Original Research Article

Environmental factors associated with fish diversity in two tributaries of river chittar, Southern Western Ghats, Tamil Nadu, India

Abstract
The present study was conducted on Ichthyofaunal diversity with habitat preference and environmental factors in the Chittar River tributaries, Southern Western Ghats, Tamilnadu, in four seasons from 2019 to 2020. The species composition is comprised of 14 species representing 4 orders, 6 families, and 12 genera. Cyprinids were the most abundant group in the assemblage composition of fishes, which was approximately 61.5%-83.33%. According to the Shannon-diversity index of fish populations in the study streams, the upstream of New Falls and the Harihara river reveal a high species richness. Among the recorded fish species, Puntius arenatus, belonging to the family Cyprinidae, is in the vulnerable categories of the IUCN List. However, the fish species exhibited a higher density in the headwaters upstream and the density decreased in the downstream. However, bedrock and boulders were observed as the predominant substrates in upstreams (sites 1 and 3) throughout the seasons. The results of Principal Component analysis of water quality factors and fish abundance and species richness revealed that dissolved oxygen, total hardness, and alkalinity have less impact on fish abundance, whereas TDS and conductivity had a substantial correlation in all downstreams. Therefore, we conclude that anthropogenic threats faced by the fish species and their management strategies are discussed.
Keywords: Environmental factors, Ichthyofaunal diversity, Shannon diversity index, Principal component analysis.

1. INTRODUCTION

Freshwater fishes of a wide variety can be found in abundance in the Western Ghats and their related river effluents, and the region is designated as a Western Ghats Hotspot [1]. The global freshwater ecoregions rely on the distribution and composition of freshwater fish species [2]. Based on fish community structure and function, the diversity of fishes in river systems flowing through the southern Western Ghats [3]. Various research on fish assemblage structure and their requirements in Indian streams are also limited, despite a few initiatives started in south India in the 1980s [4]. Despite the fact that biotic and abiotic variables impact the variety and distribution of riverine fish assemblages [5]. These factors include, stream water levels , flow variability, geo-hydrological feature of the river [6], microhabitat heterogeneity [7] and to a certain degree, aggravated by urbanization and habitat alteration [8,9]. The fact that fish might operate as a virtuous choice for detecting the repercussions of deterioration leading to anthropic origin in aquatic systems is strongly supported [10], and far more systematic management in the region of endurances in the urbanized zone [11].

A primary specification of fish species was systematized based on an in-depth review of published literature. Authors published well-intentioned accounts of fish species available in India, the major publications being [3]. In this study, an efficient, specification of freshwater fishes across two tributaries of river Chittar was documented. There is no up-to-date record of Ichthyofauna diversity from the river Chittar therefore the author attempted to record the existing fish faunal diversity, habitat preference, and physicochemical parameters

of two tributaries of river Chittar, Tamil Nadu, India. This can strengthen the discovery of conservation urgencies for freshwater fish diversity in the region.

2. MATERIALS AND METHODS

2.1 Study site

The Chittar river, its five tributaries (Aluthakanni river, New falls tributary, Five falls tributary, Gundar tributary and Harikara river) and several other contributing small streams all originate in the Courtallam hills of Tenkasi District in the southern Tamil Nadu of India. The two other small tributaries of river Chittar namely Hanumannadhi and Karuppanadhi, which are confluence with river Chittar near Thaayarthoppu. The Chittar River, together with its tributaries and streams, provides as a significant source of irrigation for the region and is a prominent tributary of the Tambaraparani River. This study would be carried out in Chittar river which is located between latitude range 9°00'25.6"N - 8°55'26.7"N and longitude range 77°11'19.4"E - 77°17'12.0"E (Altitude range 520-580f) is in southern Tamil Nadu of India. It joins with a major river Tamiraparani near Sivelaperi, Tirunelveli district, South Tamil Nadu. The catchment of the streams is on the eastern slope of the Western Ghats which means it lays on the leeward side of the south-west monsoon. The forest region of the hills receives rainfall mostly during the south-west and north-east monsoon. In the present study was achieved from the selected sites in the two tributaries which have not been extensively surveyed so far for fish diversity. The selected four sites are New falls upstream (Site 1), downstream (Site 2) and Harihara river upstream (Site 3), downstream (Site 4) and these two tributaries are joins with river Chittar as shown in Fig. 1. New falls and Hariharariver upstreams are run through dense forests in the eastern slopes of the Southern Western Ghats and confluence with River Chittar in the plain regions.

