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Research Article

Impact of prevailing factors on assemblages and status of freshwater fish fauna of River Song in the Lower Himalaya

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Keywords

Fish diversity,
Snow-fed stream,
Water quality,
Anthropogenic activities,
Habitats alteration,
CAMP status

Abstract

Regional study on the status of fish communities facilitates assessment procedures and conservation measures of fishes. Therefore, the present study investigated the impact of prevailing factors on the distribution pattern and status of freshwater fish fauna from River Song in the Lower Himalaya. In nine sampling sites under three sections (upper, middle, and down), 268 fish specimens were collected, 20 fish species belonging to 4 orders, 6 families and 12 genera were identified. *Barilius bendelisis* and *Noemacheilus rupicola* (upstream), *B. bendelisis* (midstream), and *Glyptothorax pectinopterus* (downstream) section constituted a high percentage of fish composition. The upper section was a relatively less disturbed section than other sections of the River Song. The upper section had good water quality, ample riparian vegetation, and a sufficient amount of food may affect the fish communities. However, many fish populations were declined in middle and down sections due to the disturbance through anthropogenic activities (*i.e.*, channelization, construction, and municipal wastewater) removal of vegetation in the riparian zone by local people affect the abundance and distribution of fish species. 80% of fish species have been forced into decline and need to protect their natural habitats, execute policies, and motivate people for management and conservation.

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Introduction

Freshwater systems are directly threatened by human activities (Meybeck, 2003; Vorosmarty *et al*., 2005; UNESCO, 2009). Rivers are the most ecologically fragile and economically valuable ecosystems in the world. They provide harvestable resources, particularly in Asia where river fisheries are a major source of protein (food) and employment for a large number of people (Allan *et al*., 2005) and serve as the chief source of renewable water supply for humans and freshwater ecosystems (Vorosmarty *et al*., 2005; UNESCO, 2009). Fishes are sensitive indicators of habitat degradation, environmental contamination, and overall ecosystem productivity. Habitat features influence the distribution and abundance of fishes. Fish diversity is also correlated with habitat complexity (Gorman and Karr, 1978; Schlosser, 1982) and depth, flow, and substrate types. The influence of these habitat attributes on the structure and function of fish assemblage in the streams has been studied in detaile at different latitudes (Mathew and Hill, 1980; Leveque, 1997). However, fishery scientists have long been aware that fish assemblages vary along latitudinal gradients (Lyons, 1996).

Freshwater ecosystems are threatened by habitat alteration, fragmentation, invasive species, water extraction, pollution, climate change and, to a lesser extent, exploitation (Richter *et al*., 1997; Allan *et al*., 2005; Vorosmarty *et al*., 2010) and it is more severely endangered than its terrestrial or marine counterparts, with much higher projected extinction rates (Allan *et al*., 2005; Dudgeon *et al*., 2006). Alteration of physical habitat is the most significant threat to biodiversity and ecosystem function in the majority of human-impacted (altered flows, channels and land use) river systems and management and restoration of these systems, it is important to identify areas that have the greatest potential to conserve freshwater biodiversity and the best strategies to accomplish that goal (Allan and Castillo, 2007). Regions of intensive agriculture and dense settlement show high incident threat (Vorosmarty *et al*., 2010). In addition, due to global warming, annual discharge and flow patterns to which riverine biodiversity is adapted will be transformed, adding to stresses imposed by rising temperatures (Dudgeon, 2007). Similarly, seasonal changes in discharge often radically alter the flow regime and therefore structure of streams and rivers ecosystems (Chapin *et al*., 2002).

Most of the previous studies have focused on particular species of interest either for taxonomy or aquaculture; while the few studies on fish assemblage structure and their habitat requirements in Indian rivers were carried out by Sarkar and Bain (2007), Lakra *et al*. (2010), Gupta *et al*. (2012), and Nautiyal *et al*. (2013). The Lower Himalaya is an important coldwater fish-breeding region. River Song of the Doon valley is the prime spawning-cum-nursery grounds of the mahseer (*Tor putitora*) (Nautiyal *et al*., 2008). Although, most of the fisheries researches were done in Doon valley on Eastern part; whereas, the Western part of Doon valley remained neglected due to its topography. In Eastern Doon valley it is easy to reach the river sites due to better road linkage and terrain; whereas, in the Western part of Doon valley

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the river sites are not accessible due to poor road linkage. Besides, the main perennial of western Doon valley originates from the hill area (mainly from Jaunsar, Bawar, Chakrata hills) and longitudinal variation of fish fauna in rivers having different topographical and geographical setups. In Western Doon valley very less work has been done on fish taxonomy (Singh, 1964; Uniyal and Kumar, 2006). The fish fauna of Dehradun district and around has attracted the attention of various workers during the past (Fowler, 1924; Das, 1960; Singh, 1964; Tilak, 1970; Grover, 1970; Uniyal and Kumar, 2006; Husain, 2010).

In Uttarakhand, the assessment and conservation of fish communities remains urgent and to maintain the biodiversity in freshwater ecosystems is still needed. Owing to less information on the current status of fish communities of the River Song in the Lower Himalayan region of Uttarakhand (India), we investigated to accumulate information on the distribution pattern and status of freshwater fish fauna to provide the fish assemblages in different sections of the river. The study also determines the significant prevailing factors that define the habitat for fish communities and describes the community structure in terms of diversity, species richness, and species composition.

