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RESEARCH ARTICLE

Freshwater Fish Diversity in the River Ken of Ganga Basin: Abundance, Threats and Their Management

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Abstract Systematic surveys were conducted to explore the diversity of freshwater fishes, distribution, abundance, trophic ecology and current threats of the fishes at different spatial scale of the river Ken, planned for interlinking in India. Altogether, 57 species representing 42 genera and 20 families were recorded for the first time from the studied river. Of the 57 species, seven belong to the 'endangered' category and 13 belong to the vulnerable category. Apart from Indian major carps, *Tor tor*, *Bagarius bagarius*, *Chitala chitala*, *Pangasius pangasius*, *Sperata aor*, *Wallago attu*, *Ompok pabda*, *Ompok bimaculatus*, *Labeo calbasu*, *Channa marulius*, and *Macrognathus pancalus* were the other important species. All the species have been reported for the first time in this river. Presence of a protected area and forest cover on the upper stretches of the river tends to have positive effect on the aquatic habitat which is reflected in high fish diversity as compared to lower stretches which is subjected to several anthropogenic activities. The distribution pattern, community dominance index, evenness index, similarity index and trophic ecology have been discussed. Some segment of the river showed the most diversified environmental structure and had the different fish communities. The results of this study would be useful to develop baseline information for a river, planned for river interlinking which enables predictions on the change/loss of the fish diversity in the post interlinking phases.

Keywords Diversity pattern · Abundance · Fish community · Habitat · Ken river · India

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Introduction

Worldwide, freshwater fishes are the most diverse of all vertebrate groups. They are also the most highly threatened taxa [1]. The main cause of this state is the loss and degradation of habitat. Many countries are now effectively controlling water pollution, but improvement in aquatic communities are being restricted by habitat deficiencies in river channels and floodplains [2]. River Ken is one of the important tributary of river Yamuna which has been identified for India's first interlinking project with river Betwa [3]. The interlinking projects of Ken–Betwa link involve building a dam on Ken river and diverting the water to Betwa crossing several rivers/streams. A review of literature shows that there has been no systematic study on the pattern of fish species diversity, abundance, distribution, and fish habitat aspects at different spatial scales of the river, which is urgently required for developing appropriate biodiversity management plans.

To contribute to the development of basic knowledge, studies of taxonomic diversity or species richness (the maximum number of taxa) should be supplemented, as far as possible, by studies of ecological diversity, i.e., variety of biological communities in a given area, to recapitulate the strategies developed by organisms in adaptation to the environmental conditions, and to look for species distribution patterns [4]. Also, lack of definite information on the various

threats faced by the fishes of the river system has hampered the planning and implementation of appropriate conservation and management strategies. Therefore, the present studies were initiated to assess the existing (pre-interlinking) fish biodiversity scenario. Several studies have proved that changes in environmental conditions are reflected in corresponding alterations of aquatic community structure and ecosystem functioning [5, 6]. Thus, the aim of the present study was to develop baseline data on the fish diversity, pattern of abundance and distribution with regard to habitat, trophic ecology and threats in view of proposed river interlinking.

Study Area

The river Ken has its origin from the Ahirgawan village on the northwest slopes of the Kaimur hills in the Jabalpur district of Madhya Pradesh at an elevation of about 550 m above mean sea level. It is an interstate river between Uttar Pradesh and Madhya Pradesh that flows with a discharge rate of 11,300 million m^3. The total length of the river from its origin to confluence with the river Yamuna is 427 km, out of which 292 km lies in Madhya Pradesh, 84 km in Uttar Pradesh and 51 km forms the common boundary between Uttar Pradesh and Madhya Pradesh. The river joins the Yamuna river near village Chilla in Uttar Pradesh at an elevation of about 95 m. The river is the last tributary of Yamuna before the Yamuna joins the Ganga (Fig. 1). The river basin lies between the latitudes of 23°12′ N and 25°54′ N and the longitudes of 78°30′ E and 80°36′ E. The total catchment area of the basin is 28,058 km^2, out of which 24,472 km^2 lies in Madhya Pradesh and the remaining 3,586 km^2 in Uttar Pradesh.

