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Fish communities and associated habitat variables in the upper Subansiri River of Arunachal Pradesh, eastern Himalaya, India

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Abstract: Ecological information on the rivers of eastern Himalaya, specifically the state of Arunachal Pradesh is not studied well. The present study describes fish assemblage patterns and deriving relationships between local habitat variables in the upper reaches of Subansiri River, Arunachal Pradesh. This study was carried out during October to November 2014 and February to March 2015. A total of 26 fish species belonging to eight families were recorded, in which eight species are endemic to the eastern Himalayan region. Fish species richness varied from two to 18 species in the upper reaches of Subansiri River and high species diversity was recorded in Sigin Stream (H'=2.76). Based on the seven habitat variables (water velocity, depth, channel width, percentage of substrate composition, percentage of riparian vegetation, altitude, and water temperature) then streams were categorized into lower-order and higher-order streams using principal component analysis (PCA). The site-wise fish abundance data along with habitat variable information was then subjected to the canonical correspondence analysis (CCA) for testing the association of habitat variables on fish abundance. The CCA results revealed that the abundance of large-size barbs, *Neolissochilus hexagonolepis*, *N. nigrovittatus*, *Schizothorax progastus*, and *S. richardsonii* were strongly associated with high altitude, water velocity, rich dissolved oxygen, and good riparian vegetation. On the other hand, *Channa gachua*, *Botia rostrata*, *Danio rerio*, *Devario aequipinnatus*, and *Garra nasuta* showed strong association with warm water streams with more conductivity.

Keywords: Diversity, fish assemblage, fish ecology, northeastern Himalaya, Subansiri River.

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Author contribution: SS—involved in field sampling, data collection, data analysis and manuscript drafting; KS—involved in filed sampling, supervision and manuscript editing. JAJ—involved in filed sampling, supervision, data validation, image preparation and manuscript editing

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INTRODUCTION

The questions addressed within the scope of community ecology are several; of them, one crucial objective is studying the differing species communities through changing environmental characters. Such an analysis leads us to identify the environmental factors that shape the species communities of a region (Angermeier & Karr 1983). Stream ecosystems have complex local processes occurring amongst abiotic, and biotic entities. This complexity renders a buffering capacity and stability to the system. Understanding these interrelationships with respect to stream ecosystems is challenging but critical, if one is to comprehend and conserve riverscapes. In the context of rivers, it has been repeatedly shown that fish communities change as one moves downstream from the headwaters (Platts 1979; Vannote et al. 1980) primarily because of an increase in diversity and quantity of habitats (Lowe-McConnell 1975; Gorrman & Karr 1978). Physico-chemical parameters such as dissolved oxygen and pH are also powerful drivers of fish diversity (Mathews 1986). Several other studies, showcasing the role of discharge (Horwitz 1978), substrate quality (Ambrosio et al. 2009), hydrological variability (Poff et al. 1995), and stream order (Platts 1979), have been well documented.

Multivariate statistical analyses used for understanding relationships between communities and habitat variables include regression (Angermeier & Winston 1998); principal components analysis (PCA) (Bistoni & Hued 2002); canonical correspondence analysis (CCA) (Ferreira et al. 2007; Li et al. 2012); detrended correspondence analysis (DCA) (May & Brown 2000), and non metric multi-dimensional scaling (NMDS) (Li et al. 2012; Mercado-silva et al. 2012) among many other statistical models developed over the years. Many studies correlating fish assemblages to habitat variables have been conducted in temperate as well as tropical regions across the world (Anderson et al. 1995; Fausch & Bestgen 1997; Winston 1998; Guisan & Zimmermann 2000; May & Brown 2000; Horig & Fauscch 2002; Oakes et al. 2005). In India, these studies have been done in the Western Ghats rivers (Saravanan et al. 2003; Bhat 2004; Johnson & Arunachalam 2010), central Indian rivers (Johnson et al. 2012; Shukla & Bhat 2017; Mondal & Bhat 2020), economically important fishes of the Ganga River (Lakra et al. 2010), and rivers of the western Himalaya (Johal 2002; Sivakumar 2008; Atkore et al. 2011; Johnson et al. 2020).

