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Fish diversity and assemblage structure in Ken River of Panna landscape, central India

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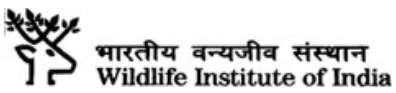

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Abstract: Fish diversity and assemblage structure in relation to habitat variables were studied in 15 sites in Panna landscape, central India. The sampling was performed between February–April 2009. Fifty species of fishes belonging to 32 genera, 15 families and four orders were recorded from the study area. Cyprinids were the dominant assemblage members in all study streams (abundance ranges from 56.6–94.5 %). The cyprinid *Devario aequipinnatus* and the snakehead *Channa gachua* had highest local dominance (80% each) in Panna landscape. High Shannon and Margalef's diversity was recorded in Madla region of Ken River. Similarity cluster analysis explained the study sites along Ken River (Gahrighat, Magradabri and Madla) had similar faunal assemblage. Canonical Correspondence Analysis (CCA) was performed to study the species association with a set of environmental variables. The CCA revealed that cyprinid abundance was associated with stream order, deeper habitat, flow and water temperature.

Keywords: Assemblage structure, central India, environmental variables, fish diversity, Ken River, Panna landscape.

INTRODUCTION

Freshwater ecosystem and their resources are an indispensable part of human life and activity, and health of those freshwater ecosystems is visible in the wellbeing of the fish assemblage they support. In lotic environment, the diversity, community structure and species assemblages are influenced by various biotic and abiotic variables (Minns 1989). Water in these habitats may look homogeneous but they are separated by various environmental factors such as temperature, depth, current and substrates into a great variety of habitats (Kottelat & Whitten 1997). Each habitat has its unique fauna which is adapted to the various abiotic features of that habitat. Identification of such abiotic gradients that result in structuring of fish assemblages is one of the main challenges for a fish ecologist. The species richness of a stream within a river basin may be influenced by local conditions and stream order along a watershed (Grenouillet et al. 2004). Williams et al. (2003) reported that the historical formation of a river basin determines the structure of the fish community. The Panna landscape in north-central Madhya Pradesh is one of the historical landscapes, located on the Vindhyan Range within the Biogeographic Province 6A Deccan Peninsula - Central Highlands (Rodgers et al. 2002). A number of perennial and seasonal streams originate from this landscape and drain into the Ken River. According to Satpura hypothesis (Hora 1950), the catchment areas of the Ken River basin (Vindhyan Hills) in central India play a key role in the migratory route of several Western

Ghats fishes. The catchment area of this river basin is characterized by extensive seasonal and annual fluctuations of environmental variables.

Variation in habitat variables such as flow, depth, substrate and water quality may have a significant impact on both assemblage structure and resource availability. The influence of habitat structure and complexity on fish assemblage structure has been tested mostly in North American streams (Gorman & Karr 1978; Schlosser 1982, 1985; Capone & Kushlan 1991) and Australian streams (Bishop & Forber 1991; Pusey et al. 1993). In India, few studies have been initiated to document the fish diversity and assemblage structure along the environmental gradients (Johnson 1999; Arunachalam 2000; Bhat 2003; 2004; Sreekantha et al. 2007; Shahnawaz et al. 2010). Basic information is also available on fishes of Ramsagar reservoir and fish assemblages of Betwa River, Khan and Khashipra rivers of Madya Pradesh (Ganasan & Hughes 1998; Garg et al. 2007; Lakra et al. 2010). However, studies on fish diversity and assemblage structure are still rudimentary in central and northern India. Therefore, the present study is an attempt to document the fish assemblage structure in relation to environmental variables of the Ken River of Panna landscape in central Indian highland.

Image 1. View of Ken River at Gharighat, Panna National Park, Madhya Pradesh.