2.2 Sample collections

Seasonal samplings from the four study sites were performed from January 2019 to February 2020, in four seasons as south-west, north-east monsoon, intermediate, and dry seasons. The samples were collected in four different habitat areas as water depth, width, flow and riparian cover of the river chittar during the day time for 2-4hours at each study site. The fishes were collected mainly using by mono filamentous gill nets with varying mesh sizes (6-13mm) and drag net. Visual surveys and identified using fish taxonomy textbooks (Jayaram, 2010). In the collected samples were preserved in 5-10% formalin, at Sri Paramakalyani Centre of Excellence in Environmental Sciences, Manonmaniam Sundaranar University, Alwarkurichi, Tamil Nadu.

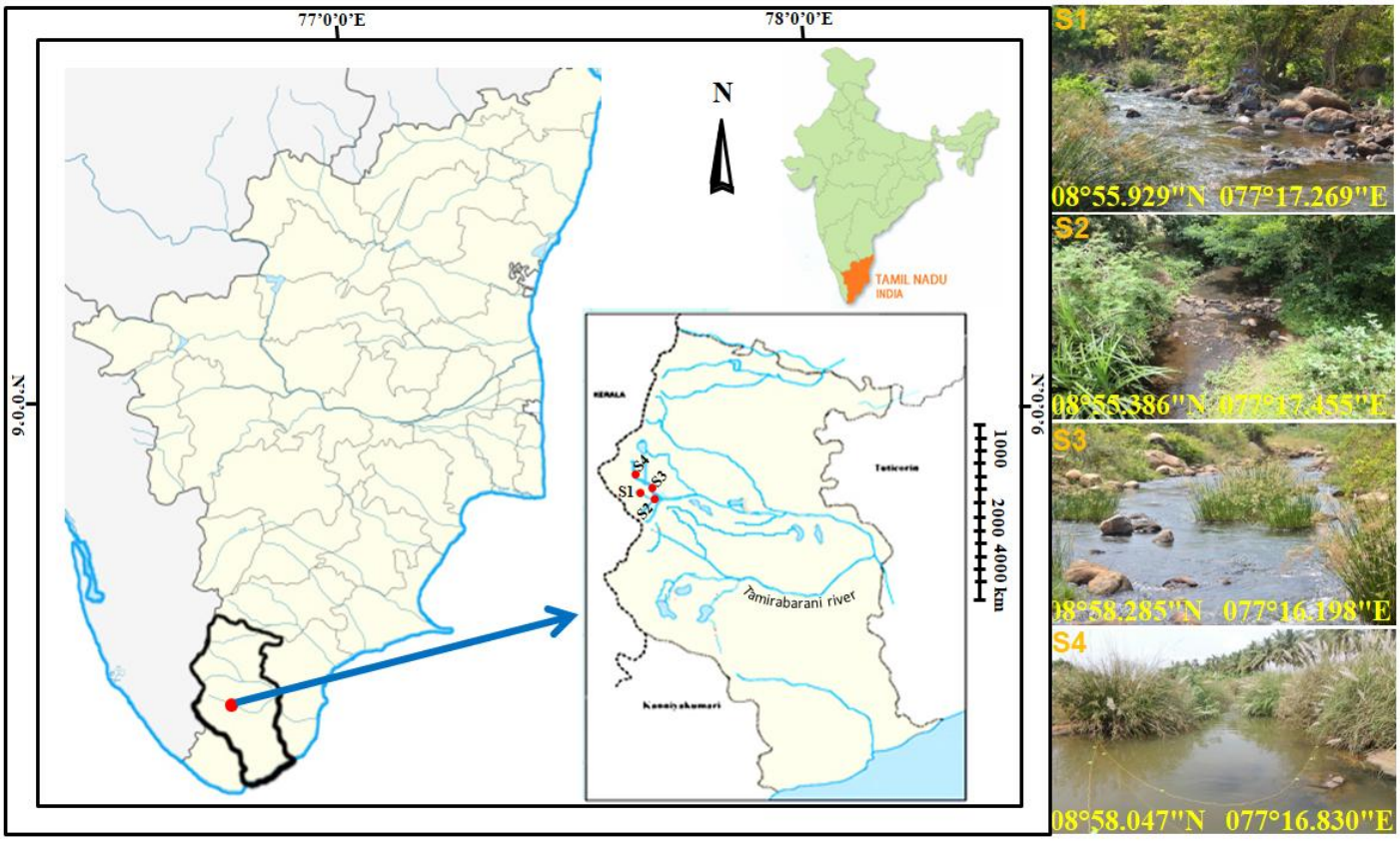

Figure 1. Map showing the selected study sites in two tributaries of river Chittar. Photographic evidence of the study sites with latitude and longitude as **S1-** New falls upstream; **S2-** New falls downstream; **S3-** Harihara river upstream; **S4-** Harihara river downstream.

