and Betwa rivers

Inter-river-linking is a complex issue which comprises a matrix of ecological, socioeconomic, and cultural aspects. Arrays of matrices and comprehensive suggested criteria (Cox, 1999) are available to enumerate positive and negative impacts of the proposal to justify or reject the Inter Basin Water Transfer Projects (IBWT). A cost–benefit assessment is required to properly evaluate any project proposal based upon the various matrices. However, a preliminary assessment of the likely impacts of Ken–Betwa river-linking has been created, based on the available information.

Construction of dam on the river Ken

The Ken River is already barricaded by construction of two dams on the main river and three on its tributaries. As a result, the river course has been fragmented, causing serious obstruction to the migratory fish species, *Tor tor, Bagarius bagarius* and *Anguilla bengalensis*, which inhabit the rivers. The dams have also altered the hydrological regime, sedimentation pattern, and feeding and breeding grounds of the native fish. Dams have considerable influence on downstream river ecosystems, in many cases extending for hundreds of kilometers below the barricade (Dudgeon et al., 2005). Diminishing populations of Indian major Carps, Catfish, Murrels, and Featherback and increasing invasion of hardy exotic fishes could be attributed to the massive river modification activities.

One of the fish species, *Anguilla bengalensis bengalensis*, which is rarely sighted in the main trunk of the river Yamuna, is still available in both the Ken and Betwa rivers. Construction of Daudhan dam on the river Ken and related developmental activities would lead to extermination of this valuable fish species from the river.

Both the rivers harbour sparse Mahseer (*Tor tor*) populations; the proposed dam in the river Ken would block free movement of these fish to their breeding and feeding grounds, and hence would cause further depletion of the species from the system. The positive aspect of the project is the proposed Daudhan reservoir (approximate area 9000 ha), which would provide a valuable water resource for reservoir fish production. However, fish diversity would decrease in the affected river stretch as well as in the reservoir. Further deposition of nutrients in the reservoir can lead to emergence of algal blooms and depletion of dissolved oxygen.

Diversion of water from the river Ken

The river Ken holds some sizeable populations of *Chitala chitala, Notopterus notopterus, Sperata seenghala, Sperata aor, Labeo rohita, Wallago attu* and *Channa marulius*. The proposed construction of Daudhan dam and the annual diversion of 1020 MCM of water from the river Ken to the Betwa would considerably reduce wetted perimeter, depth, and water level in the river Ken below the Daudhan dam. The altered habitat would expose some of the feeding and breeding grounds and shelters of the native fish species. Depletion in water volume and velocity would negatively affect the above-mentioned populations. The river Ken also harbours eight Near-Threatened fish species; the proposed obstruction and water diversion would result in depletion of those populations.

Transfer of water from the Ken river into the Betwa

Since both rivers traverse through similar basins, most of the river characteristics showed similarity in sediment, water quality, plankton, periphyton, benthic organisms, and fish diversity. The Ken and Betwa rivers showed no statistically significant difference in sediment and water quality parameters at a 95% level of significance of the given data ($p > 0.05$).

Therefore, addition of water from the Ken River into the Betwa would augment the water volume and velocity (as long as the water is released in a manner similar to the natural seasonal flow) without any conspicuous negative impacts on physicochemical, biological, and fishery parameters of the recipient river. Hence, the proposed water augmentation has the potential to mitigate the depleting biota, piscine diversity, and fishery in the water-deficient river Betwa. The additional water transferred from the river Ken would help in rejuvenating depleting fishery and aid in revival of the nine Near-Threatened fish species recorded in the Betwa River.

Command area of the proposed link canal

A number of wetlands or large tanks situated in the command area of the proposed Ken–Betwa link canal are facing acute water shortages due to insufficient and erratic rains over the last few years. Hence, the proposed link canal would help in augmenting the water level in these wetlands and boost fish production from these water bodies. Further, the additional water in the canal command area would help in promotion of fishery development in the area.