MATERIAL AND METHODS

Study area

Ken is one the major rivers of Bundelkhand region of central India, and flows through the Panna National Park in Madhya Pradesh (Image 1). It is one of the sub-basins of the Yamuna, and the important tributaries of this river are Sonar, Bearma, Bewas, Kopra, Urmil and others. Among these, the Sonar is the largest tributary that rises in the Vindhyan Hills in the southwest of Sagar District and flows through its valley in Damoh District and it travels a distance of 427km and joins the Yamuna at Chilla Village, near Fatehpur in Uttar Pradesh (Jain et al. 2007). It cuts through the landscape from south to north and forms the famous Ranneh Falls, which is located in the Crocodile Park (Ken Ghariyal Sanctuary) of Panna National Park. This river is known as an angler's paradise, because the king of freshwater fish Mahseer *Tor tor* is found in abundance. The vegetation type in Panna landscape is characteristic of tropical dry deciduous element. In terms of biome characteristics, it is classified as 'high-rainfall dry deciduous forest' and is largely dependent on monsoon rainfall during July–September, which usually fluctuates within the range of 600–1100 mm (Jayapal et al. 2007). Following the monsoon, there is a cool season until February, followed by dry summer when the temperature often exceeds 45^{0}C (Karanth et al. 2004). Water is a limiting factor during this season, even though, some stretches of streams inside the park hold some water as isolated pools. But the main channel of Ken River retains natural deep pools, rapids and cascades with heterogeneous riparian cover during summer, which probably provides shelter for fish when most of the other streams dry up. A total of 15 sites on streams/ rivers of the Ken River basin within Panna National Park were selected for the present study (Fig. 1) and the summary of site description is given in Table 1. The sampling was undertaken between February–April 2009, since during this period most of the streams inside the park retain minimum surface flow.

Data collection

Fish sampling was performed in different habitats such as pools, riffles, runs and cascades in 100m reach of all study sites, using monofilament gill nets of different mesh sizes (10–34 mm), drag, scoop and cast net. Fish sampling protocol followed the method of Johnson & Arunachalam (2009). After collection, fish were examined, counted and released back into the system. A few specimens of unidentified species were

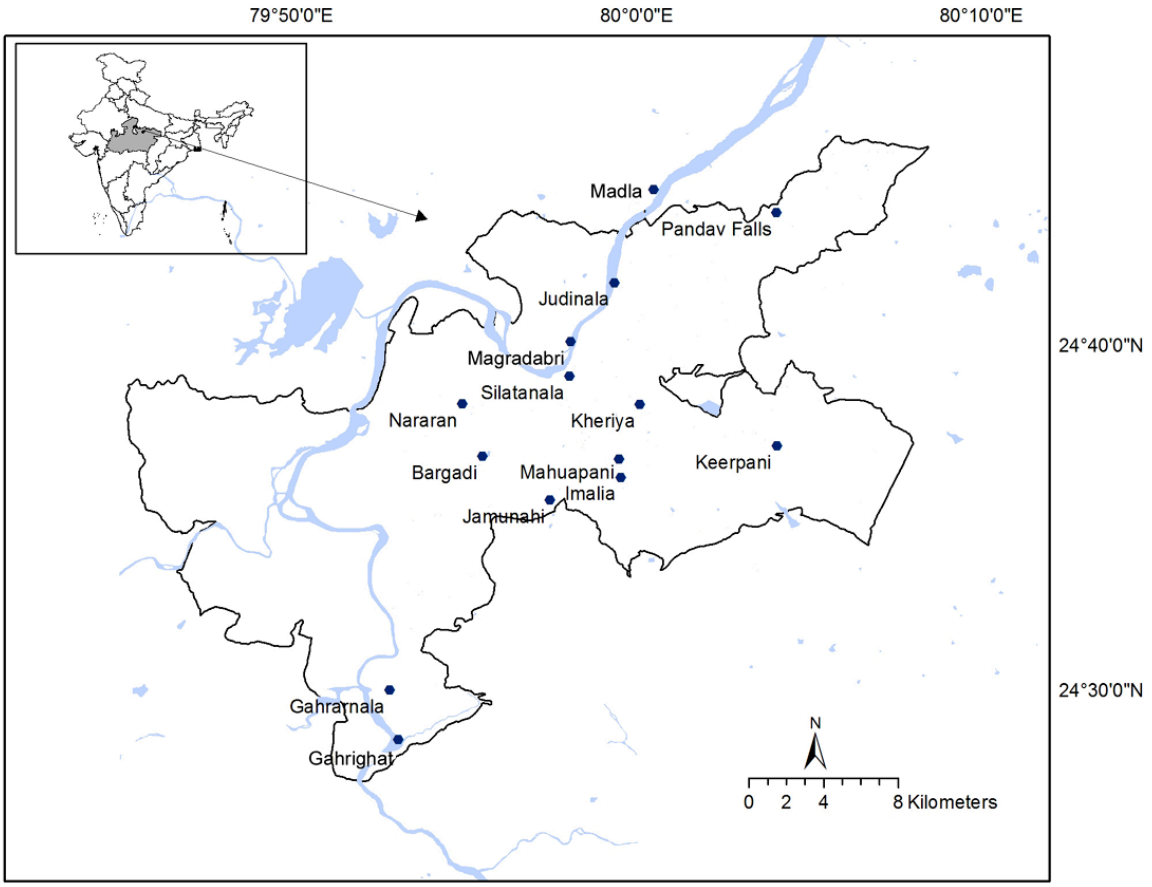

Figure 1. Sampling sites in Panna landscape, Madhya Pradesh.