2.3 Habitat and water quality analysis

The habitat parameters were taken by using the habitat inventory methods [12]. Although the particle size based on the Wentworth classification was grading substrate as bedrock, boulders, pebbles, gravels, sand, mud and leaf litter [13]. Water samples were collected from each study site, in 2Lplastic containers, labelled and transported to the research laboratory for examination. The physicochemical parameters were analysed by standard methods [14].

2.4 Data analysis

The Principal Component Analysis (PCA) based on habitat characteristics and Physico-chemical parameters with species richness, and substrate type were performed by using the recent software analysis of PAST (2.14). The fish Base website was referred and to evaluate habitat predilection, conservation status and trends IUCN websites were surfed.

Fish abundance data were subjected to diversity measures by counting the number of species in the habitat of the community, species richness (S). In this present investigation the number, the frequencies of the species have discoursed with the Shannon Diversity Index [15].

$$H' = -\sum pi.1n\ pi$$

Where H'= Shannon index; Pi= is the proportion of individual found of the species.

3. RESULTS

3.1 Fish diversity and species assemblages

During the period of the study from river Chittar, Out of 37 individuals was collected from four selected sites 32 species belonging to the order Cypriniformes. Species composition

comprised of 14 species representing 4 orders, 6 families and 12 genera were recorded from the study streams (Table. 1). Among them the family with the maximum number of representatives was Cyprinidae. Cyprinids were the most dominant group in the assemblage composition (61.5%-83.33%). However, the upstream of New falls (site 1) all the species were represented mostly the hill stream species such as *Garra mullya, Bhavania australis* and *Noemacheilus triangularis. Rasbora daniconius, Garra mullya, Amblypharyngodon microlepis* and *Dawkinsia filamentosa* were recorded throughout the study period. An exotic fish *Oreochromis mossambicus* was noted from the down streams site 2 and 4 in Table 1. Diversity was very low due to low species richness in down streams but in upstreams diversity was high. There was not much seasonality in the Shannon-Weiner diversity indices of the fish species was found highest indices values during the intermediate season except at site 1 were summarized in Table 2 and Fig 2. The most abundance and richness of fish species were greatest during the intermediate season, when all of the study streams was represented in Fig. 3 and Fig. 4.

Fish species in the study streams was exhibited higher density of the headwater upstreams and the density were decreased in the downstream. From that sites 1 and 4 recorded were highest and lowest density of the fish species as respectively (Table 4). Whereas, the fish species from cyprinids predominated in all of the study sites across the Chittar River.

3.2 Fish diversity vs. Habitat characteristics

Habitat characteristics from the study sites such as habitat traits and substrate type were noted Table 3. In all the sites, stream width was appeared high level in monsoon seasons compared to dry and intermediate season. Low depths were observed during dry seasons and the high depths were observed during the north-east monsoon and followed by the south-west monsoon. Streamflow was high during monsoon seasons compared to dry and intermediate periods. Substrate type in all the study sites was observed as the bedrock in predominant level and followed by boulders. Small boulders, sand with leaf litter were next to bedrock with different proportions during different seasons. In sites 1 and 3 (upstream), bedrock, and boulders were the major substrates in all the seasons. In sites 2 and 4 (downstream), sand and leaf litter and followed by boulders were the major substrates in all the seasons (Table 3).

Fish density, fish species richness, habitat area, habitat diversity, species diversity index, the relative abundance of cyprinids and percentage of Cyprinidae species were presented in Table 4. In all the sites, the stream habitat area was high range during the north-east monsoon season compared to the dry periods.