Material and Methods

Selection of Sampling Sites

Based on the similarity of the physical habitat and distance coverage, five study sites (~90 km from each) were selected covering 460 km of the river Ken from both the states of Uttar Pradesh and Madhya Pradesh. These are: Amanganj (K1), Patan (K2), Mandala (K3), Banda (K4), Chilla (K5). The details of sampling sites are shown in Table 1. The study was carried out on a seasonal basis covering pre-monsoon, monsoon and post-monsoon periods during 24 months study (2007–2009).

Sampling of Fishes

Fish sampling locations were documented using global positioning system. Fishes were collected using cast net, gill net, and other indigenous nets with the help of expertise of local fishermen who carried out experimental fishing. Different types of gear including cast nets, gill nets, scoop nets, drag nets (all with varying mesh sizes), traps and other local contrivances were used for collecting the fishes allowing us to of different range of sizes and to minimize the bias due to specific gears. At each site/subsite, four gill nets were deployed overnight. The cast nets (5.5 m^2) were cast 30 times at each reach (site) covering about 100 m^2 of river segment allowing 3–5 min settling time at each cast. Fish sampling was done in channel and near shoreline as per Bain and Knight [7]. The catch per unit effort (CPUE) of the gill net was calculated for each sampling sites following Biswas [8]. Representative specimens of all fish species were fixed in 10 % formaldehyde, transferred to the laboratory and stored in glass bottles. They were also subsequently identified following taxonomic keys [9, 10]. Fish markets and landing centers associated with the river system were also visited to monitor and look for the presence of any species, which were not available during the experimental fishing. Data regarding threats faced by the fish fauna were obtained from both primary (direct observations and interactions with local stakeholders and fishermen) and secondary sources. The conservation status of fish was adapted from published sources [11].

Analysis of Biological Indices

(a) Community Dominance Index (CDI) of McNaughton, Goulding et al. [12]

$$CD1 = \frac{Y1 + Y2}{Y} \times 100$$

where, Y1 + Y2 = Abundance of two dominant species; Y = Total species abundance

(b) Relative Abundance (RA)

$$RA = \frac{N}{S}$$

where, N = Total number of individuals of species; S = Total number of fishes

(c) Diversity Index (Shannon and Weiner Index) (H)

$$H = -\Sigma pi \ln pi$$

where, $Pi = \frac{Ni}{N}$(Ni = Total number of individuals of species i); N = Total No. of individuals of all species

(d) Species Richness (Margalef Index) (d)

$$d = \frac{S - 1}{In\, N}$$

where, S = Total No. of species; N = Total No. of individuals of all species

(e) Evenness (Pielou Index) (E)