Materials and methods

Study area

The present study was conducted in River Song, a tributary of River Ganga in the Lower Himalaya region of Uttarakhand (28º43' to 31º27'N latitudes and 77º34' to 81º02'E longitudes) (Fig. 1). The River Song a perennial river drains the eastern part of the Doon valley. A reconnaissance survey of one year of the River Song was made from January to December 2016 to select the nine sampling sites in three section of the river basin i.e., Maldevta (upstream section; US), Lachiwala (midstream section; MS) and Doiwala (downstream section; DS) at an altitude of 695m, 508m, and 396m a.s.l. (above sea level), respectively.

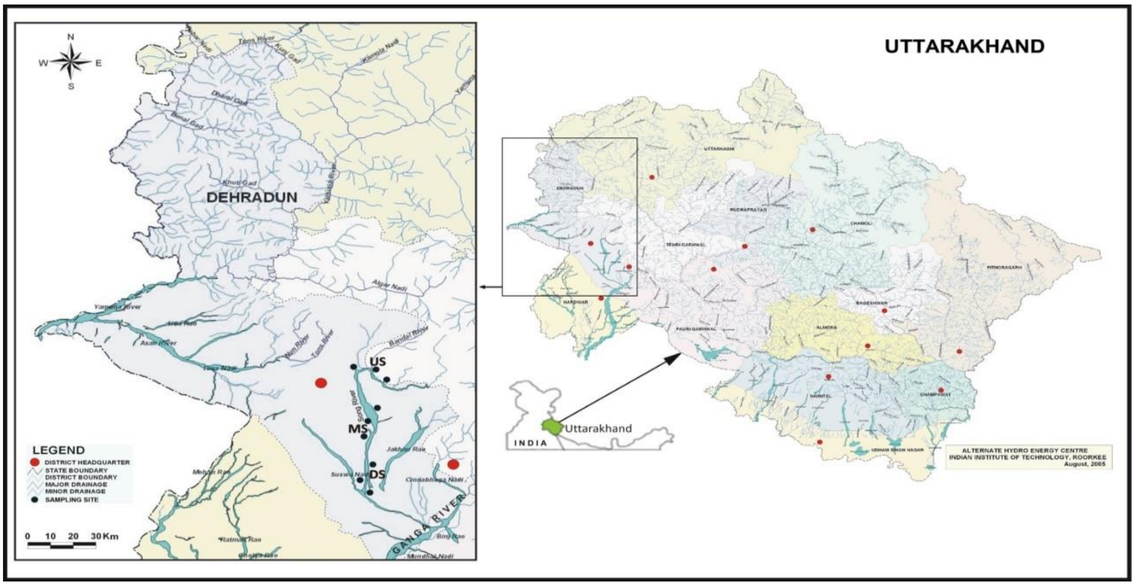

Figure 1: Location map and sampling sites in different sections of Rive Song.

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The river has an undulating valley covered by pebbles and boulders with a very little matrix with a thin mantle of soil. Pebble consists mostly of quartzite and an appreciable mound of limestone with silty clay bands. Soil is loamy clay with an outcrop of reddish clay. The climate and vegetation vary greatly with elevation dominated by *Shorea* sp. associated with *Terminalia tementosa*, *Lagerstromia parviflora*, *Adina cordifolia*, *Kydia calycina*. Occasional *Anogeissus latifolia*, *Terminalia belerica*, *Stereospermum suaveolens*, *Lannea coremonetelica* and *Syzygium cumini* vary in proportion. The underwood is generally light and consists of *Ougenia oojeinensis, Grewia elastic, Mallotus philippinensi*, *Ehretia laevis*, *Cassia pistula*, *Emblica officinalis*, etc. In most area *Syzygium cumini* is quite common. The undergrowth consists of *Carissa opaca*, *Cole brookie oppossititolia*, *Murray koenigii*, *Ageratum comyzoidea*, and *Crataegus crenulata*.

Field and habitat sampling

Data on physicochemical parameters [Air and water temperature (ºC), mean depth (m), mean width (m), mean velocity (m s^{-1}), discharge (m^3 s^{-1}), pH, dissolved oxygen (mg L^{-1}), free carbon dioxide (mg L^{-1}), alkalinity (mg L^{-1}), conductivity (NTU), total hardness (mg L^{-1}), chloride (mg L^{-1}) and total dissolved solids (g L^{-1})] was measured seasonally at the designated sampling sites along with the fish diversity of River Song during January to December 2016. Selected physicochemical parameters were measured and analyzed by the following standard methods outlined in Welch (1952), Golterman (1969), Trivedy and Goel (1984), and American Public Health Association (APHA, 2005).

Fish sampling and identification

Fish specimens were collected randomly by using cast nets with mesh size (1cm×1cm and 1.5cm×1.5cm) and hand picking at each sampling section along with 100–200m segment of the river from January to December 2016. However, some fishes were also procured from the local fishermen at sampling sites. All fish samples were kept in a bucket and placed in the stream to maintain the water temperature. Unidentified fish samples were preserved in 10% formalin solution and brought to the laboratory for further identification. The preserved specimens were kept in glass, plastic jars of different sizes with proper labels containing the date of collection, locality (site of collection), geographical/ecological note, number of examples and collector’s name, etc. In Doon valley, four seasons were observed viz. Summer (April, May, and June), Monsoon (July, August and September), Autumn (October, November, and December) and Winter (January, February, and March).