Table 1. Summary of study sites in Ken River basin of Panna landscape, Madhya Pradesh.

Site code	Sites	GPS coordinates
1	Gahrighat	24.47556^{0}N & 79.88477^{0}E
2	Gahrarnala	24.49955^{0}N & 79.88060^{0}E
3	Jamunahi	24.59151^{0}N & 79.95807^{0}E
4	Imalia	24.60248^{0}N & 79.99216^{0}E
5	Bargadi	24.61274^{0}N & 79.92532^{0}E
6	Mahuapani	24.61131^{0}N & 79.99154^{0}E
7	Keerpani	24.61761^{0}N & 80.06767^{0}E
8	Ghatera	24.62413^{0}N & 79.00315^{0}E
9	Nararan	24.63804^{0}N & 79.91558^{0}E
10	Kheriya	24.63782^{0}N & 80.00150^{0}E
11	Silatanala	24.65147^{0}N & 79.96756^{0}E
12	Magradabri	24.66810^{0}N & 79.96793^{0}E
13	Judinala	24.69663^{0}N & 79.98927^{0}E
14	Madla	24.74175^{0}N & 80.00823^{0}E
15	Pandav Falls	24.73058^{0}N & 80.06748^{0}E

preserved in buffered formalin (10%) and transported to the laboratory for species confirmation. Species identification and confirmation were carried out using available literature (Talwar & Jhingran 1991; Jayaram 1999) and the species valid nomenclatural names were adopted as per the Catalogue of Fishes of the California Academy of Sciences (Eschmeyer & Fricke 2011). At each sampling site, a set of the following environmental variables were recorded: stream order, altitude, stream width (m), water depth (cm), velocity (m/Sec), water temperature (^{0}C), conductivity (µS/cm) and riparian cover (%). Riparian cover was estimated using spherical densiometer. Sampling protocol for habitat variables followed Pusey et al. (1993).

Analysis

Information on structure of fish assemblages was extracted by adopting different univariate indices, namely local distribution index, Margalef's species richness index and Shannon diversity index. The calculation of these indices followed the methods

of Johnson & Arunachalam (2009), and Muchilisin & Azizah (2009). Local distribution index was calculated by D= (Ni.st/N.st) x 100, where Ni.st is total number of sites where the fishes are found; N.st is total number of sites. Margalef's species richness was calculated using the equation R = (S-1)/ln N, where S is the number of species, N is the total number of individuals. The Shannon index of diversity was obtained by the following equation H' = -∑pi ln (pi), where pi = ni/N; ni is the number of individuals of 'i'th species and N = ∑ni. The indices were used to compare the species distribution, richness and diversity across the study sites. Quantitative data of species along with the number of individuals belonging to each species were used to calculate percent similarity index using Bray-Curtis similarity index based on Padhye et al. (2006). Dendrograms were constructed to understand the similarity of fish assemblage structure between the sampling sites. This was done using Bray-Curtis similarity index using non-transformed species abundance data (Anderson 2001) using PAST programme. Further, the species abundance and environmental variables with separated sites were submitted to Canonical Correspondence Analysis (CCA), which is a direct gradient ordination technique that extracts the best synthetic gradients from field data on biological communities and environmental features: it forms a linear combination of environmental variables that maximally separate the niche of the species (ter Braak & Verdonschot 1995). It is also a powerful exploratory tool for simplifying complex data sets and has the advantage over integrated analysis of both species and environmental data at each site (Taylor et al. 1993). In order to reduce the complexity of ordinance biplot, only cyprinid species were included in CCA. The resulting species abundance-environmental variables biplot is an ordination diagram in which species and sites are represented by points with respect to the supplied explanatory variables, represented by arrows. The arrows point in the direction of maximum variation in value of the corresponding variable. The arrow of a variable runs from the centre of the diagram to an arrow head, the coordinates of which are the correlation of the variable with axes (ter Braak 1986; ter Braak & Verdonschot 1995). The CCA was obtained with XLSTAT® 2012 version programme.