$$E = \frac{H}{In\, S}$$

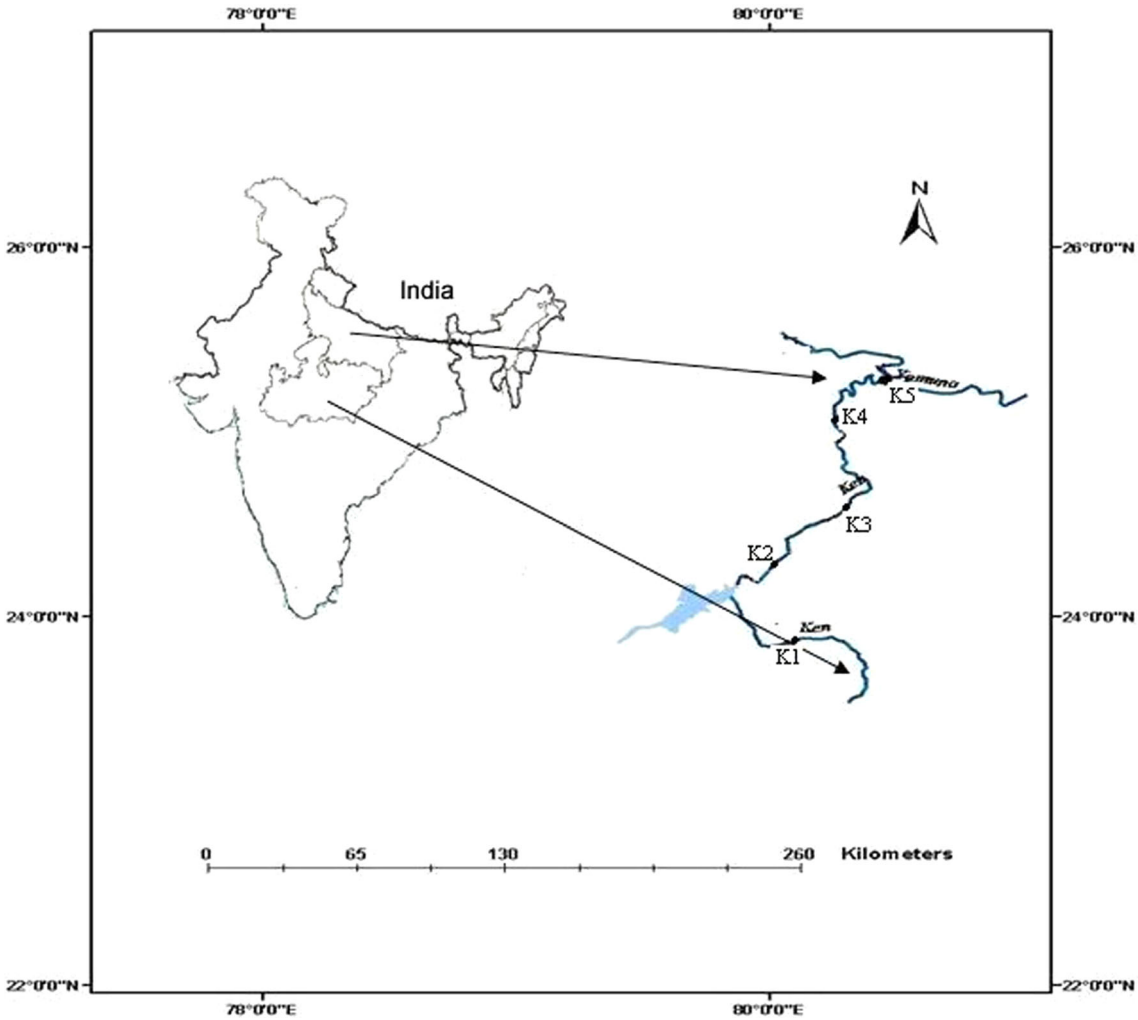

Fig. 1 Map of the study area showing sampling sites, River Ken, India

where, H = Diversity index; S = Total number of species

Trophic Structure and Score

Based on the feeding habitat, fishes were classified into various trophic groups [13, 14]. The gut contents of fishes were analyzed and four types of trophic level of fishes were considered (planktivorous, PL; benthic feeder, BE; omnivorous, OM; carnivorous, CA) and recorded. The trophic level score [15] indicated the relative frequency of the fish using a particular trophic level among all the trophic levels available in that aquatic system.

Results and Discussion

Fish Diversity and Species Composition

In the present study, a total of 57 species representing 42 genera and 20 families (Table 2) were recorded from the five sampling sites in river Ken. Similar studies have been carried out by Bhat [16], Sarkar et al. [17], Srivastava [18], Sarkar et al. [19, 20] and Lakra et al. [21]. Five families were common to all sites; Cyprinidae, Bagridae, Siluridae, Mastacembelidae and Schilbeidae. However, 11 families were recorded from upstream and downstream (K1, K4 and K5). While, the middle stretch of the river (K2 and K3) had highest number of families, species and genera (Figs. 2, 3).

As in other areas of the world Australia, Madagascar, New Zealand and South America [22], Cyprinids are found to be the most dominant group (16 genera and 26 species) with a wide distribution. Similarly, studies on several Indian rivers showed that fish communities are dominated by Cyprinidae [19, 23]. The commercial value of the fish biodiversity analyzed herewith includes 49, 21 and 6 species with potential to food supply, aquarium trade and sport fishing respectively (Table 2).

Assessment of the threat status of 57 fish species showed that 7 fish species are endangered (EN), 13 are vulnerable and 20 at lower risk. The data on 6 species were not

Table 1 Details of the sampling sites in river Ken

Sampling sites	Stream type	Position	Altitude (ft)	Land use pattern
Amanganj (K1)	Upstream	N 24°19.998′ E 080°04.778′	985	Agricultural activities, Gangau Dam, proposed Daudhan dam
Patan (K2)	Upstream (proposed interlinking site)	N 24°41.401′ E 079°54.947′	607	Buffer zone (PA), agriculture activities, Forest
Mandla (K3)	Midstream	N 24°44.272′ E 080°00.633′	638	Buffer zone (PA), Bariyarpur weir, agricultural activities
Banda (K4)	Downstream	N 25°28.586′ E 080°20.095′	722	Discharge of sewage
Chilla (K5)	Downstream (confluence point)	N 25°46.158′ E 080°31.593′	240	Agricultural activities

PA protected area (National park)

available to categorize their threat status. Sarkar et al. [17] reported presence of 5 endangered and 11 vulnerable species in Gomti river.