Identification of fish species level was done by using different keys given by Day (1878), Shrivastava (1992) and Badola (2009), Talwar and Jhingran (1991), and Jayaram (1999). All morphometric measurements were done on the left side of body based on the description provided by Shrivastava (1992), LeCren (1951), and Sharma and Grover (1982). The fishes were classified according to Nelson (2006) with modifications that of Talwar and Jhingran (1991) and Jayaram (1999). All identified

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fishes were released thereafter into the water at each sampling site.

Data analyses

The physicochemical data were normalized prior to statistical analyses using logarithm transformations i.e., log (x+1) and run ANOVA test using MS Excel to show significant differences in physicochemical parameters among all sections. Data obtained on fish communities were further analyzed by determining various ecological indices including the Shannon-Wiener species diversity index (Shannon and Wiener, 1963), richness index (Margalef, 1957), and evenness index (Pielou, 1969) was used to several changes in community structure of fish fauna at each section. The percentage composition of fish communities between sections was calculated using MS Excel. Principal component analysis (PCA) was applied to explore relationships between environmental and fish communities variables during different seasons using CANOCO Version 5.0 (Ter Braak and Smilauer, 1999). The analysis of similarities test (ANOSIM) was carried out using PAST (Hammer, *et al*., 2007) to determine whether significant differences in physicochemical variables and fish composition occurred among different sections of the River Song. Cluster analysis using Ward's linkage and the Euclidean distance as a measure of dissimilarity was used to explore the relationships between sections. Environmental variables and fish communities were used as metrics (PAST, Hammer *et al*., 2007).

Results

Physicochemical parameters

The results of physicochemical parameters recorded at selected sampling sections are depicted in Table 1. The water temperature was recorded minimum (9.0ºC) during Winter at upstream and maximum (27.0ºC) during Summer at downstream sites. The hydraulic characteristics, chiefly width, depth, velocity and discharge increased towards the downstream. The concentration of dissolved oxygen (DO) was recorded lowest (8.0 mg L^{-l}) during SU at MS and highest (14.0 mg L^{-l}) during WI at US. In general, DO and free carbon dioxide in water are reciprocal to each other. The free CO_2, pH alkalinity and conductivity also increases towards the downstream sites during different seasons (Table 1). The chloride in water was recorded minimum (12.8 mg l^{-l}) during Summer and Monsoon at US and maximum (42.0 mg L^{-l}) during Monsoon at DS. The total hardness was recorded minimum (24.0 mg L^{-l}) and maximum (78.0 mg L^{-l}) at DS during Autumn and Winter respectively. The peak total dissolved solids (TDS) during the Monsoon depends on the geological characteristics of watershed, rainfall, and amount of surface runoffs. The ANOVA test indicated no significant difference (R=0.016, P=1.0) for physicochemical variables among different sections.

Fish fauna

During the present study, 268 fish specimens of Class Teleostomi were collected and 20 fish species belonging to 4 orders, 6 families, and 12 genera were identified. 15 taxa were recorded in the US followed by 12 at MS and 6 at DS sections.

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Table 1: Mean±SD and range of physicochemical parameters recorded at different sections in River Song during the present study (January to December 2016).

Physicochemical parameters	Upstream section (US)			Midstream section (MS)			Downstream section (DS)		
	Mean	±SD	Range	Mean	±SD	Range	Mean	±SD	Range
Air temperature (ºC)	22.25	7.05	10.0–36.0	23.17	6.59	14.0–36.0	24.42	6.80	15.0–37.0
Water temperature (ºC)	15.17	4.53	9.0–21.0	17.50	5.45	10.0–26.0	17.92	5.58	12.0–27.0
Mean width (m)	4.13	1.96	1.96–8.20	4.43	2.24	2.5–9.0	5.13	2.38	3.1–9.8
Mean depth (m)	0.90	0.21	0.65–1.30	0.84	0.23	0.60–1.20	0.75	0.28	0.44–1.20
Mean velocity (m s^{-1})	0.43	0.22	0.22–0.92	0.45	0.29	0.15–0.89	0.46	0.27	0.19–0.98
Discharge (m^3 s^{-1})	2.33	2.93	0.37–8.53	2.64	3.25	0.23–9.07	2.88	3.76	0.29–11.52
Dissolved oxygen (mg L^{-1})	11.67	1.07	10.0–14.0	11.00	1.28	8.0–12.0	9.0	0.6	8.0–10.0
Carbon dioxide (mg L^{-1})	0.81	0.28	0.44–1.56	0.92	0.30	0.66–1.56	0.79	0.44	0.44–1.78
Alkalinity (mg L^{-1})	24.17	6.34	15.0–35.0	28.75	6.44	20.0–45.0	31.25	7.72	25.0–55.0
TDS (g L^{-1})	0.30	0.29	0.07–0.98	0.35	0.31	0.09–0.99	0.39	0.41	0.08–1.26
pH	7.59	0.24	7.1–7.8	7.57	0.32	7.2–8.2	7.80	0.43	7.2–8.5
Electric conductivity (S cm^{-1})	252.50	13.53	235.0–265.0	291.42	16.60	264.0–314.0	298.67	14.80	278.0–328.0
Chloride (mg L^{-1})	17.15	5.18	12.8–28.4	23.58	2.02	18.0–26.0	30.58	7.54	15.0–42.0
Total hardness (mg L^{-1})	57.50	8.91	46.0–72.0	45.43	11.39	29.0–74.0	36.75	16.31	24.0–78.0