RESULTS

A total of 50 species of primary freshwater fishes belonging to 32 genera, 15 families and four orders were recorded from the study area (Table 2). Among the species, *Devario aequipinnatus* and *Channa gachua* had highest local dominance (80% for each) followed by *Esomus danricus* (66.6%) and *Garra mullya* (60%). They were represented in most of the study sites. The Mahseer *Tor tor* (Image 2) was recorded from Gahrighat, Magradabri and Madla in Ken River and also in Pandav Fall Stream. Number of species, species abundance, cyprinid abundance, Shannon diversity and Margalef's richness index for study sites are given in Table 3. The total number of species as well as abundance was highest in the Madla area of Ken River, whereas the lowest was recorded in Mahuapani Stream. Similarly, the Madla area of Ken had a high Shannon diversity index (3.48), whereas the Mahuapani stream registered a low Shannon diversity index (0.99). Cyprinids were the dominant members of the assemblage structure in the study area and comprised 56.6–94.5 % in the assemblage structure. The maximum cyprinid population was recorded from Jamunahi stream, while low cyprinid population was observed in Nararan stream (Table 3). Among the species, the distribution of 14 species (*Acanthacobitis botia, Clupisoma montana, C. garua, Crossocheilus latius, Devario devario, Garra gotyla, Glyptothorax telchitta, Labeo angra, L. rohita, Lepidocephalichthys guntae, Ompok pabda, Osteobrama cotio, Pseudambassis baculis* and *Salmosphasia balookee*) were reported in the Himalayan river system and they were not reported from peninsular India. Similarly, three species commonly found in rivers of peninsular India (*Nemacheilus denisoni, Rita gogra*

Image 2. The Mahseer *Tor tor*, 40cm standard length from Ken River, Madhya Pradesh

Table 2. List of fish species recorded from the study sites of Ken River basin, Madhya Pradesh.

Species	Sites*														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cyriniformes Cyprinidae															
Bangana dero	4	-	-	-	-	-	-	-	-	-	-	12	-	16	-
Barilius bendelisis	15	-	-	-	-	-	-	-	-	-	-	10	-	12	-
Cirrhinus mrigala	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
Cirrhinus reba	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
Gibelion catla	48	-	-	-	-	-	-	-	-	-	-	32	-	14	-
Danio rerio	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-
Devario aequipinnatus	32	-	-	27	23	14	-	32	22	32	15	35	25	30	18
Devario devario	-	-	-	-	-	-	-	-	-	-	-	12	-	6	-
Esomus danricus	-	-	25	12	18	12	17	45	2	43	33	-	31	-	-
Garra gotyla	38	-	-	-	-	-	-	-	-	-	-	24	-	12	-
Garra mullya	-	24	12	22	-	-	15	-	-	18	34	-	15	19	42
Crossocheilus latius	22	-	-	-	-	-	-	-	-	-	-	18	-	18	-
Labeo angra	3	-	-	-	-	-	-	-	-	-	-	5	-	-	-
Labeo calbasu		-	-	-	-	-	-	-	-	-	-	10	-	12	-
Labeo pangusia	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
Labeo rohita	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-
Osteobrama cotio	-	-	-	-	-	-	-	-	-	-	-	21	-	3	-
Rasbora daniconius	12	-	4	13	-	-	-	-	3	8	-	12	14	7	-
Puntius amphibius	10	11	8	-	8	-	-	-	6	14	13	-	-	36	-
Puntius conchonius	-	-	-	-	9	-	-	-	12	-	-	24	25	33	-
Puntius sarana	-	-	-	-	-	-	-	-	-	-	-	2	-	6	-
Puntius sophore	-	-	3	-	-	-	-	-	2	-	-	-	-	7	-
Puntius ticto	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-
Salmophasia bacaila	18	-	-	-	-	-	-	-	-	-	-	-	-	9	-
Salmophasia balookee	12	-	-	-	-	-	-	-	-	-	-	28	-	6	-
Salmophasia boopis	8	-	-	-	-	-	-	-	-	-	-	13	-	14	-
Tor tor	23	-	-	-	-	-	-	-	-	-	-	24	-	5	9
Balitoridae															
Acanthocobitis botia	4	5	3	8	-	-	4	-	3	-	-	-	-	-	6
Nemacheilus denisoni	5	-	-	-	-	-	-	-	9	-	-	10	-	-	12
Cobitidae															
Lepidocephalichthys guntea	-	-	-	-	4	-	-	-	8	11	-	-	6	-	4
Siluriformes Bagridae															
Mystus cavasius	4	-	-	-	-	-	-	-	-	4	-	18	4	30	-
Rita gogra	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Siluridae															
Ompok bimaculatus	-	-	-	-	-	-	-	-	-	-	-	11	-	14	-
Ompok pabda	-	-	-	-	-	-	-	-	-	-	-	4	8	6	-
Wallago attu	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
Schilbeidae															
Clupisoma montana	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-
Clupisoma garua	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-