Fish assemblage studies in the eastern Himalayan streams in the Indo-Burma biodiversity region have not been conducted. Northeastern India's remote regions especially, Arunachal Pradesh, has many networks of flowing freshwater and associated resources. Studies on the rivers of Arunachal Pradesh are scanty (Nath & Dey 1997; Bagra et al. 2009) and literature addressing habitat-fauna correlations are missing. The high diversity in the region is attributed to the region's tectonic and consequently zoogeographical history (Kottelat 1989). The absence of information on the ecology of the rivers of the region and especially the Subansiri is glaring. In fact, with the controversies that the Lower Subansiri Hydro-Electric Project (LSHEP) has been embroiled in, this study gains even more importance as probably the only source of ecological information on the river.

With the above background, the present study was conducted to address the following questions: i) what type of fish fauna are associated with upper Subansiri River basin? and ii) which habitat variables are crucial drivers in the formation of fish assemblages in the streams of the upper Subansiri River basin?

METHODS

Study Area

This research effort was carried out in the upper Subansiri River basin of Arunachal Pradesh, eastern Himalaya. This river is one of the largest tributaries of the Brahmaputra River. It originates from the Tibetan Plateau and enters India through Taksing in the upper Subansiri District, of Arunachal Pradesh. It then courses through the entirety of the Upper and Lower Subansiri districts, covering a distance of 442km, and finally confluences with the Brahmaputra River at Lakhimpur, Assam. Twenty-one streams were sampled along the altitudinal gradient ranging from 200m in Daporijo, to 3,000m in Taksing (Figure 1) for fish and habitat characters in the seasons: post-monsoon (October–November 2014) and pre-monsoon (February–March 2015). The landscape is dominated with wild bananas and bamboo which give way to oak forests and finally alpine vegetation at two higher reaches. The region experiences heavy rains from the months of April to September. Winters are cold, and peak in the months of December and January. Sampling time is thereby limited to October, November, February, and March.

The fauna and flora of the region have affinities to southern China and the Malayan Peninsula because the river basin lies in the region where two biodiversity hotspots, viz., the Himalaya and the Indo-Burma, coalesce. There are innumerable rivulets flowing into the