Four species were common to all sections of the river viz. *Barilius bendelisis*, *Acanthocobitis botia* (Syn. *Noemachelius botia*), *Glyptothorax pectinopterus* and *Glyptothorax cavia*. Seven species were exclusive upstream followed by 3 species at midstream. The high diversity of *Noemachelius* (5 species) and *Barilius* (3 species) were recorded. The order Cypriniformes included 75% of the fish species. The family Cyprinidae dominated with 9 species followed by Cobitidae (6 species), Sisoridae (2 species), besides other families such as Belonidae, Channidae and Mastacembelidae had one species each (Table 2).

Seasonal abundance of fishes were recorded lowest 1.7±0.4 (DS), 2.3±0.3 (MS) and 2.7±0.4 (US) (Fig. 2) during Monsoon, due to the high discharge and urban area which altered the habitat conditions. Whereas, it was recorded highest 24.0±1.0 (US), 10.33±0.5 (MS), and 8.0±0.6 (DS) during Autumn. The results of the percentage composition of fishes showed that *Barilius bendelisis* constituted the highest percentage 20.3% followed by *Noemacheilus rupicola* (18.84%), *Glyptothorax cavia* (13.04%) in the upstream section; however, *Tor putitora*, *Puntius ticto* and *Danio devario* constituted lowest (2.17%) each of the total percentage composition of the fish fauna. At midstream, *Barilius bendelisis* constituted the highest percentage *i.e.*, 21.05% followed by *Glyptothorax pectinopterus* and *Lepidocephalus guntea* (10.53%) each and *Tor tor* (9.21%); whereas *Channa gauchua* and *Puntius ticto* constituted lowest (3.95%) each (Fig. 3). At downstream, *Barilius bendelisis* constituted highest percentage (29.63%) followed by *Glyptothorax pectinopterus* (25.93%) and *Glyptothorax cavia* (16.67%); whereas, *Noemachelius botia* constituted lowest (5.56%).

The Shannon-Wiener species diversity index $\overline{H}$ ranged between 1.28 (SU) at MD and 2.40 (AU) at US.

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Table 2: Systematic position (checklist), diversity, preferential habitat and conservation status of fish fauna recorded at different sections in River Song during the present study (January to December 2016).

Class	Order	Family	Genus	Species	Local Name	US	MS	LS	Preferential Fish Habitat	CAMP Status
Teleostomi	Cypriniformes	Cyprinidae	*Tor*	*tor*	Lal Mahseer	+	+	–	Pools, rapids	En
			Tor	*putitora*	Sunhari Mahseer	+	+	–	Pools, rapids	En
			Puntius	*ticto*	Bhuri, Phuti	+	+	–	Runs, riffles	LRnt
			Barilius	*barna*	Fulra	–	+	+	Pools, runs	LRnt
			Barilius	*bendelisis*	Chaal, Dhaur	+	+	+	Pools, runs	LRnt
			Barilius	*vagra*	Fulra	–	+	–	Pools, runs	LRnt
			Danio	*devario*	Dhono, Chand	+	–	–	Runs, rapids	LRnt
			Schizothorax	*richardsonii*	Asela, Sohal	+	–	–	Rapid, riffles, runs, pools	Vu
			Garra	*gotyla*	Gotla, Bhangnera	+	–	–	Rapid, runs, pools	Vu
		Cobitidae	*Lepidocephalus*	*guntea*	Gadera/ Ghiwa	–	+	–	Shallow pools, riffles, gravel beds	NE
			Noemachelius	*botia*	Gadera, Bakati	+	+	+	Shallow pools, riffles, gravel beds	LRnt
			Noemachelius	*montanus*	Gadera	+	–	+	Shallow pools, riffles, gravel beds	En
			Noemacheilus	*beavani*	Gadiyal	+	–	–	Shallow pools, riffles, gravel beds	DD
			Noemacheilus	*rupicola*	Gadera	+	–	–	Shallow pools, riffles, gravel beds	LRnt
			Noemacheilus	*multifaciatus*	Gadera	+	–	–	Shallow pools, riffles, gravel beds	En
	Siluriformes	Sisoridae	*Glyptothorax*	*pectinopterus*	PathatChat	+	+	+	riffles, pools	LRnt
			Glyptothorax	*cavia*	Patharchat	+	–	+	riffles, pools	En
	Beloniformes	Belonidae	*Xenentodon*	*cancila*	Saubam, Sooa	–	+	–	Shallow pools, riffles	LRnt
	Perciformes	Channidae	*Channa*	*gauchua*	Shovan, Dawla	–	+	–	Rapid, runs, pools	NE
		Mastacembelidae	*Mastacembelus*	*armatus*	Bam, Gaj	+	–	–	Rapid, runs, pools	NE

CAMP: Conservation Assessment and Management Plan; En: Endangered; VU: Vulnerable; LRnt: Low Risk-near threatened; DD: Data deficient; NE: Not Evaluated; + = Present; – = Absent of fish taxa