Species	Sites*														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sisoridae															
Glyptothorax telchitta	4	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Claridae															
Clarias magur	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
Heteropneustidae															
Heteropneustes fossilis	-	-	-	-	10	-	-	16	-	6	-	-	8	-	-
Perchiformes Ambassidae															
Pseudambassis baculis	32	-	-	-	-	-	-	-	-	-	-	-	-	3	-
Pseudambassis ranga	-	-	-	-	-	-	-	-	-	-	-	34	-	18	-
Nandidae															
Nandus nandus	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
Gobiidae															
Glossogobius giuris	-	-	-	-	-	-	-	-	-	-	-	4	-	7	-
Channidae															
Channa gachua	15	15	-	-	12	4	5	14	4	19	18	6	-	4	6
Channa marulius	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Channa punctatus	2	-	-	-	-	-	-	-	10	-	-	-	-	6	-
Channa striatus	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-
Mastacembelidae															
Mastacembelus armatus	1	-	-	-	-	-	-	-	2	-	-	-	-	13	-
Cyprinidontiformes Belonidae															
Xenentodon cancila	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-

* = 1 - Gahrighat; 2 - Gehranala; 3 - Jamunahi; 4 - Imalia; 5 - Bargadi; 6 - Mahuapani; 7 - Keerpani; 8 - Ghatera; 9 - Nararan; 10 - Kheriya; 11 - Silatanala; 12 - Magradabri; 13 - Judinala; 14 - Madla; 15 - Pandav Falls.

Table 3. Variation in species abundance, cyprinid abundance, Margalef's richness index and Shannon index in Ken River basin, Madhya Pradesh.

Site code*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Total number of species	21	4	6	5	7	3	5	4	12	9	5	23	9	43	7
Individuals	312	55	55	82	84	30	51	107	83	155	113	369	136	444	97
Cyprinids Abundance	245	35	52	74	58	26	42	77	47	115	95	290	110	290	69
Percentage of Cyprinids abundance	78.5	63.6	94.5	90.2	69	86.6	82.3	72	56.6	74.2	84	78.5	80.8	65.3	71.1
Margalef 's richness index	3.48	0.75	1.25	0.91	1.35	0.59	1.02	0.64	2.49	1.59	0.85	3.72	1.63	6.89	1.31
Shannon index	2.69	1.26	1.48	1.52	1.82	0.99	1.47	1.28	2.2	1.97	1.53	2.94	2.01	3.48	1.63

* = 1 - Gahrighat; 2 - Gehranala; 3 - Jamunahi; 4 - Imalia; 5 - Bargadi; 6 - Mahuapani; 7 - Keerpani; 8 - Ghatera; 9 - Nararan; 10 - Kheriya; 11 - Silatanala; 12 - Magradabri; 13 - Judinala; 14 - Madla; 15 - Pandav Falls.

and *Salmosphasia boopis*) were recorded for the first time in the Yamuna River basin. Thus, short notes on meristic and morphometric features of new records are given at this section.

Notes on new records (Image 3 a–c)

***Salmosphasia boopis*:** Body elongate and laterally compressed. Body scales large, 40–41 scales present across the lateral line. Dorsal fin inserted well anterior

Image 3. New records to Ken River, Madhya Pradesh a - *Salmophasia boopis*; b - *Nemacheilus denisoni*; c - *Rita gogra*.

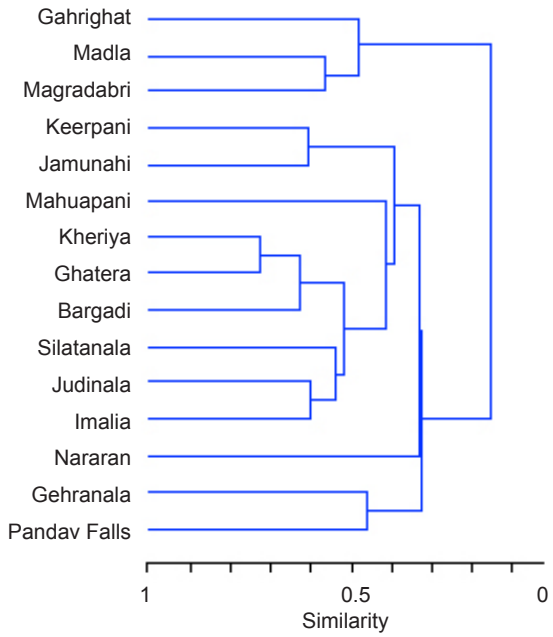

Figure 2. Dendrogram resulting from Bray-Curtis similarities of species abundance data of study sites.

to the origin of anal fin. Fin rays counts: dorsal - iii/7; pectoral - i/14; pelvic - i/8; anal - iii/12.