In order to determine the Principal Component Analysis was used to investigate the impact of habitat factors on fish species richness. The PCA demonstrated a distinct separation of fish species richness along with Substrates, Mean width, Depth (%), Flow (m/sec), and Riparian cover (%) was measured as different level at diverse study sites (Fig. 5). A total of 4 components were extracted with higher eigenvalue (13.91) were accounted to about 97.63% of the total variance at sites of New falls upstream (S1) andHarihara river upstream (S3). However, the seasonality of substrate characteristics such as bedrock's significant relationship with species richness was higher variance at study sites S1 and S2 during the intermediate season.

Table 1. An annotative specification of freshwater fish species known from the selected sites of river Chittar.

Order	Family	Genus	Species	Study sites				IUCN
				1	2	3	4	
Cypriniformes	Cyprinidae	Amblypharyngodon	*Amblypharyngodon*	*	*	*	*	LC

			microlepis (Bleeker, 1854)					
		Devario	*Devario aequipinnatus* (McClelland, 1839)	*	*	*	-	LC
		Rasbora	*Rasbora daniconius* (Hamilton, 1822)	*	*	*	*	LC
		Puntius	*Puntius bimaculatus* (Bleeker, 1844)	*	-	*	-	LC
			Puntius arenatus (Day, 1878)	*	*	*	*	VU
			Puntius sophore (Hamilton, 1822)	*	-	-	-	LC
		Dawkinsia	*Dawkinsia filamentosa* (Valenciennes, 1844)	*	*	*	*	LC
		Garra	*Garra mullya* (Sykes, 1839)	*	*	*	*	LC
	Cobitidae	Lepidocephalichthys	*Lepidocephalichthys thermalis* (Valenciennes, 1846)	*	-	*	*	LC
	Balitoridae	Noemacheilus	*Noemacheilus triangularis* (Day, 1865)	*	-	*	-	LC
		Bhavania	*Bhavania australis* (Jerdon, 1849)	*	-	-	-	LC
Cyprinodontiformes	Aplocheilidae	Aplocheilus	*Aplocheilus lineatus* (Valenciennes, 1846)	*	*	-	-	LC
Perciformes	Cichlidae	Oreochromis	*Oreochromis mossambicus* (Peters, 1852)	-	*	-	*	VU
Synbranchiformes	Mastacembelus	Mastacembelus	*Mastacembelus armatus* (Lacepede, 1800)	*	-	-	-	LC

Table 2. Diversity (Shannon- diversity Index) of fish population in Study streams

Sites	South-west monsoon	North-east monsoon	Intermediate season	Dry season
1	0.976	0.996	1.023	0.957
2	0.765	0.813	0.797	0.810

3	0.800	0.855	0.805	0.798
4	0.668	0.808	0.730	0.671

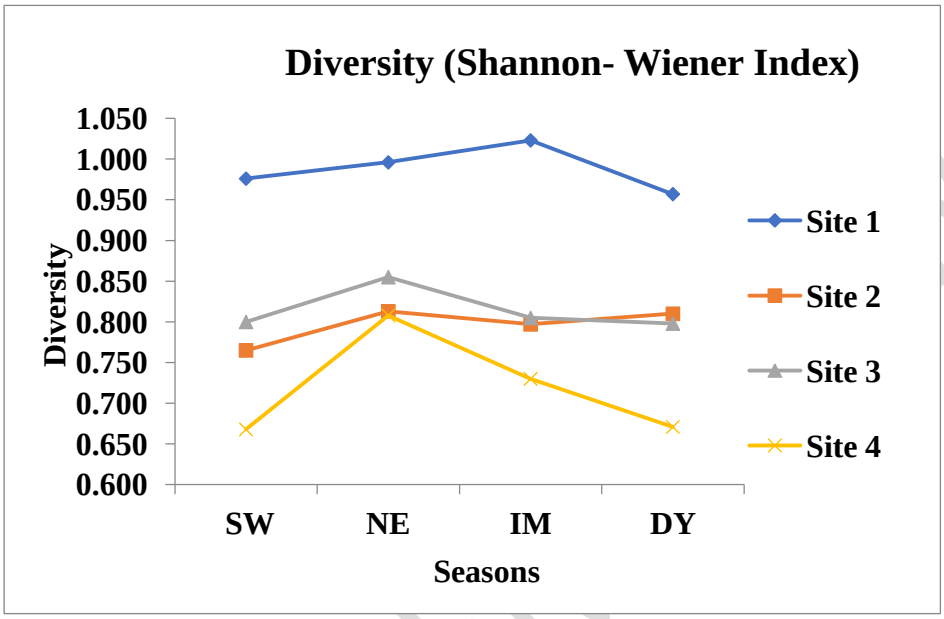

Figure 2. Shannon index of fish diversity in four seasons from the study sites of Chittar River and it indicates as SW – South-west Monsoon; NE – North-east Monsoon; IM- Intermediate; DY- Dry Season.