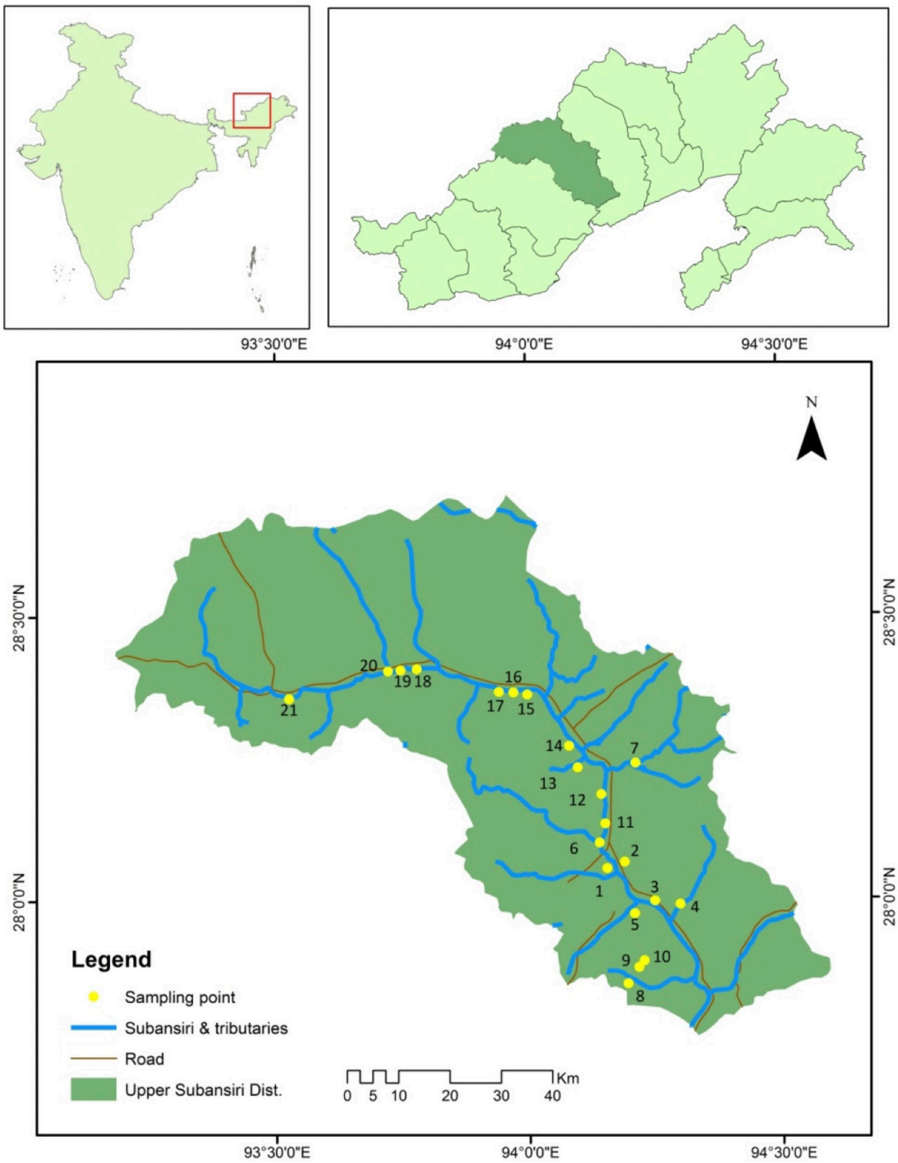

Figure 1. The sampling locations in the upper Subansiri River basin, Arunachal Pradesh, India: 1—Sippi | 2—Sakro | 3—Sigin | 4—Singyum | 5—Menga | 6—Bui | 7—Silin | 8—Godak | 9—Wuon | 10—Mara | 11—Ryo | 12—Lingram | 13—Lingde | 14—Aying | 15—Gamte | 16—Mede | 17—Ginyo | 18—Digbhak | 19—Dasi | 20—Kete | 21—Kudok.

Subansiri through either bank. The major tributaries of the Subansiri River are Sigin in Daporijo, Sippi in Chetam, Menga in Giba, Silin and Sichi in Taliha, Sikin Kro and Singyum in Dumporijo. A few small towns of the district, such as Daporijo, Dumporijo, and Taliha; are located close to major river confluences involving the river Subansiri. A lot of the stream channels have been altered for the purpose of irrigation or road constructions. Among other land-use activities of the region, slash and burn (*Jhum*) cultivation is prevalent throughout the landscape and is one of the important occupations. Fishing activities are only for purposes of subsistence and not commercial. Fishing techniques include both traditional and modern methods. Traditional fishing involves angling, basket traps, and use of river-bed substrates to construct seasonal fish breeding spots within the river channel. Modern methods are mostly destructive and include cast netting, gill netting, dynamite use, and some cases of poisoning and electro-fishing.

Habitat Inventory

At each sampling site, a 100m reach was selected for quantifying stream habitat variables such as depth, velocity and substrates. Before starting the inventory, altitude and GPS coordinates of sampling location were recorded. After that, 8–10 transects were drawn across the channel, using a rope calibrated at every meter. At each of those calibrations, depth, flow and substrate type were recorded at every 1m interval. Depth was recorded using a measuring rod and velocity was recorded using a flow probe hand-held digital flow meter. In the case of substrate, percentage composition of different substrates categories (bedrock - >512mm; boulder 128–512 mm; cobbles 64–128 mm; pebbles 16–64 mm; gravel 8–16 mm; sand/silt/leaf-litter) were recorded for each transect. Based on the depth and velocity profile, mean depth and mean width were calculated for each site. Methods for recording habitat variables were followed the methods of Pusey et al. (1995) and Johnson & Arunachalam (2010). In addition to that the percentage of riparian cover along the stream, bank stability, water clarity and land use patterns were recorded for each sampling location. Riparian cover was recorded using a spatial densitometer. Bank stability, land-use pattern and water clarity were given score values through 1–4 ranging from pristine to heavily modified.

Fish Sampling

Fish sampling was carried out using different fishing gear such as cast nets and gill nets of varying mesh sizes from 0.5 to 5cm. Gill nets were deployed in pool habitats for four hours. Run and riffle habitats were sampled using a cast net. In addition, drag nets and locally made contraptions were used to acquire small fish. Fish sampling protocol was adopted from Johnson et al. (2012). After collection, fishes were examined and photographed. A few fishes were preserved in 10% buffered formalin for species confirmation and other laboratory analyses. The rest were released back into the stream after noting their length and weight. Fish species were confirmed using latest taxonomic literature (Jayaram 2010) and current nomenclature was followed according to the catalogue of fishes (Fricke et al. 2020).