Community Dominance Index (CDI) and Relative abundance (RA)

The CDI showed marked differences between the sampling sites (Table 3). The authors found that as many as 24 species had an abundance of around 100 individuals out of the total 12,204. Cyprinids such as *Salmostoma bacaila* (21.2 %) and *Puntius ticto* (15.1 %,) recorded in highest abundance. Overall, the relative abundance of three Indian major carps, namely *Catla catla* (0.2 %), *Labeo rohita* (1.2 %) and *Cirrhinus mrigala* (1.7 %) was relatively poor. Among the threatened species like *Rita rita* (a bagrid) *Eutropiichthys vacha* (a Schilbeid) *Ompok bimaculatus* (a silurid), *Notopterus notopterus* (a Notoptrid) and *Channa marulius* (a channid) were recorded in good abundance which indicates the stability of their population in spite of natural and anthropogenic threats in the river. This might be due to factors like entry of fishes into river due to inundation and low fishing efforts due to high water depth in post-monsoon months [17, 19]. Beside this, some of the rare species like *Tor tor*, *Chitala chitala* and *O. pabda* which have been subjected to a rapid decline in their population and have been listed as endangered were found to be poor in abundance. This may be due to the interference of several anthropogenic activities such as poaching and physical barriers like dams and weirs which were constructed during 1905–1915. The blockage prevents these migratory fishes from having access to portions of their native ranges upstream of the dam for spawning, thus resulting in genetic isolation thus declining in population [21]. The midstream of the river has shown higher relative abundance value for the threatened fish species, suggesting the need of proper conservation and management.

Though most of the study sites were located in undisturbed areas, some of the introduced exotic species were found with low to moderate abundance (e.g. *Cyprinus carpio*, *Oreochromis mossambica*). The presence of these species in the middle stretch is invasive to native fish fauna of that area. It may also cause difficulty to manage other species of conservation importance and may become more challenging due to the interaction during the processes of interlinking and climatic changes [17, 19, 21, 24, 25].

Distribution pattern

The present results on the distribution pattern of migratory species, suggests that there is a measurable effect of dams and weirs located up to the middle stretch of the river. The distribution of certain migratory species like *T. tor*, *C. chitala*, *O. bimaculatus*, *Pangasius pangasius* were restricted to sites K2, K3 and K4 located in the downstream of Gangau dam and Bariyarpur weir. The presence of some migratory fishes (*Bagarius bagarius*, *O. pabda*, *Walago attu*, *Sperata aor)* in the upstream, could be due to their capability of swimming and passing over the dam during high flow conditions. This restricted movement may lead to isolation of other fish populations upstream from the dam. It will further result in decreased intraspecific genetic diversity or local extirpation of migratory species. The dissimilarity in the fish assemblage between upstream and downstream of the dam was also described by Anderson [26] and Lakra et al. [21]. Only 4 species (*P. sarana*, *S. bacaila*, *R. rita* and *Mastacembalus armatus*) were recorded from all the sampling sites. Some Cyprinds like *L. fimbriatus*, *Securicula gora* and *Crossocheilus latius latius* were distributed in the middle stretches, whereas *Barilius bendelisis*, *Raiamas bola*, *Chagunius chagunio* and some non-cyprinids such as *Gudusia chapra*, *P. pangasius*, *Johnius coiter* and *Rhinomugil corsula* were distributed in the lower stretches of the river and were less abundant in these areas.