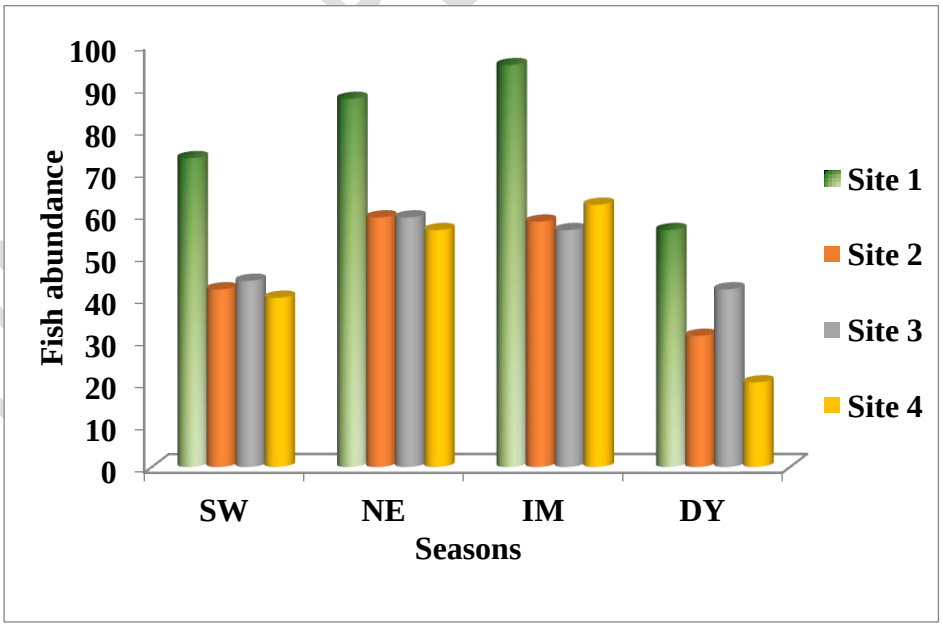

Figure 3. Abundance of fish species in the study sites of Chittar River. The results show as SW – South-west Monsoon; NE – North-east Monsoon; IM- Intermediate; DY- Dry Season.

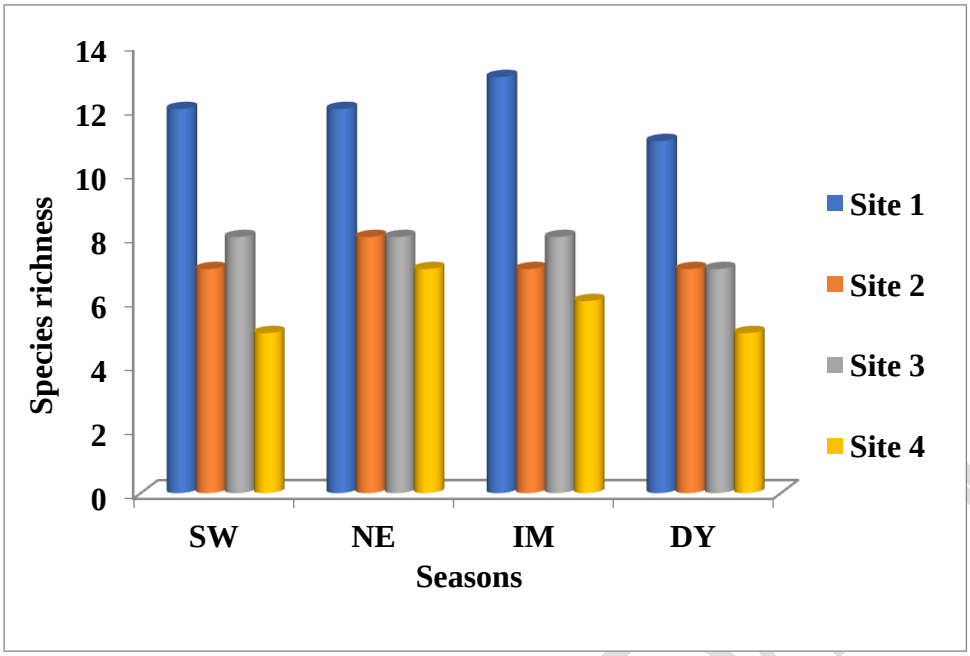

Figure 4. Fish species richness in four seasons from the study streams of Chittar River (SW – South-west Monsoon; NE – North-east Monsoon; IM- Intermediate; DY- Dry Season)

Table 3. Habitat characteristics of study sites such as habitat traits and substrate type were signified for four seasons.