Data Analysis

Fish abundance data was subjected to different univariate indices, namely Shannon index, evenness index and Margalief's species richness for investigating species diversity patterns. The Shannon index of diversity was obtained by the following equation $H' = \sum pi \ln pi$, where $pi = ni/N$; where ni is the number of individuals of 'i'th species and $N = \sum ni$. Evenness index was calculated by $E = H'/\ln S$, where S is the number of species. Margalief'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 95% confidence intervals (95% CI) for Shannon and evenness indices were estimated using bootstrap methods with 9999 permutations using PAST programme (Hammer et al. 2001). In order to identify major categories of stream classes, the PCA was performed. In PCA analysis, correlation matrix of seven variables, viz., flow, depth, width, percentage composition of substrate, percentage of riparian cover, altitude, and temperature were considered. Whereas, the bank stability, land-use pattern, habitat diversity, and water clarity were not used for PCA, as these were nominal data and did not have any numerical qualities. Further, the CCA analysis was performed using 13 variables, including the ones not considered for PCA, to test the null hypothesis that the habitat variables do not influence species composition. In order to do this, a permutations test (n=999) was run and p-values for each canonical axis was considered (Legendre & Legendre 1998). Before using the data in CCA, the habitat variables with nominal data were converted into scores (see Table1) on the basis of Mercado-silva et al. (2012). The PCA and CCA were performed using PAST programme (Hammer et al. 2001).

Table 1. Scoring criteria of habitat variables with nominal data for CCA (Mercado-silva et al. 2012).

Variable	Scores	Criteria
Water Clarity	1	Turbid
	2	Moderately Turbid
	3	Transparent
Habitat Diversity	1	Single habitat type for 90%
	2	Two habitat types
	3	Three or more habitat types
Land-use Pattern	1	Urban/Pasture/Agricultural
	2	Modified natural
	3	Natural
Substrate Diversity	1	Soft sediments >90%
	2	Mix of > 3 substrates
	3	Rocky Substrates >90%
Riparian Cover	1	No riparian cover
	2	Modified riparian cover
	3	Natural

RESULTS

Fish Diversity and Assemblages

A total of 26 species of primary freshwater fishes belonging to 16 genera, eight families and three orders were recorded from the upper Subansiri River (Table 2). Maximum species richness was found in Sigin stream (18 species), which is a low land stream located near Daporijo town, followed by Sippi with 12 species of fishes, which is located near the confluence of Sippi stream and the

Subansiri. Among all the species, *Garra gotyla* had the highest local dominance (recorded in 11 streams) followed by *Neolissochilus hexagonolepis*, *Schizothorax richarsonii* and *Schistura devdevi* (recorded each from 10 streams each). Among the species, eight species (*Aborichthys garoensis*, *A. kempi*, *A. tikaderi*, *Exostoma labiatum*, *Neolissochilus nigrovittatus*, *Psilorhynchus arunachalensis*, *Schistura nagaensis*, *S. tirapensis*) are endemic to the northeastern Himalaya. Images of some of the rare and endemic fishes recorded from upper Subansiri River are given in Image 1.

The site-wise information on species diversity, richness, evenness and fish assemblages are presented in Table 3. Of all the streams sampled, the Sigin Stream had the highest species diversity (H'=2.76, 95% CI 2.09-2.57) and richness (R=4.37) followed by Sippi (H'=2.34, 95% CI 2.68–2.95; R=3.56) whereas the headwater stream Dasi had low species diversity and richness (H'=0.43, 95% CI 0.23–0.63; R=0.39). The high value of evenness index observed in Aying stream (E=0.98, 95% CI 0.86–1.11) revealed that the species were distributed evenly in the community.

Stream Categories and their Characteristics

The first two components of the PCA explained 57.72% of the total variation in the data. The PCA of the sites categorized into headwaters (lower order streams) and downstream (higher-order streams). The bi-plot of site scores with habitat variables is displayed in Figure 2. Sites with low principal component 1 loadings (Sippi, Sakro, Sigin) had high water temperature and conductivity whereas sites with high component 1 scores (Kete, Mede, Bhagdik, Lingde) had good quality of riparian vegetation, high level of dissolved oxygen, swift flowing habitat and positioned in higher altitude (qualified as headwater streams). On the other hand, sites with high component two scores have greater width and depth, i.e., characters of higher order streams.

Image 1. Rare and endemic fishes recorded from the upper Subansiri River, Arunachal Pradesh. a—*Aborichthys kempi* | b—*Aborichthys tikaderi* | c—*Exostoma labiatum* | d—*Neolissochilus nigrovittatus* | e—*Psilorhynchus arunachalensis* | f—*Schistura nagaensis*. © J.A. Johnson.