Table 2 Diversity, number of individuals and RA (%) of the fish sampled at different sampling sites (K1–K5) in River Ken

Family/species	Status	K1	K2	K3	K4	K5
Cyprinidae						
C. reba[a]	VU	0	36(1.0)	0	26(3.7)	102(2.3)
C. mrigala[a]	LRnt	75(4.4)	29(0.80)	0	0	72(1.6)
C. catla[a]	VU	0	0	36(2.0)	0	0
C. carpio[a]	NE	0	0	14(0.8)	0	0
Garra gotyla[b]	VU	0	44(1.22)	19(1.0)	0	0
L. bata[a]	LRnt	0	24(0.67)	46(2.5)	1(0.1)	27(0.6)
L. boggut[a]	LRnt	61(3.6)	106(2.9)	0	0	0()
L. calbasu[a]	LRnt	98(5.7)	41(1.1)	40(2.2)	0	69(1.6)
L. dyochilus[a]	VU	7(0.4)	29(0.8)	35(1.9)	0	0
L. gonius[a]	LRnt	45(2.6)	145(4.0)	0	15(2.2)	0
L. rohita[a]	LR-lc	38(2.2)	97(2.6)	45(2.5)	0	74(1.7)
L. fimbriatus[a]	LRnt	0	40(1.1)	0	0	0
Osteobrama cotio cotio[ab]	LRnt	0	257(7.1)	0	0	146(3.3)
P. chola[b]	VU	0	0	0	0	10(0.2)
P. sarana[ab]	VU	60(3.5)	75(2.0)	178(9.7)	39(5.6)	42(0.9)
P. ticto[ab]	LRnt	0	496(13.7)	236(12.9)	53(7.6)	768(17.3)
P. sophore[ab]	LRnt	214(12.5)	115(3.1)	0	60(8.6)	14(0.3)
Rasbora daniconius[b]	LR-lc	0	0	97(5.3)	0	324(7.3)
S. bacaila[a]	DD	425(24.9)	959(26.5)	39(2.1)	66(9.5)	1,102(24.8)
T. tor[ac]	EN	0	65(1.8)	45(2.5)	0	0
C. chagunio[a]	LR-lc	0	0	0	16(2.3)	74(1.7)
R. bola[ab]	VU	0	0	0	0	8(0.2)
C. latius latius[ab]	DD	0	7(0.1)	0	0	0
Amblypharyngodon mola[ab]	DD	68(4.0)	0	0	0	24(0.5)
B. bendelisis[b]	NE	0	0	0	4(0.6)	0
Danio davario[ab]	LRnt	36(2.1)	0	0	0	0
Bagridae						
Mystus tengara[a]	NE	0	51(1.41)	27(1.5)	0	65(1.5)
Mystus cavasius[ab]	LRnt	36(2.1)	0	0	46(6.6)	0
Mystus vittatus[ab]	VU	0	0	56(3.1)	0	0
R. rita[a]	EN	145(8.5)	85(2.3)	102(5.6)	10(1.4)	219(4.9)
Aorichthys aor[ac]	LRnt	74(4.3)	40(1.1)	26(1.4)	0	56(1.3)
Aorichthys seenghala[ac]	LRnt	0	69(1.9)	47(2.6)	11(1.6)	50(1.1)
Siluridae						
W. attu[ac]	LRnt	32(1.9)	37(1.03)	34(1.9)	36(5.2)	52(1.2)
O. pabda[a]	EN	26(1.5)	12(0.3)	13(0.7)	0	56(1.3)
O. bimaculatus[a]	EN	0	34(0.94)	49(2.7)	0	109(2.5)
Notopteridae						
N. notopterus[ab]	EN	24(1.4)	58(1.61)	39(2.1)	0	78(1.8)
C. chitala[ab]	EN	0	5(0.1)	16(0.9)	0	0
Nandidae						
Nandus nandus[a]	LRnt	34(2.0)	27(0.7)	41(2.2)	25(3.6)	0
Sisoridae						
B. bagarius[a]	VU	41(2.4)	28(0.7)	0	0	0
Glyptothorax brevipinnis[b]	DD	0	1(0.03)	0	0	0
Mastacembelidae						
Macrognathus pancalus[a]	LRnt	0	40(1.1)	23(1.3)	0	0