Conclusions

The Ken and Betwa rivers originate and traverse through similar landscapes; hence, they represent similar morphometric, geographic, and ecological conditions. The present study reveals severe abstractions in the rivers as a result of construction of a number of irrigation projects. But due to diverse habitats in the rivers, the physicochemical, biological, and fishery parameters still reveal a reasonable state, despite indication of depleting fishery, disappearance of certain species, and invasion of exotic fishes. The river Ken holds rare sizeable specimens of *Sperata aor, Sperata seenghala, Bagarius bagarius, Wallago attu, Ophiocephalus marulius, Notopterus cheetala*, in addition to Indian major Carps. *Anguilla bengalensis bengalensis* and *Tor tor* are two other rare species available in the rivers. Fish samples of the above species collected from the river Betwa were comparatively smaller in size due to less water availability and higher magnitude of habitat loss. Likewise, the Shannon-Wiener diversity and Evenness indices showed marginally more plankton diversity in the river Ken as compared to the Betwa. Therefore, it seems that transfer of water from the Ken River to the Betwa would not abruptly alter the physicochemical parameters of the recipient river, if the transfer was done in such a manner as to mimic the seasonal flow regime. But, construction of another barrage and water transfer may pose a threat to the depleting biota, fish diversity, and fisheries of the river Ken. Although fish production could marginally increase in the proposed reservoir, the fish will be typically lacustrine with a mixture of native and exotic species, which are less ecologically resilient than the native species. Hence, the loss of aquatic biodiversity is of great concern, since biodiversity adds resilience to ecosystems and fisheries for residents in the basins.

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References

Adholia, U.N., 1977. Fish fauna of the River Betwa. Geobios. 4 (6), 272–273.

Adoni, A. D., 1985. *Work Book on Limnology*. Bandna Printing Service, New Delhi.

Ali, I., 2004. Inter-linking of Indian rivers. Current Science 86(4), 498–499.

APHA, 2005. Standard methods for examination of water and wastewater. 21st Edn. APHA AWWA, WPCF, Washington DC, USA.

Arrington, D.A. and Winemiller, K. O., 2003. Diel changeover in sandbank fish assemblages in a neotropical floodplain river. J. Fish. Biol. 63(2), 442–459.

Cox, W.E., 1999. Proceeding of International Workshop on Inter basin water transfer, International Hydrological Programme, UNESCO, Paris.

Desai, V.R., Kumar, D. and Srivastava, N.P., 1997. Fish fauna of Ravishankar Sagar Reservoir. J. Inland Fish. Soc. India. 29(2), 53–56.

Dubey, G.P. and Mehra, R.K., 1959. Fish and fisheries of Chambal river. Proc. All India Congress Zool. 2, 647–665.

Dubey, G.P. and Verma, M.N., 1965. A preliminary study of the fish fauna of Madhya Pradesh. Vikram University Journal. 8(4), 52–59.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z., Knowler, D., Leveque, C., Naiman, R.J., Prieur-Richard, A. H., Soto, D., Stiassny, M.L.J., 2005. Freshwater biodiversity: importance, threats, status, and conservation challenges. Biol Rev. 8, 163–182.

Froese, R., Pauly, D. (Eds.), 2010. FishBase. [Version 10/2011] http://www.fishbase.org

Gopal, B., 2000. River conservation in the Indian subcontinent. In: P.J. Boon, B.R. Davies, G.E. Pelts (Eds.) *Global perspectives on river conservation: science, policy and practice*, pp. 233–261. Wiley, London.

Gopal, B. and Chauhan, M., 2003. River Restoration in India: A Case Study of River Yamuna East Asia Regional Seminar on River Restoration, Kuala Lumpur, 2003, January 13–15.

Greenacre, M. J., 1984. *Theory and Applications of Correspondence Analysis*. Academic Press, London.

Hora, S.L. and Nair, K.K., 1941. Fishes of Satpura range, Hosangabad district, Central Province., Rec. Indian Museum 43(3), 361–373.

IUCN, 2013. The IUCN Red List of Threatened Species. Version 2013.1 http://www.Iucnredlist.org>Downloaded on December 2013.

Johnson, J.A., Parmar, R., Ramesh, K., Sen, S. and Murthy, R. S., 2012. Fish diversity and assemblage structure in Ken River of Panna landscape, central India. J. Threat. Taxa. 4 (13), 3161–3172.

Joshi, K.D. and Biswas, B.K., 2010. Piscine diversity and fisheries in the river Ken, proposed for inter-river-linking. J. Inland Fish. Soc. 42(2), 25–31.

Joshi, K.D. and Laal, A.K., 2007. Status of piscine diversity in reservoirs of Central India: Measures for conservation. In: W.S. Lakra, U.K. Sarkar (Eds.), *Fresh Water Fish Diversity of Central India*, pp. 99–104. NBFGR, Lucknow U.P.