Habitat traits	South-west (SW)				North-east (NE)				Intermediate (IM)				Dry (DY)			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Mean depth (m)	0.85	0.98	0.8	0.95	0.98	1.21	0.95	1.31	0.42	0.47	0.44	0.46	30	40	35	30
Mean width (m)	1.85	2.5	1.65	2.21	5	6	5.5	7.7	0.56	0.89	0.49	0.79	0.35	0.45	0.45	0.65
Flow (m/sec)	0.47	0.84	1.1	0.75	0.84	0.75	0.84	0.66	0.47	0.66	0.56	0.66	0.1	0.14	0.19	0.14
Riparian cover (%)	70	60	80	70	60	70	70	60	70	50	70	40	60	60	70	70
Substrate (%)																
Bedrock	35	25	40	25	35	25	40	25	35	25	40	25	35	25	40	25
Boulder	20	20	10	15	20	20	10	15	20	20	15	15	20	20	10	15
Small Boulder	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Gravel	10	10	10	10	10	15	15	15	10	15	10	10	5	10	10	5
Sand	15	20	10	25	20	20	20	30	15	20	10	20	20	25	20	35
Sand + Leaf litter	10	15	20	15	5	10	5	5	10	10	15	20	10	10	10	10

Table 4. Total fish density (100m. reach), habitat area, and indices of habitat diversity, relative abundance of cyprinid species, fish species richness and fish diversity in the study sites during four seasons

Parameters	South-west (SW)				North-east (NE)				Intermediate (IM)				Dry (DY)			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Fish density	73	42	44	40	87	59	59	56	95	58	56	62	56	31	42	20
Species richness	12	7	8	5	12	8	8	7	13	7	8	6	11	7	7	5
Habitat area (m^2)	185	250	165	221	500	600	550	770	56	89	49	79	35	45	45	65
Habitat diversity	0.825	0.814	0.755	0.778	0.778	0.879	0.834	0.828	0.816	0.836	0.775	0.841	0.79	0.775	0.75	0.733
Species diversity index	0.976	0.765	0.800	0.668	0.996	0.813	0.855	0.808	1.023	0.797	0.805	0.730	0.957	0.810	0.798	0.671
Relative abundance of cyprinids (%)	782.2	69	81.8	75	75.9	84.7	76.3	73.2	76.8	82.8	76.8	80.6	80.4	80.6	76.2	70
Percentage of cyprinid species	66.7	71.4	75	80	66.7	75	75	71.4	61.5	71.4	75	83.3	72.7	71.4	71.4	80