Table 2 continued

Family/species	Status	K1	K2	K3	K4	K5
M. armatus[a]	VU	54(3.2)	50(1.3)	30(1.6)	22(3.2)	121(2.7)
Schilbeidae						
E. vacha[a]	EN	26(1.5)	52(1.4)	34(1.9)	0	312(7.0)
Clupisoma garua[ac]	VU	14(0.8)	0	0	45(6.5)	80(1.8)
Channidae						
C. marulius[a]	VU	0	49(1.36)	30(1.6)	0	90(2.0)
C. striatus[a]	LRnt	23(1.3)	0	0	0	0
Ambassidae						
Chanda nama[ab]	LR-lc	38(2.2)	181(5.0)	108(5.9)	45(6.5)	0
Heteropneustidae						
Heteropneeustes fossilis[a]	VU	0	9(0.25)	13(0.7)	0	0
Belonidae						
Xenentodon cancilla[ab]	LRnt	0	112(3.1)	139(7.6)	69(9.9)	74(1.7)
Balitoridae						
Nemachilus botia[ab]	LRnt	0	0	36(2.0)	0	0
Cichilidaae						
O. mossambica[a]	LRnt	0	0	4(0.2)	0	0
Gobiidae						
Glossogobius giuris[a]	LRnt	0	0	66(3.6)	56(8.1)	0
Clupeidae						
G. chapra[a]	LR-lc	0	0	0	45(6.5)	104(2.3)
Pangasiidae						
P. pangasius[ac]	LRnt	0	0	0	4(0.6)	0
Sciaenidae						
J. coiter[ab]	DD	0	0	0	0	69(1.6)
Mugilidae						
R. corsula[a]	VU	0	0	0	0	54(1.2)
Cobitidae						
Lepidocephalus guntea[ab]	LR-lc	12(0.7)	26(0.72)	65(3.6)	0	0
Total individuals		1,706	3,531	1,828	694	4,445
F value		1.416*	17.538	12.090	1.606*	26.885

EN endangered, *VU* vulnerable, *DD* data deficient, *LRnt* lower risk near threatened, *Lrlc* low risk least concern

* Results of ANOVA showing variation among sites ($p < 0.05$)

[a] Food fish

[b] Ornamental fish

[c] Sport fish

Diversity Index

The Shannon–Weaver diversity indices (Table 3) of the fishes showed not much variation across different sites except K3. The high species diversity is attributed to presence of intact ecological set up except low alterations in K1 and K4. The higher diversity index shows the existence of a balance between total species and total individual of every species. However, a region which has higher species richness does not necessarily show a higher index of diversity. It will depend on the total individuals of each species, on the evenness, in other words whether that community was dominated by one or two species [27]. For instance, site K2 had a higher species richness as compared to other locations. However, the diversity index was slightly lower as compared to other sites. Locally, the species richness and the diversity index at site K3 were higher than other sites. This site is located nearby the National Park and protected by national regulation and thus its biodiversity richness is well protected as commercial fishing is prohibited in this area. Moreover, these sites (K2 and K3) were also seen to support large group of