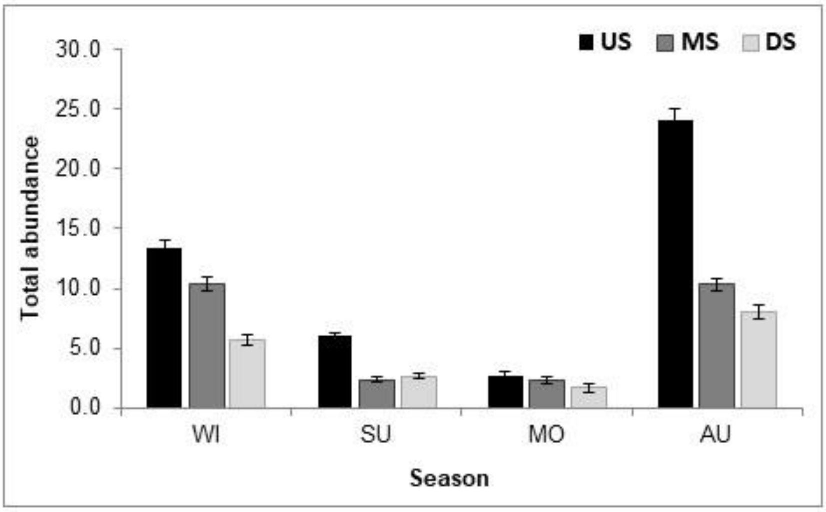

Figure 2: Seasonal abundance of fish species at different sections of River Song during January to December 2016. US=Upstream, MS=Midstream, DS=Downstream, WI=Winter, SU=Summer, MO=Monsoon, AU=Autumn.

The richness index was recorded the lowest (2.40) at DS during AU and highest (6.15) at US during SU; however, the evenness index was recorded as lowest (0.67) during WI at US and highest (0.94) MD and DS (Fig. 4). PCA yielded two principle components showing clear allocation of fish species and environmental variables at different sections. The two axes explained 86% of the variance in the data with

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eigenvalues for Axis 1=0.682 and Axis 2=0.175 (Fig. 5). The variation in the availability of fish species has been recorded in different sections of River Song during different seasons. Result of cluster analysis produced major clusters showed clear separation of upstream section of river to the other sections based on physicochemical parameters and fish abundances (Fig. 6). The ANOSIM test indicated no significant difference (*R*=0.211, *P*=0.085) in physicochemical variables among different sections with pair wise tests revealing no significant differences between US and MS, and MS and DS (*p*=0.283 and 0.458, respectively) except US and DS with marginally significant difference (*p*=0.059). However, the ANOSIM test indicated a highly significant difference (*R*=0.654, *p*=0.0004) in fish assemblages among different sections with pair wise tests revealing significant differences between US and MS, US and DS, and MS and DS (*P*=0.030, 0.029 and 0.031, respectively).

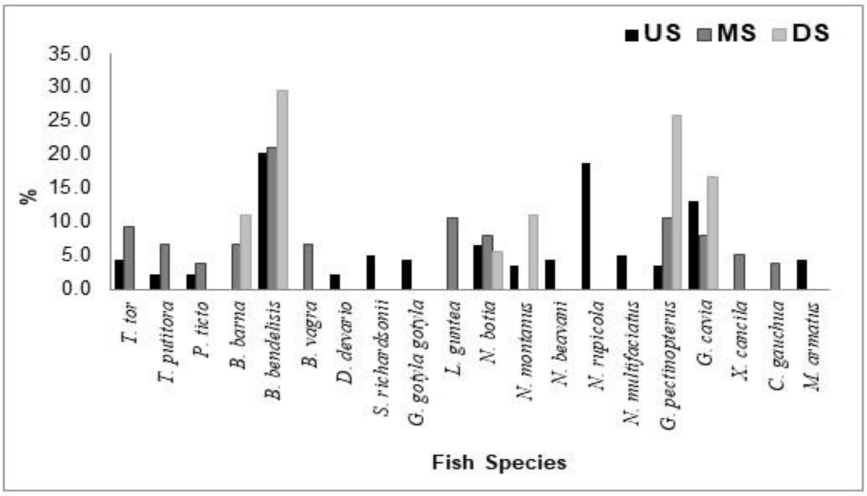

Figure 3: Percentage compositions of fish fauna at different sections of River Song from January to December 2016. US=Upstream, MS=Midstream, DS=Downstream.

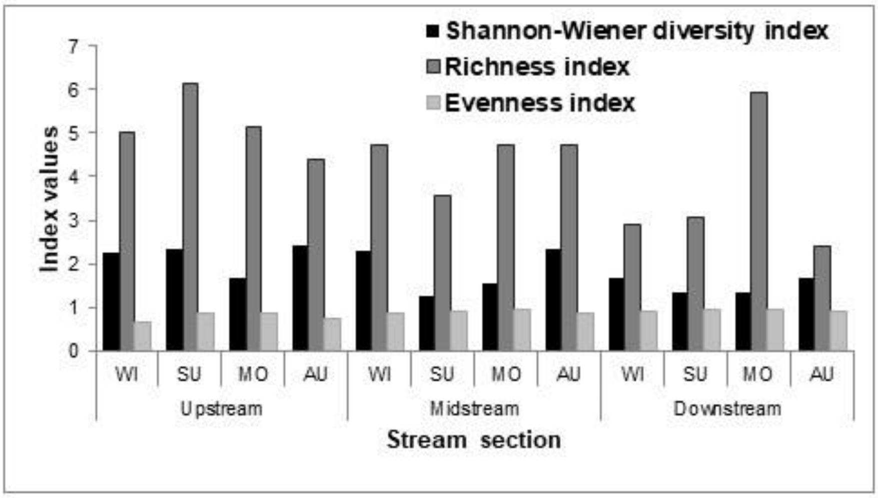

Figure 4: Shannon-Wiener species diversity index, richness index, evenness index of fish fauna at different sections in River Song from January to December 2016. WI=Winter, SU=Summer, MO=Monsoon, AU=Autumn.