***Nemacheilus denisoni*:** Body loach-like, marked with 12 broad vertical bands and a black band at the base of caudal fin. A black spot present at base of origin of dorsal fin and rows of small spots also present on dorsal and caudal fins. Fin rays counts: dorsal - iii/8; pectoral - i/8; pelvic - i/7; anal - iii/5.

***Rita gogra*:** Head depressed, occipital process subcutaneous, extends to predorsal plate. Dorsal and pectoral fins bear strong osseous spine. Barbels three pairs, maxillary barbel extends to operculum. Mandible reaches base of pectoral fin and nasal barbel short. Fin rays counts: dorsal - i/6; pectoral - i/10; pelvic - i/7; anal - iii/9.

Cluster analysis of species composition in Ken River basin revealed that fish assemblages of Ken River had two distinct clusters based on the Bray-Curtis similarity (Fig. 2). The sites along Ken River (Gahrighat, Magradabri and Madla) had more similar faunal assemblage and they were grouped together. The rest of the streams that drained into Ken River had a similar assemblage and they formed a major group in the cluster. Further, the streams associated with Ken River in the northeastern region of Panna landscape such as Khaiya, Ghatera, Bargadi, Silatanala, Judinala and Imalia had a similar assemblage and they formed a separate cluster within the major group. At the same time Nararan, Gehranala and Pandav Fall streams had distinct fish assemblages which were grouped separately.

Environmental variables vs. fish abundance

Most environmental characters measured exhibited a high level of differences across the fifteen study sites (Table 4). River sites (Gahrighat, Magradabri and Madla) had more water depth and channel width than other sites. High velocity was recorded in Gahrighat (0.68m/sec) followed by Magrdabri (0.52m/sec). In contrast, high percentage of canopy cover (94%) and low water temperature (19.8^{0}C) were observed in Imalia stream. The species and site scores biplot based on CCA of the cyprinid fish composition displayed 12.1% of weighted variance in the abundance and 49% in weighted averages and class total of species with respect to the environmental variables. The eigenvalues of axis 1 and 2 accounted 0.62 and 0.20 respectively. Indeed, the biplot generated by CCA suggested that stream order, flow, depth and width

Table 4. Environmental variables of study sites of Ken River basin in Madhya Pradesh

Sites	Stream order	Altitude	Mean Depth (cm)	Stream width (m)	velocity (m/sec.)	Riparian cover (%)	Temperature (°C)	Conductivity (µS/cm)
Gahrighat	6	269	224	46.4	0.68	32	23.6	06
Gehranala	3	327.7	42	12.2	0.02	56	24.3	46
Jamunahi	2	417.9	28	03.6	0.00	40	24.8	53
Imalia	3	395.5	46	08.3	0.16	94	19.8	07
Bargadi	3	370	32	06.4	0.03	65	24.9	64
Mahuapani	2	444.4	86	08.5	0.005	80	21.1	08
Keerpani	2	391.8	16	02.0	0.12	80	21.4	16
Ghatera	2	393.2	38	06.4	0.01	60	24.4	33
Nararan	2	294.6	22	02.5	0.05	75	22.0	07
Kheriya	4	371.6	57	20.6	0.06	82	24.6	46
Silatanala	4	250.9	40	12.6	0.02	62	24.3	52
Magradabri	6	194	116	54.6	0.52	40	23.8	07
Judinala	3	266.3	76	07.5	0.23	85	22.0	14
Madla	6	189.5	176	82.2	0.34	20	25.4	20
Pandav Falls	3	241.9	36	05.2	0.28	55	21.8	06