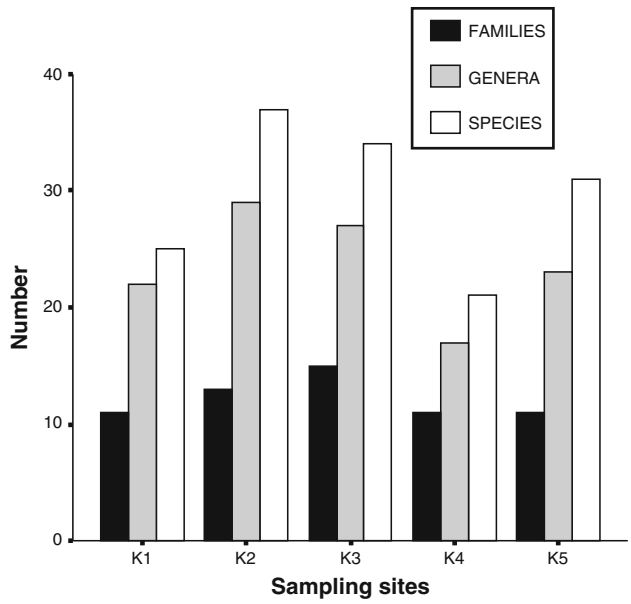

Fig. 2 Distribution of families, genera and species according to sampling sites

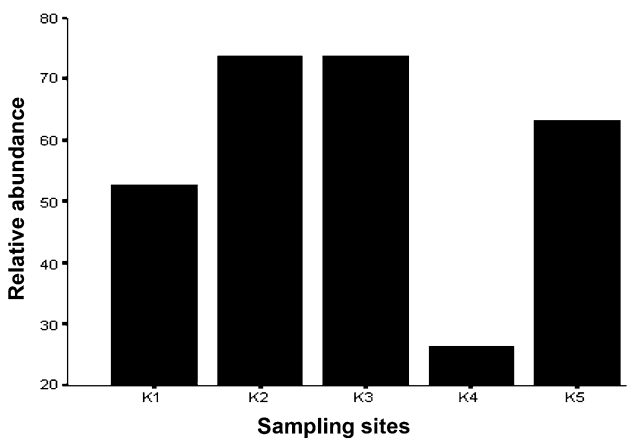

Fig. 3 RA (%) of threatened species at different sampling sites

macrophytes and good amount of riparian cover that might have importance in fish assemblage and aggregation [20, 21, 28, 29]. Low species richness at site K1 may be correlated with low water depth and water scarcity due to low rainfall. Polluted river water, high fishing intensity and catch of all life stages were noticed in K4 which could be the reason for low species richness. Similar observations were reported in other studies of the Ganges basin [17, 19, 21] Overall, the diversity indices indicate a good correlation with species richness across the sites and could be utilized by the biodiversity conservation managers for prioritization of sites for conservation and habitat restoration.

Evenness and Similarity indices

The evenness index varied from 0.76 to 0.98, the highest evenness index was found at site K3, while the lowest at K5 (Table 3). The higher evenness index of site K3 was slightly higher than other sites indicating the frequencies of dominant species present at this site. The data showed that *P. ticto* and *S. bacaila* were the dominant species at this site.

The similarity index between pair wise comparisons of sites were analyzed by using cluster analysis. The similarity in species composition in five sites is shown as a dendrogram (Fig. 4). Maximum similarity was observed between sites K2 and K3. The similarity in species composition among these sites can be related to the similarity in their altitudinal ranges and land use pattern. Some other studies [21, 28, 29] with regards to species composition pattern at the regional scale indicate the similarity of species composition in the same altitudinal regimes than regions in different altitudinal regimes that support the importance of habitat in shaping fish community structure. However, the present results between K2 and K5 do not follow the same trend, which might be due to the presence of reservoir near both the sites.

Catch per Unit Effort (CPUE)

In river Ken, gill nets and drag nets of various sizes dominated among the fishing gears. The mean CPUE (Fig. 5) at different sampling sites ranged from 0.6 to 1.6 kg indicating higher fishing intensity at the sites K5 and K3 which might be due to the presence of more deep habitat, rural and semi urban land use pattern and low to moderate water velocity etc. A study reported higher CPUE in the river Brahmaputra during winter and premonsoon months [30].

Table 3 Indices of diversity, evenness, species richness and CDI of fish community in River Ken

Sampling sites	Tot. sp.	Tot. ind.	Species richness (d)	Pilou's evenness (J')	Diversity (H')	CDI	Dominant species
K1	25	1,706	3.22	0.84	2.74	37.45	*P. sophore*, *S. bacaila*
K2	37	3,531	4.44	0.78	2.85	41.2	*P. ticto*, *S. bacaila*
K3	34	1,828	4.39	0.98	3.18	22.64	*P. sarana*, *P. ticto*
K4	21	694	3.05	0.91	2.82	19.45	*S. bacaila*, *Xenentodon cancilla*
K5	31	4,445	3.57	0.76	2.72	42.06	*P. ticto*, *S. bacaila*

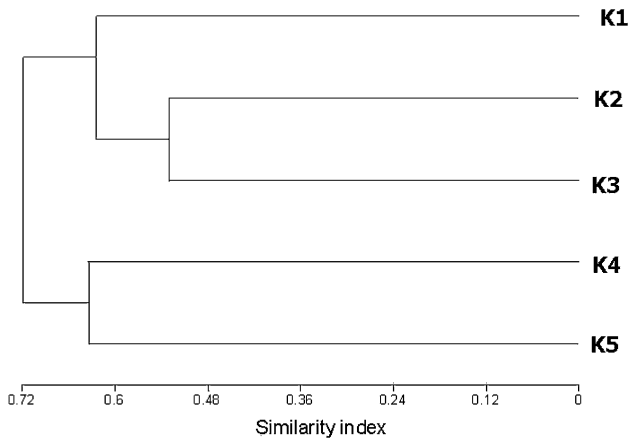

Fig. 4 Bray curtis similarity plot of freshwater fish in river Ken according to sampling sites (K1–K5)