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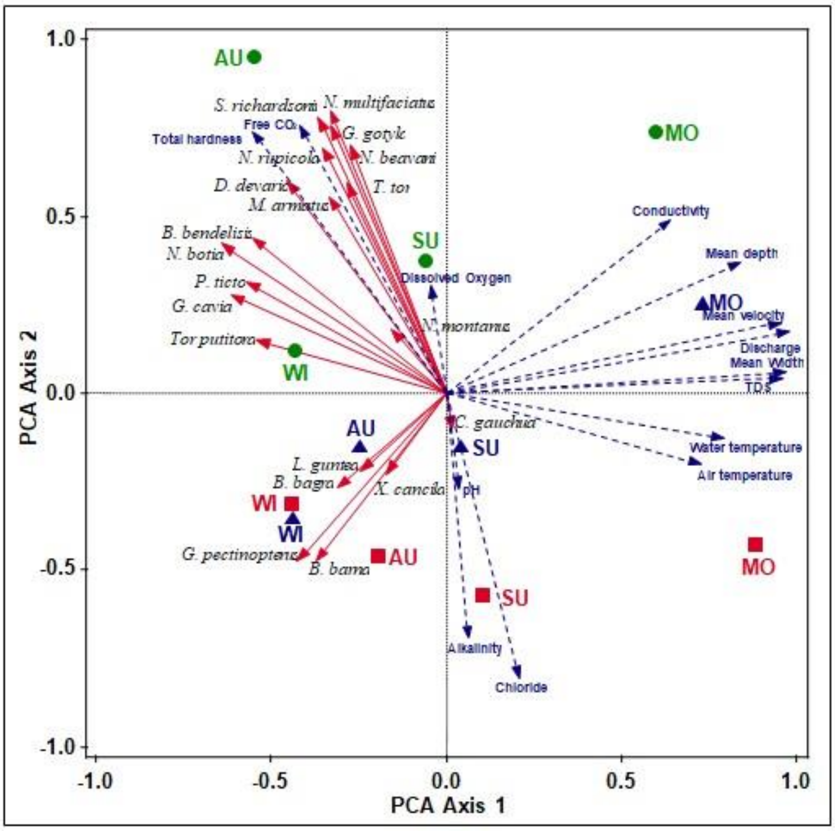

Figure 5: Ordination diagram of PCA of fish species (solid arrows) and environmental variables (dotted arrows) at different sections (circle, triangle, and square). The length of an arrow and its closeness to PCA axes is a measure of its strength. Circle=Upstream, Triangle= Midstream, Square=Downstream. WI=Winter, SU=Summer, MO=Monsoon, AU=Autumn.

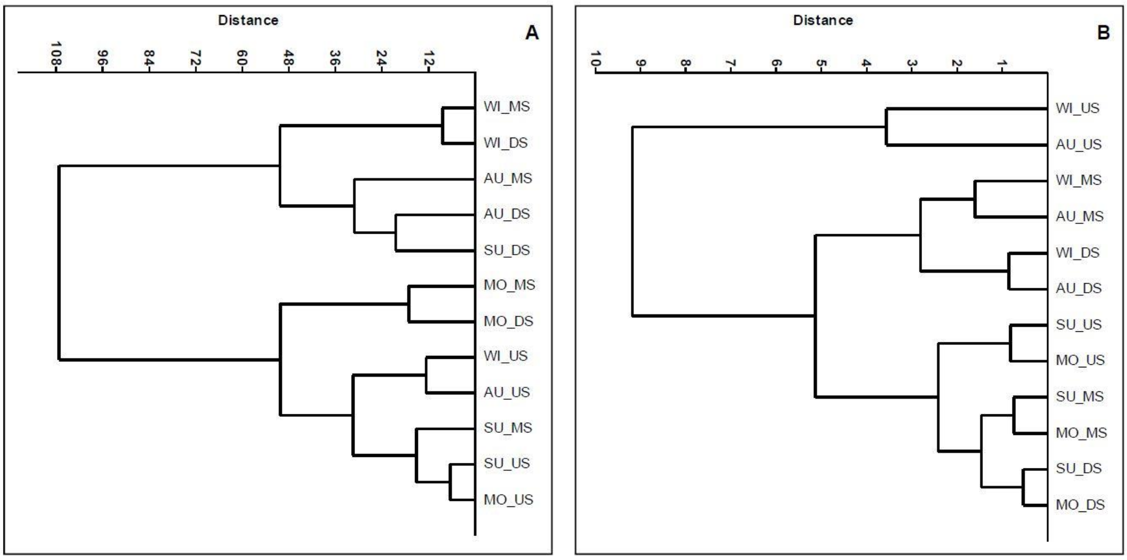

Figure 6: Cluster analysis based on physicochemical parameters (A) and abundance of fish (B) sampled across 9 river sites in River Song using Ward's linkage and the Euclidean dissimilarity measures. The shorter the distance, the more similar the seasons are in terms of their physicochemical parameters and fish community structure. US=Upstream, MS=Midstream, DS=Downstream, WI=Winter, SU=Summer, MO=Monsoon, AU=Autumn.