Table 2. List of fish species and abundance recorded from the upper Subansiri River, Arunachal Pradesh.

Species name	Sippi	Sakro	Sigin	Singyum	Menga	Bui	Silin	Godak	Wuon	Mara	Ryo	Lingram	Lingde	Aying	Gamte	Mede	Ginyo	Bhagdik	Dasi	Kete	Kudok
Cypriniformes **Daniodinidae** *Devario aequipinnatus*	4	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Devario devario	2	1	2	2	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Danio rerio	1	3	2	1	3	2	1	2	-	-	-	-	-	-	-	-	-	-	-	1	-
Opsarius bendelisis	4	3	3	-	2	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyprinidae *Garra gotyla*	-	-	7	-	6	2	3	4	5	4	-	2	-	-	-	4	-	-	2	1	-
Garra lamta	-	2	-	-	3	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Garra nasuta	-	-	3	-	-	1	-	-	4	-	-	-	-	2	-	-	-	-	-	-	-
Neolissochilus hexagonolepis	1	-	1	-	4	6	-	-	-	-	-	-	3	3	1	3	2	2	-	-	-
Neolissochilus nigrovittatus	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-
Schizothorax progastus	-	-	-	-	-	-	-	-	-	-	5	-	2	-	1	2	1	-	-	-	5
Schizothorax richardsonii	-	-	-	-	-	-	-	-	-	7	4	-	3	2	4	3	2	1	-	7	4
Tariqilabeo latius	2	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psiloehynchidae *Psilorhynchus arunachalensis*	1	-	3	4	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemachilidae *Aborichthys garoensis*	-	2	5	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Aborichthys tikaderi	1	-	3	1	-	-	-	5	1	-	-	-	-	-	-	-	-	-	11	-	-
Aborichthys kempi	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paracanthocobitis botia	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Schistura devdevi	1	-	3	-	-	-	-	5	-	3	2	1	3	2	1	2	-	-	-	-	-
Schistura nagaensis	-	3	2	1	4	-	-	2	-	2	-	-	-	-	-	2	-	-	-	-	-
Schistura tirapensis	-	1	4	1	1	1	3	1	2	-	1	-	-	-	-	-	-	-	-	-	1
Bottidae *Botia rostrata*	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Siluriformes **Siluridae** *Amblyceps mangois*	-	-	1	1	-	-	-	1	-	3	-	1	-	2	2	-	-	-	-	-	-
Sissoridae *Exostoma labiatum*	-	-	-	-	-	-	-	2	3	-	-	1	-	-	-	-	-	-	-	-	-
Glyptothorax cavia	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Perciformes **Channidae** *Channa gachua*	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Channa stewartii	-	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Fish species and habitat variable associations

The results of CCA revealed that there is no strong association observed between habitat variables and species abundance (Permutations=999, trace=2.061, p=0.204). Among the variables, the conductivity had very strong association with fish abundance data (p=0.01). On further inspection, it found that the first two axes explained 54.32% of the inertia (31.53% and 22.79% for axis 1 and axis 2 respectively) in the data matrix. There was a significant association between habitat variables and species abundance on the first canonical axis (P=0.02) and second canonical axis (P=0.01).

The triplot depicting associations of sites and species to habitat variables is given in Figure 3. The CCA plot revealed that the stream Kete, Mede, Bhagdik, Lingde, Ryo, Ginyo, and Gamte had good quality of riparian vegetation, high level of dissolved oxygen, swift flowing habitat and positioned in higher altitude, which were in turn strongly associated with fish species *Neolissochilus hexagonolepis*, *N. nigrovittatus*, *Schizothorax progastus*, *S. richardsonii*, and *Schistura tirapensis*. In the plot, the stream Silin segregated itself as an outlier among all site,