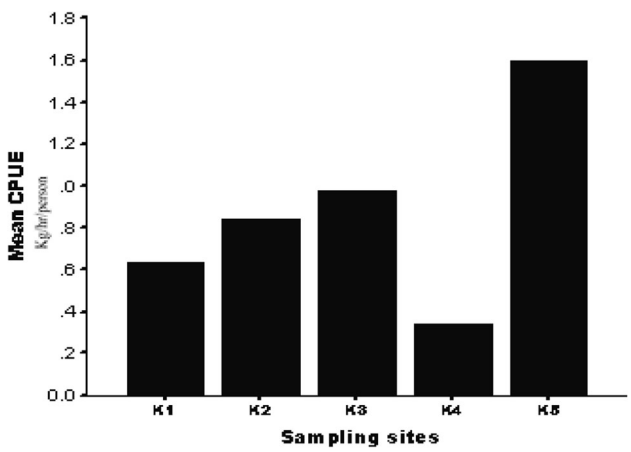

Fig. 5 Annual CPUE (kg/h) of different sites of Ken river

Trophic Structure and Score

The analysis of trophic niches of the available fish species indicated dominancy of CA (19 species) followed by omnivores (17 species) and BEs (9 species) as shown in Fig. 6. The higher composition of carnivore species indicates the presence of less ecosystem stress in the river Ken. As the degradation intensifies, species at the top of the trophic structure, i.e., the carnivores, would disappear first, followed in sequence by benthic insectivorous, general insectivorous, PL and OM forms [31]. However, the downstream reaches, especially at site K4 was expected to be the cause of concern due to habitat degradation and pollution [32]. The trophic level scores to find out the frequency of the fish using the particular trophic level among all the trophic levels available in different sampling sites were calculated. The mean trophic level score was recorded higher at K4 (35.58) and lower at K2 (26.74) as shown in Fig. 7. This indicates that the fishes at site K4 were likely responding to ecosystem stress, resulting in low

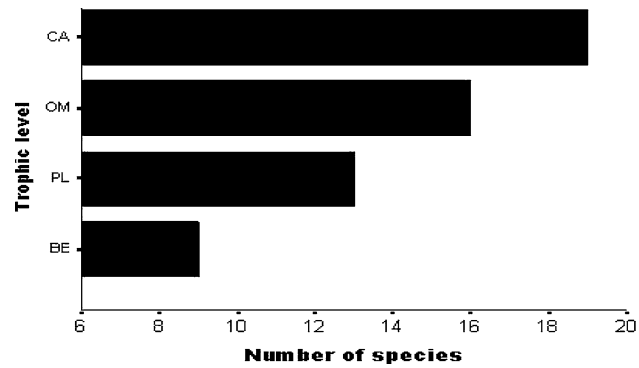

Fig. 6 Number of species at different trophic level. *PL* planktivore, *BE* benthic feeder, *OM* omnivore, *CA* carnivore

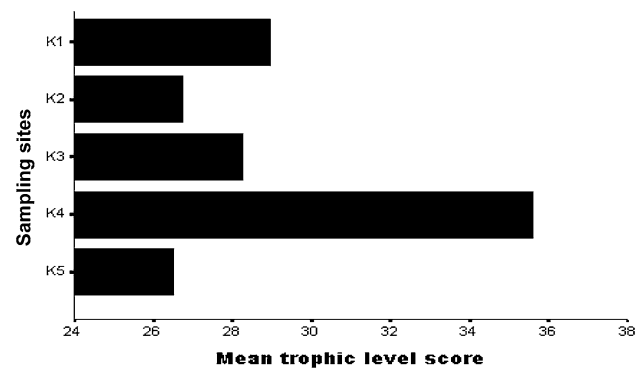

Fig. 7 Comparison of the mean trophic level score at different sampling

species richness and low abundance of threatened species as compared to other sites [32].

Conclusion

The results presented herein provided for the first time a systematic assessment of freshwater fish diversity of river Ken which supports an exceedingly rich species spectrum of threatened, migratory and commercially important fishes. The presence of higher percentage of carnivore species indicates a relatively healthy, trophically diverse fish community. Destructive fishing methods, siltation and dams are depleting the fish fauna of the river to a large extent. This study allows consideration of a long-term conservation strategy for icthyofauna in river Ken. Since this river will be interlinked with Betwa river in near future, the study may be beneficial for further assessment of biodiversity. The presence of 7 endangered and 13 vulnerable species of regional conservation concern in the river. They make it a high priority area for implementing appropriate conservation and management measures.

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