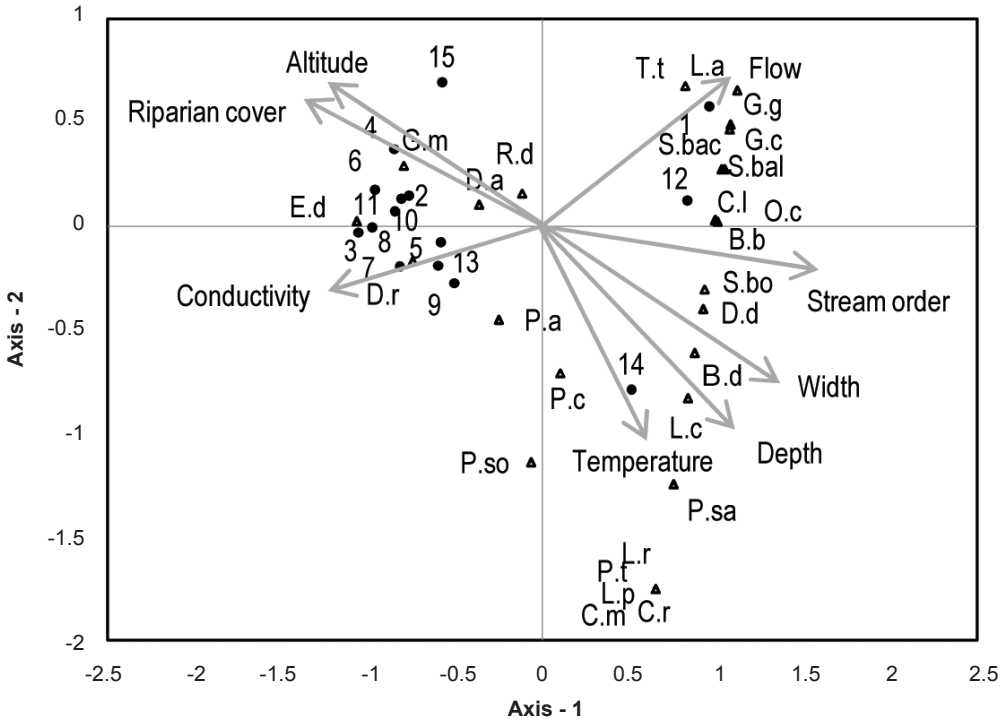

Figure 3. Canonical Correspondence Analysis (CCA) biplot depicting the distribution of fish species along the environmental parameters in 15 study sites in Panna landscape, Madhya Pradesh. [Site labels: 1- Gahrighat; 2- Gehranala; 3- Jamunahi; 4- Imalia; 5- Bargadi; 6- Mahuapani; 7- Keerpani; 8- Ghatera; 9- Nararan; 10- Kheriya; 11- Silatanala; 12- Magradabri; 13- Judinala; 14- Madla; 15- Pandav Falls. Species codes: B.d - *Bangana dero*; B.b - *Barilius bendelisis*; C.m - *Cirrhinus mrigala*; C.r - *Cirrhinus reba*; G.c - *Gibelion catla*; D.r - *Danio rerio*; D.a - *Devario aequipinnatus*; D.d - *Devario devario*; E.d - *Esomus danricus*; G.g - *Garra gotyla*; G.m - *Garra mullya*; C.l - *Crossocheilus latius*; L.a - *Labeo angra*; L.c - *Labeo calbasu*; L.p - *Labeo pangusia*; L.r - *Labeo rohita*; O.c - *Osteobrama cotio*; R.d - *Rasbora daniconius*; P.a - *Puntius amphibious*; P.c - *Puntius conchonius*; P.sa - *Puntius sarana*; P.so - *Puntius sophore*; P.t - *Puntius ticto*; S.bac - *Salmophasia bacaila;* S. bal -*Salmophasia balookee*; S.bo - *Salmophasia boopis*; T.t - *Tor tor*.

were the most important variables for the first axis. Flow was a very important variable for the second axis, although riparian cover and altitude were still influenced (Fig. 3). The biplot of the species and site score produced from CCA show the distribution of species and sites in ordination space (Fig. 3). In this plot 27 cyprinid species have been depicted to provide insight into their composition and distribution. The fish abundance sites such as Gahrighat, Magradabri and Madla along Ken River (site label 1, 12 & 14 in Fig. 3) were associated with more deeper habitat, flow, stream order and temperature, whereas the abundance were not influenced by altitude, conductivity and riparian cover (Fig. 3). Further, it also explained that the species such as *Tor tor, Salmophasia boopis, Salmophasia balookee, Salmophasia bacaila, Labeo angra* and *Gibelion catla* were displaced high weighted average for flow, whereas *Bangana dero, Labeo calbasu* and *Puntius sarana* scored a high weighted average for width, depth and temperature. The distribution of *Danio rerio, Devario aequipinnatus, Esomus danricus* and *Rasbora daniconius* were influenced by altitude, riparian cover and conductivity.