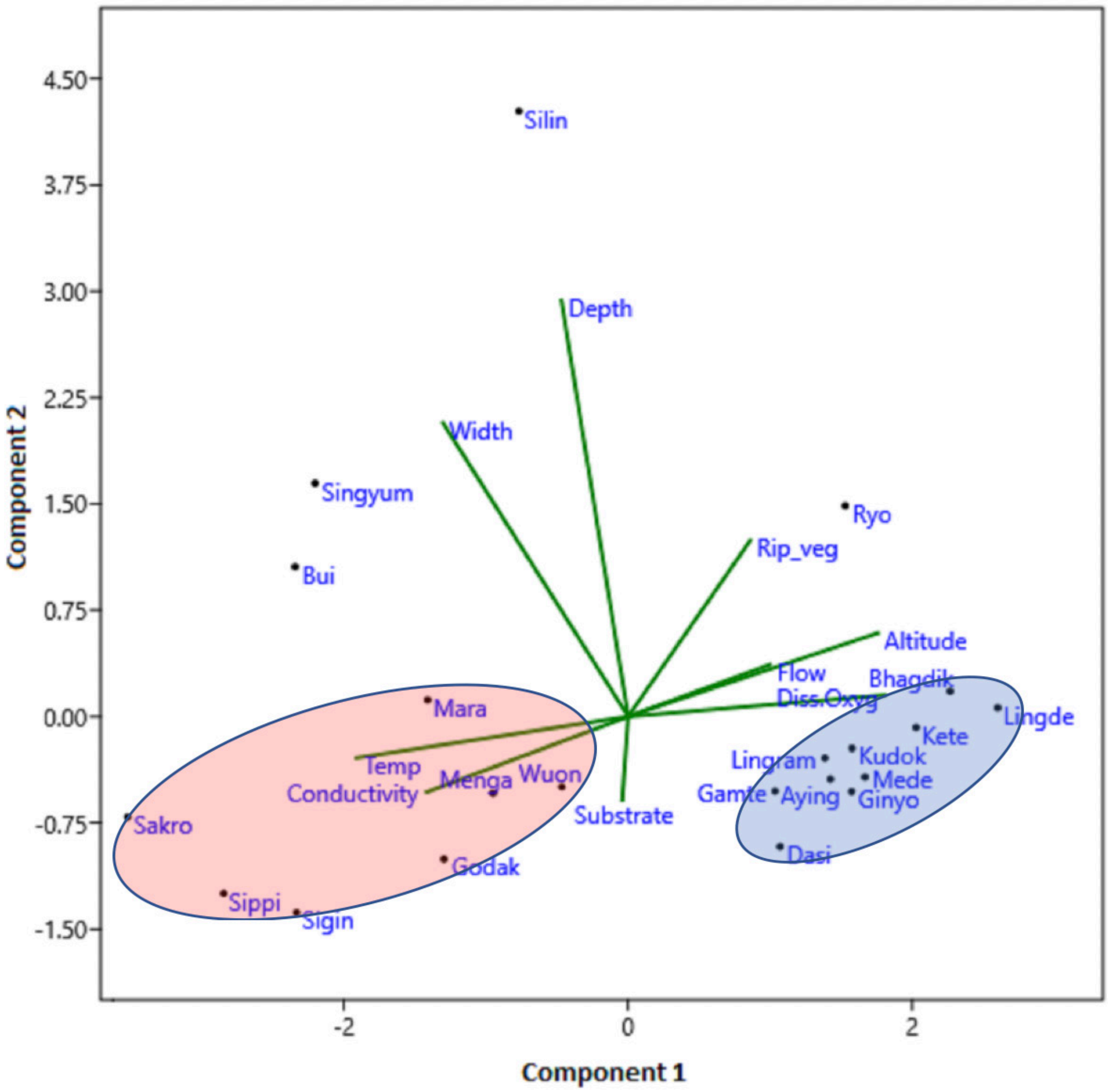

Figure 2. PCA bi-plot of sites with habitat variable vectors (Blue: headwater streams; Red: lowland rivers).

however, it was strongly associated with more number of *Aborichthys garoensis* and *Garra lamta*. The species, *Botia rostrata*, *Channa gachua*, *Danio rerio*, *Devario aequipinnatus*, *Garra nasuta*, *Glyptothorax cavia*, and *Psilorhynchus arunachalensis* formed a cluster near Sippi site and showed preferences to streams with relatively greater stream volumes, conductivity and warm temperature. The high altitude streams, Wuon, Lingram, and Godak located in south of Daporijo Town formed a separate group in terms of fish community.

DISCUSSION

Assessing the species richness and habitat variables influencing their distribution are central to the subject of conservation science. Species composition in streams within a river basin is determined by large- and small-scale processes. The large-scale factors refer to biogeographic history, tectonic movements and latitude of given landscape. In the present study, the fish composition recorded from upper Subansiri River is a true representation of eastern Himalayan elements and most of the species occur in other sub-basins of Brahmaputra (Tamang et al. 2007; Bagra et al. 2009;

Table 3. Species diversity and assemblages in the upper Subansiri River, Arunachal Pradesh.