Joshi, K.D. and Mahanta, P.C., 2009. Asela snowtrout, *Schizothoraxrichardsonii* (Gray): its natural history and domestic attributes. Fishing Chimes. 28(10 and11), 90–93.

Joshi, K.D., Biswas, B.K., Lal, S., Vass, K.K., 2009. Piscine diversity in the river Betwa. Journal Inland Fish. Soc. 41(1), 61–64.

Karmakar, A.K. and Dutta, A.K., 1988. On a collection of fishes from Bastar district, Madhya Pradesh. Rec. Zool. Survey, India. Occ. Paper No. 98.

Karmchandani, S.J., Desai, V. R., Pisolkar, M. D. and Bhatnagar, G.K., 1967. Biological investigations on the fish and fisheries of Narmada river (1958–1966). Bull. Cent. Inland Fish. Res. Inst., Barrackpore 10, 1–39.

Lakra, W.S, Sarkar, U.K., Kumar, R.S., Pandey, A., Dubey, V.K. and Gusain, O.P., 2010. Fish diversity, habitat ecology and their conservation and management issues of a tropical River in Ganga basin. India. Environmentalist 30, 306–319.

Lakra, W.S., Sarkar, U.K., Dubey, V.K, Sani, R. and Pandey, A., 2011. River interlinking in India: status, issues, prospects and implications on aquatic ecosystems and freshwater fish diversity. Rev Fish Biol Fish. DOI:10.1007/s11160-011-9199-5.

Mahanta, P.C.; Usha, M., Joshi, K.D., 2011. Coldwater fisheries and culture. In: *Handbook of Fisheries and Aquaculture*, pp. 302–325. I.C.A.R Publication, New Delhi.

Misra, AK, Saxena, A, Yaduvanshi, M, Mishra, A., Bhadauriya, Y. and Thakur, A., 2007. Proposed river linking project of India: a boon to nature. Environ Geol. 51, 1361–1376.

Motwani, M.P. and David, A., 1957. Fishes of the river Sone with observations of the Zoogeographical significance. J. Zool. Soc. India. 9(1), 1–7.

NCIWRDP, 1999. Integrated water resource development: A plan for action, National Commission on Integrated Water Resource Development Plan, MOWR. New Delhi.

National Water Development Agency (NWDA), 1982. http:// www.ndwda.gov.in

Needham, J. G. and Needham, P. R., 1962. *A Guide to the Study of Freshwater Biology. 5th Edition*. Holden-Day, Inc., San Francisco.

Postel, S., and Richter, B. D., 2003. *Rivers for life: managing water for people and nature*. Island Press, Washington, D.C.

Presscott, G.W., 1962. *Algae of the Western Great Lake Area*. Brown Comp Pub, Dubuque, Lowa.

Sarkar, U.K., Lakra, W.S., Dubey, V.K., Pandey, A., Tripathi, M., Sani, R. and Awasthi, A., 2013. Freshwater Fish Diversity in the River Ken of Ganga Basin: Abundance, Threats and Their Management. Proc. Natl. Acad. Sci.. India, Sect. B. Biol. Sci. 1007/s 40011-013-0266-7.

Saxena, R. and Srivastava, P., 1989. A check list of fish fauna of Kunwari river (tributary of Chambal river), North M.P.J. Inland Fish. Soc. 21(2), 41–44.

Shannon, C.E, Wiener, W., 1963. *The mathematical theory of communication*. University of Illinois Press, Urbana.

Srivastava, C.B., Ravish, Chandra and Wishard, S.K., 1970. On a collection of fish from river Ken in Banda district (U.P.). Rec. Zool. Surv. India. 64(1-4), 131–134.

Talwar, P.K. and Jgingran, A.G., 1991. *Inland Fishes of India and adjacent countries (Vol. 1 and 2)*. Oxford & IBH Publishing Co. Pvt Ltd., New Delhi.

Ward, H.B. and Whipple, G.C., 1992. *Freshwater biology*. McGraw Hills and Co., New York.

Welcomme, R., and Halls, A., 2003. Dependence of tropical river fisheries on flow. In: R.L. Welcomme, T. Petr (Eds.), Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries.Vol. 2, pp. 267–284. FAO Regional Office for Asia and the Pacific, Bangkok. RAP Publication 2004/17.