DISCUSSION

Ken River in Panna landscape has a diverse fish fauna of high conservation importance. When compared to other sub-basins of the Yamuna River basin, Ken River has lesser species richness than that of Champal basin and Betwa, where 71 and 60 species of fishes were reported respectively, but the fish assemblages were similar to that of these neighbouring basins (Dubey & Verma 1959; Vyas et al. 2012). In this study, cyprinids dominate the assemblage structure in Panna landscape as they occupy all possible habitats due to their high adaptive variability (Johnson & Arunachalam 2009). Three of the cyprinids species such as *Devario aequipinnatus, Esomus danricus* and *Garra mullya* were widely distributed in most of the study sites and they also have widespread distribution in India (Talwar & Jhingran 1991; Jayaram 1999) and they are a common and abundant species in Indian waters. Such extensive distribution and their common high abundance suggest that most of these species are capable of tolerating a wide range of environmental conditions (Pusey et al. 1993). However, in the present study a comparatively low percentage of cyprinid population was recorded in Nararan Stream. This is mainly due to the introduction of *Channa gachua* and *C. punctatus* in the temple tank, which in turn contribute to the assemblages structure of this stream. A noteworthy observation is the occurrence of *Salmophasia boopis, Nemacheilus denisoni* and *Rita gogra* (known so far from the rivers of peninsular India) in Vindhyan ranges (Yamuna River basin) and this is interesting in the context of Ichthyogeography. The *Salmophasia boopis* was reported from streams/ rivers originating from the Western Ghats of Tamil Nadu, Kerala, Karnataka and Maharashtra (Dahanukar 2011a). Similarly, *Nemacheilus denisoni* is also widely distributed in the Western Ghats rivers (Menon 1987). On the other hand, *Rita gogra* was reported from Krishna, Godavari and Narmada river basin of Deccan regions and distributed in Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh and Chhattisgarh states (Dahanukar 2011b). These distribution records of peninsular forms in Vindhyan Ranges recollect the possibility of prehistoric river valley modifications as proposed by Hora (1950). However, number of species per family recorded in Ken River basin revealed that more number of species were recorded belonging to the cyprinid family as compared to other families, which clarify that speciation occurred in this landscape in recent times.

Another interesting finding is the occurrence of a viable population of the Mahseer *Tor tor* in Ken River of Panna landscape. In the present study this species was recorded from Gahrighat, Magradabri and Madla along the Ken River and Pandav Fall stream. It is a mighty game fish, which has provided a worthwhile source of sport for international anglers. It reaches up to 78kg or more and there is a record of anglers having captured a 45kg fish (Menon 1999; Rayamajhi et al. 2010). Twenty years ago, they figured prominently in commercial catches in certain stretches of the Narmada and Tapti rivers, but the landings are reported to have declined remarkably in recent years (Talwar & Jhingran 1991). Presently, size ranges from 1.5–2 kg have been reported from its native ranges and this species distribution is restricted only in certain pockets of Protected Areas in Narmada, Tapti, Betwa and Chambal rivers in Central India. The reduction in population is mainly due to degradation of feeding and breeding habitat due to construction of barrages

and dams that in turn affect the breeding migration of this species towards upstream and finally that leads to patchy and fragmented populations in different rivers. This patchy distribution and selective harvesting of this big sized barb have also led to the disappearance of this species from its native ranges. However, in the present study we noted different life history stages of *Tor tor* in Gahrighat region of Ken River indicating that this species breeds upstream in the main Ken River, which provides some promise for survival of this species. However, further study on habitat use, spawning site selection and life history traits of this species in Ken River is warranted.

The present study also revealed that the main Ken River had high diversity of fish compared to its associated streams, which shows that the diverse habitat conditions such as rocky and deep pools, velocity, etc. in Ken River support great variety of fauna (Kaemingk et al. 2007). Moreover, it is a well established fact that there is occurrence of higher species richness at the confluence of tributary streams with the main river than in the tributary streams (Falke & Gido 2006). Further, the low diversity of fish documented in streams associated with Ken River is mainly due to the drying of streams during summer.

In addition to that, a variety of factors like water quality, habitat availability, flow variability and nutrient supplies from riparian habitats control the abundance and distribution of stream fishes. Such environmental variables are easier to predict than other biotic variables like predation and competition. Earlier, single water quality parameter was used to correlate with fish abundance (Echelle et al. 1972; Matthews 1987). Hawkes et al. (1986) hypothesised that the combination of different water quality parameters is likely to operate "in concert with each other as a multivariate system and not as isolated unvariate variables". In this study, the combinations of eight environmental variables were used to correlate with cyprinid abundance among the study streams. The CCA analysis revealed that the environmental variables such as water depth, flow, water temperature and stream order substantially influence fish assemblage structuring in the Ken River basin. These variables have previously been considered important factors in structuring fish assemblage (Matthews 1998; Angermeier & Winston 1999; Marchetti & Moyle 2001; May & Brown 2002). In harsh and variable environments such as streams and rivers, abiotic factors are likely to play an important role in determining fish assemblage structure.

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