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Discussion

Seasonal changes in water temperature in rivers closely follow seasonal trends in mean monthly air temperature and daily time scales and among locations due to climate, extent of streamside vegetation, and the relative importance of groundwater inputs. River Song showed an increase in size as one proceeds downstream, because tributaries and groundwater add to the flow. However, the diversion and channelization of water for agricultural activities, construction, etc. alter the shape and dimensions of the stream system (Brookes, 1988). DO may change seasonally and daily in response to shifts in temperature. High Summer temperatures permit high microbial respiration, with the result that the downstream average partial pressure of CO_2 is about 20 times the atmospheric value (Kempe *et al.*, 1991). Higher activities of organisms during Summer might also reduce DO content of water. At upstream sites with turbulent and relatively low water temperature that have received limited pollution and diffusion maintain oxygen and CO_2 near saturation. Photosynthetic activity in highly productive (*e.g.*, vegetation and fallen leaves) settings can elevate oxygen to supersaturated levels. High levels of organic waste can reduce DO concentrations below life-sustaining levels and CO_2 can be elevated from groundwater inputs or biological activity (e.g., respiration) and high anthropogenic activities may add to the alkalinity at DS.

In general, the conductivity increases towards a drop in elevation (Kasangaki *et al.*, 2008). Our results were also congruent with the conductivity decreases toward DS. However, differences in conductivity result mainly from the concentration of the charged ions in solution, and to a lesser degree from ionic composition and temperature (Allan and Castillo, 2007). Rock weathering, other natural sources, and anthropogenic inputs must account for the majority of dissolved ions (e.g., chloride) in river water (Berner and Berner, 1987) which may influence the extent of chloride in river water DS. The total hardness is determined by cations that form insoluble compounds with soap and it correlated with calcium, alkalinity, and pH (Allan and Castillo, 2007). In fluvial ecosystems, key abiotic features of the environment are usually those related to current, substrate, temperature, and sometimes water chemistry variables such as alkalinity and dissolved oxygen. Many factors influence the composition of river water, and as a consequence, it is highly variable in its chemical composition. However, the geography and the topography of an area also affect the water quality of the river. Anthropogenic activities, natural processes *e.g.*, erosion, weathering, geochemical and geological characteristics of the environment as well as the ever increasing population of the world have kept changes in natural water bodies constant (Adefemi and Awokunmi, 2010).

The diverse environment supports species-rich fish communities that contribute to the overall high biodiversity of rivers/streams ecosystems (Schiemer and Waidbacher, 1992, Ward and Stanford, 1995). The seasonal difference in the availability of fishes is due to the change in physicochemical parameters and altitudinal variation in different sampling sections (Fig. 2). Habitat parameters i.e., rich

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oxygen and moderate range of water temperature influence the fish species abundance and distribution in the US. *Schizothorax richardsonii*, *Danio devario*, *Garra gotyla*, *Noemachelius* spp. and *Mastacembelus armatus* were exclusive to US. These species prefer the cold and clear water and were predominant from October to April (Badola, 2009). Also, stream responses to altered flow regimes include channel adjustments, interruption of the recruitment cycle of riparian plants, loss of spawning cues for fishes and numerous habitat changes (Poff *et al*., 1997).

During the Monsoon season abundance of fishes was recorded lowest due to the high discharge and urban area which altered the habitat conditions. Also, the extreme flow conditions associated with urbanization can have very strong effects on the biota and stream fishes can more readily shift location in response to high-flow events (Allan and Castillo, 2007). During Autumn fish abundance was recorded highest owing to favourable current velocity and moderate water temperature affected the feeding and physiological performance of fishes. Fish abundance was greatest in low-velocity and at base flow the main channel habitat of pools, riffles and glides contained higher numbers (Schwartz and Herricks, 2005). During Winter and Summer the fish abundance was affected by fluctuations in water temperature which forces them to hide. The percentage composition and diversity of fish assemblages influenced by the abiotic environment, interactions among species and the taxon richness at different sections of River Song. In general, each taxa contributed to the whole composition of the fishes at different sections of the river. The diverse fish fauna at upstream section showed the ample availability of food and less disturbed. However, seasonal fluctuations in water level change the habitat and food availability for many fishes. Also, Zaret and Rand (1971) revealed that the greater diet of fishes overlap in the wet compared to the dry season.

The low diversity in fish fauna at the midstream section was mainly due to the water abstraction into other channels and reduced water volume which in turn affects the diversity of fish species. Freshwater fish are one of the most threatened taxonomic groups (Darwall and Vie, 2005) because of their high sensitivity to the quantitative and qualitative alteration of aquatic habitats (Laffaille *et al*., 2005; Sarkar *et al*., 2008; Kang *et al*., 2009). However, the upstream section had relatively less disturbance and good water quality, riparian vegetation, sufficient amount of food (e.g., periphyton and benthic macroinvertebrates) may affect the fish communities in the river. Also, the downstream section with high anthropogenic activities and the removal of vegetation in the riparian zone along the river by local people have an effect on the abundance and distribution of fish species. The increasing river size downstream may influence the diversity and richness of fish communities. Local biological diversity is a subset of regional species richness, which in turn is a function of area, climate, and history. Our results agree that the number of species is greater in large river basins than in smaller basins and increases downstream partly due to the effect of increasing river size, and also because some species such as

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large river fishes are not adapted to smaller streams (Allan and Castillo, 2007).