Site	Number of species	Number of individuals	Shannon diversity (H’)	Evenness index (E)	Species richness index (R)
Sippi	12	22	2.34	0.86	3.56
Sakro	8	17	2.01	0.93	2.47
Sigin	18	49	2.76	0.88	4.37
Singyum	9	13	2.03	0.85	3.12
Menga	10	29	2.20	0.90	2.67
Bui	8	21	1.86	0.80	2.30
Silin	6	13	1.74	0.95	1.95
Godak	10	26	2.16	0.87	2.76
Wuon	5	15	1.49	0.89	1.48
Mara	5	19	1.52	0.91	1.36
Ryo	4	12	1.24	0.86	1.21
Lingram	4	5	1.33	0.95	1.86
Lingde	5	12	1.55	0.94	1.61
Aying	5	11	1.59	0.98	1.67
Gamte	5	9	1.43	0.83	1.82
Mede	7	17	1.88	0.93	2.12
Ginyo	3	5	1.06	0.96	1.24
Bhagdik	2	3	0.64	0.94	0.91
Dasi	2	13	0.43	0.77	0.39
Kete	3	9	0.68	0.66	0.91
Kudok	3	10	0.94	0.86	0.87

Kansal & Arora 2012). Further, the fish fauna recorded in the upper Subansiri River is similar to that of fishes reported from downstream of Subansiri in Assam. Eight species (*Aborichthys tikaderi*, *Exostoma labiatum*, *Neolissochilus nigrovittatus*, *Schistura devdevi*, *Schistura nagaensis*, *Schistura tirapensis*, and *Schizothorax progastus*) recorded from the upper Subansiri region are a new addition to Subansiri River fish list (Bakalial et al. 2014). The presence of recently described species *Psilorhynchus arunachalensis* in this region revealed that further inventory of remote areas is necessary.

At smaller scales, the habitat variables such as flow, riparian vegetation, water temperature and so on would determine the species composition in streams (Ricklefs 1987). The first step towards understanding the role of habitat variables on fish assemblages is categorizing streams into headwater and lowland streams on the basis of local factors in multivariate space. The results of PCA revealed that the streams of upper Subansiri River are categorized into headwater streams (with high altitude, low water temperature, good riparian cover, greater flow and rich dissolved oxygen) and lowland streams (with greater depth, width and high conductivity). The CCA results inferred that the distribution of few species such as *Schizothorax* sp., *Neolissochilus* sp., and *Exostoma labiatum* are strongly associated with pristine riparian vegetation, greater flows, and higher altitudes. Further, we observed that that species richness improved with an increasing order of stream volume or order as demonstrated by Platts (1979).

One could elaborate here that the PCA results and inferences drawn from the CCA are coinciding and are highly suggestive in that fish distribution in the upper Subansiri basin is primarily differentiated by the types of streams: smaller headwaters at high altitudes and rivers with larger volumes of water at comparatively lower heights. Stream volume was shown to be influencing species diversity by Gorman & Karr (1978); hydrological force, i.e., flow velocity selects species morphologically suited to such conditions (Suarez et al. 2011). Even in our study, the number of species increased with an increase in depth and to some extent with the increase of width. Loaches (*Aborichthys kempi*, *Schistura nagaensis*, and *Psilorhynchus arunachalensis*), snakeheads (*Channa* sp.), small barbs *Opsarius bendelisis* and *Danio rerio*) associated themselves with the depth and width vectors

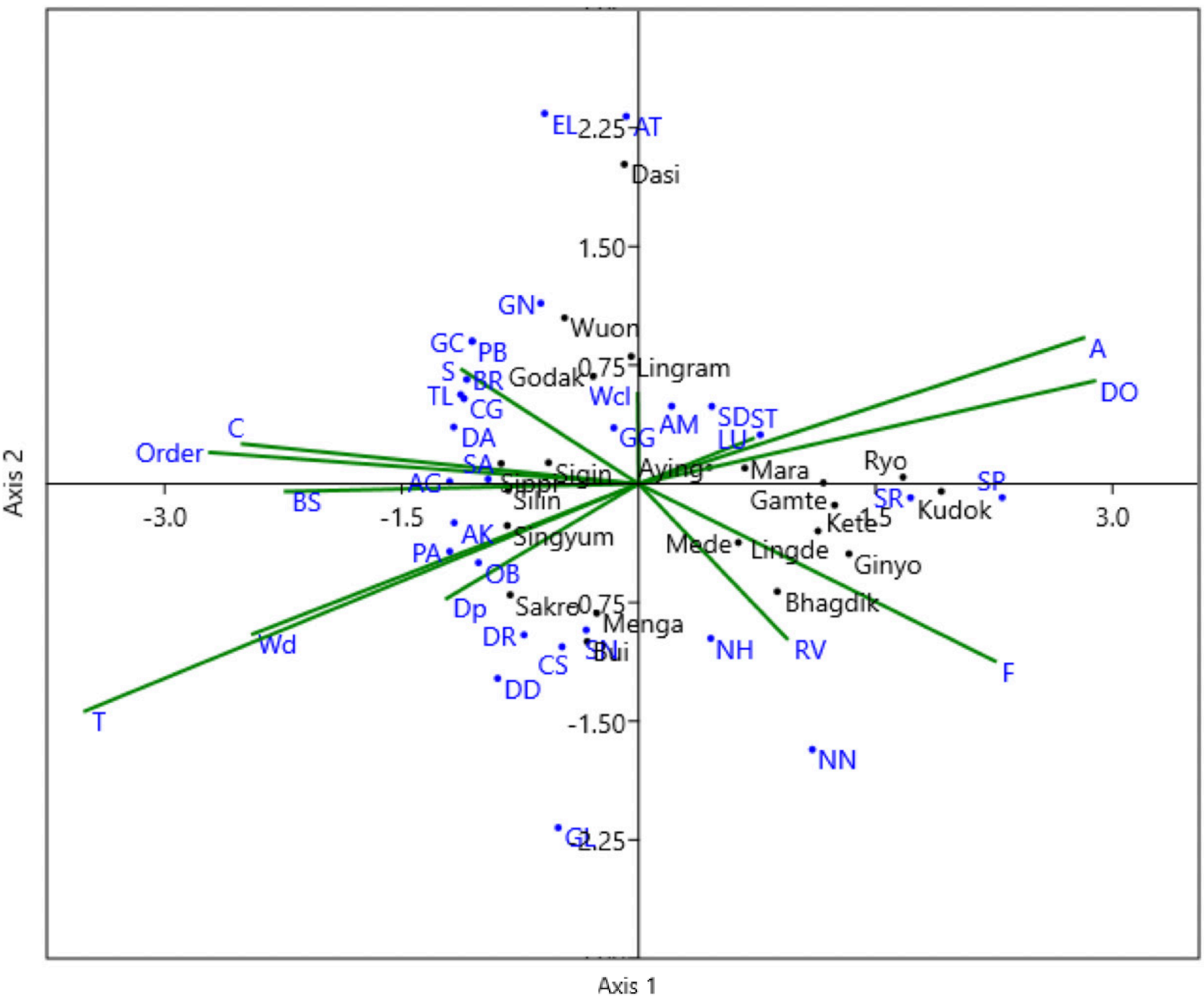

Figure 3. CCA tri-plot depicting the associations of streams and species to habitat variables: AK—*Aborichthys kempi* | AG—*Aborichthys garoensis* | AT—*Aborichthys tikaderi* | AM—*Amblyceps mangois* | BR- *Botia rostrata* | CG—*Channa gachua* | CS—*Channa stewartii* | DA—*Devario aequipinnatus* | DD—*Devario devario* | DR—*Danio rerio* | EL—*Exostoma labiatum* | GG—*Garra gotyla* | GL—*Garra lamta* | GN—*Garra nasuta* | GC—*Glyptothorax cavia* | NH—*Neolissochilus hexagonolepis* | NN—*Neolissochilus nigrovittatus* | OB—*Opsarius bendelisis* | PA—*Psilorhynchus arunachalensis* | PB—*Paracanthocobitis botia* | SD—*Schistura devdevi* | SN—*Schistura nagaensis* | ST—*Schistura tirapensis* | SP—*Schizothorax progastus* | SR—*Schizothorax richardsonii* | TL—*Tariqilabeo latius*.

of the CCA. Sites and species associated with depth, width, conductivity, temperature automatically had lower loadings on altitude, dissolved oxygen, land-use and flow velocity variable vectors.

The drainage of the river is unique regarding minimal human induced perturbations, landscape, biodiversity and habitat. People of the region are dependent majorly on the natural resources. Some basic advancement in the form of hospitals and roads can be seen, but with a poor quality of schools and very little awareness; one can expect a population surge soon. Along with these, the proposed hydropower plants in the upper region of the river basin are also going to irreversibly alter the riverine habitats and associated fish communities.

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