The PCA showed distribution of fish species and environmental variables at different sections of the river varied seasonally. Five species *i.e*., *Lepidocephalus guntea*, *Barilius vagra*, *Barilius barna*, *Xenentodon cancila* and *Glyptothorax pectinopterus* associated with the Winter and Autumn seasons at MS and DS on the bottom left quadrant of the triplot. These fish species were found in foot hills and prefer good water quality (low velocity and clear water) and food (*e.g.*, algae). Simon *et al*. (2005) water velocity was lowest during the Autumn and early Winter which corresponded to algal abundance. The rest of 15 fish species along with DO, total hardness and free CO_2 corresponded to the upstream section during various seasons on the upper left quadrant. These variables may support the various fish taxa and accounted for the species adaptations to physical habitat, food resources, and specific temperature and flow conditions. On the upper right quadrant, the mean depth, mean width, velocity, discharge, conductivity and TDS corresponded to the Monsoon season at the US and MS sections.

During the Monsoon the fast current and breeding period of fishes force them to upward and downward migration (Uniyal and Kumar, 2006). Most of the physicochemical variables loaded highly on the upper and bottom right side of triplot corresponded to the midstream and downstream sections of the river during Summer and Monsoon seasons. The physiochemical parameters mainly temperature, pH, alkalinity, and chloride corresponded to the Monsoon (DS) and Summer (MS and DS) along with single species *Channa gauchua* at bottom right quadrant of the triplot. These sections of the river required conservation measures to save the fishes. In the catchment of River Song, the upstream station a forested headwater was located in a relatively undisturbed area and midstream and downstream stations the largest stream sites that were relatively disturbed area where agricultural activity, channelization replaced forest and influenced both channel features and fish ecology. Also, river chemistry varies with geology, upstream–downstream location and season, due to the influence of seasonal changes in discharge regime, precipitation inputs and biological activity (Allan, 2004; Allan and Castillo, 2007).

The cluster analysis showed upstream had a high availability of fishes often indicating suitable habitat variables and showed seasonal resemblance. However, at midstream and downstream sections of the river showed close seasonal association with each other due to the geology, slope, and quality and quantity of riparian vegetation. Vegetation strongly influences flow paths, channel shape, and water chemistry of river and human land use adds further complications. Vegetation changes along a river's length, across ecological regions or due to human activities the stream is affected in multiple ways (Allan, 2004). Fishes harvest plant material for the construction of lodges (Westlake, 1975), while some fish can be placed in a trophic guild without difficulty, others cannot, due to their morphological specializations, flexibility in their diet, due largely to

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changes in habitat and food availability driven by seasonal fluctuations in water level. Also, urbanization can have a very strong influence on stream flow (Dingman, 2002) and influence the structure and function of rivers and streams, modifying the hydrological regimes, nutrient dynamics, and chemical pollutants (Bassi *et al*., 2014). Furthermore, illegal fishing and/or overfishing, water pollution, and harvesting of eggs by water birds and reptiles affect fish communities.

As per Conservation Assessment and Management Plan CAMP IUCN-based (Molur and Walker, 1998) status (Table 2), out of 20 fish species collected during the present study period, 2 species are vulnerable, 5 species are endangered, 9 were low risk-near threatened, 3 not evaluated and for 1 species data is deficient. Similarly, Moyle and Leidy (1996) estimate that some 20% of the world's freshwater fishes are imperiled or already extinct, and that estimate may be low due to undetected extinctions (Stiassny, 2002). Gorman (1988) has argued that environmental variation is more influential than resource availability in limiting population densities of stream fishes. Fishes exhibit flexibility and overlap in their use of resources, and assemblage structure reflects the combined influence of environmental variation, particularly in hydrology, together with differences among species in their ecology (Allan and Castillo, 2007). The biological diversity of freshwater ecosystems is experiencing much greater declines than is seen in the majority of terrestrial ecosystems (Dudgeon *et al*., 2006). There is an urgent need to understand the conservation priorities and to design a conservation action plan for fish fauna. The most important conservational aspect of biodiversity of the river like Song is to create awareness in stake holders through communication, cooperation, and education for the improvement of water quality and in-stream habitat, management of riparian zones and conservation of associated riparian vegetation.

The upstream section of River Song had comparatively good water quality and a less disturbed section indicating the high availability of fish species which may enhance fish abundance and richness. However, towards the downstream section a rapid decline in fish diversity due to overfishing by various disparaging fishing methods, illegal/overfishing, water pollution, and eggs harvesting during breeding season. Natural disturbances such as flash flood, landslides, soil erosion, etc. have also been responsible for the depletion of fish communities. Also, overexploiting, anthropogenic activities, and removal of streamside vegetation decline the fish communities in the downstream section. Channelization of water for agricultural, municipal, and industrial demands exhibit variability in patterns of river flow and generate varieties of contaminants which influences the physicochemical and biological condition of water. Consequently, there is an urgent need for an action plan for the conservation of habitat, fishery development and assessment procedures. Additional safety measures should be taken to control illegal fishing by a total ban on fishing especially during breeding season.

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