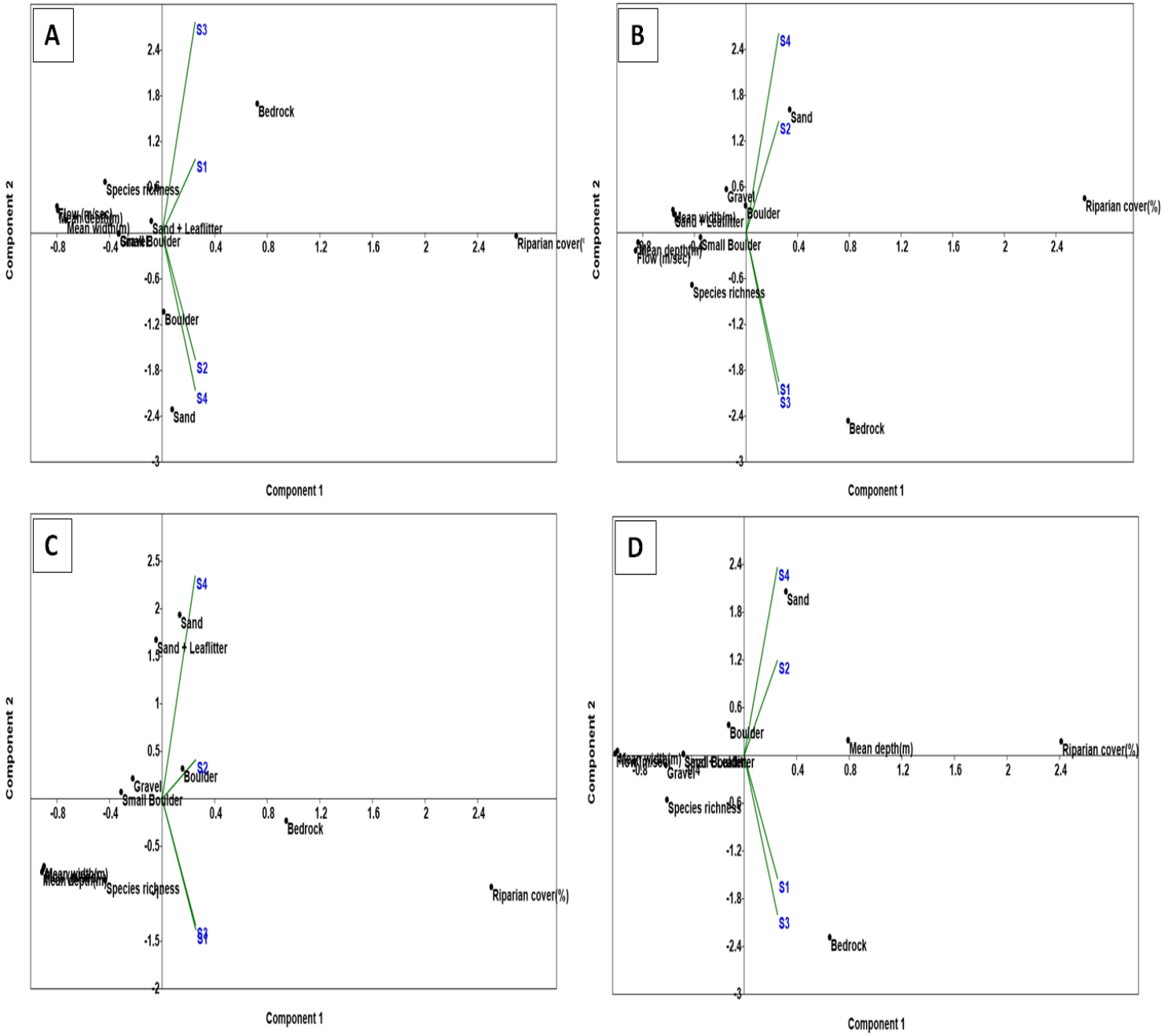

Figure 5. Principal Component Analysis (PCA) based on the fish diversity and habitat characteristics in four seasons from the study sites of Chittar river, Tamil Nadu (A- South-west monsoon; B- North-east monsoon; C- Intermediate season; D- Dry season).

3.3 Fish diversity vs. Physico-chemical parameters

Physico-chemical parameters of water laterally with Principal Component Analysis scores of fish abundance, richness and water quality parameters of study streams in four seasons were recorded. This study shows seasonal variations for the different Physico-chemical parameters of the study sites during the four seasons in Table 5. The humidity of the atmosphere was found to be almost similar during the south-west and north-east seasons. Lower values of alkalinity and hardness in Harihara river upstream and higher values of alkalinity and hardness downstream indicate the agricultural performance in the buffer zones in Table 6. In the results of Principal Component Analysis of water quality variables and the fish abundance

and species richness showed that higher eigenvalue (13.73) with total variance were explained as 93.36%. Notwithstanding that, the correlation of physico-chemical parameters with fish density and richness explained the significant proportion of the variance at S1 and S3 sampling locations during the intermediate season (Fig. 6). Despite the fact that dissolved oxygen, total hardness, and alkalinity had no impact on fish abundance, although TDS and conductivity exhibited a substantial relationship.

Table 5. Physico-chemical parameters of water from study sites during four seasons

Parameters	South west (SW)				North east (NE)				Intermediate (IM)				Dry (DY)			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
AT^{0}C	26	30	27	31	24	29	25	28	22.5	28	24	29	32	36	32	36
WT ^{0}C	24	27	24	28	23	28	23	26	21	24	23	26	28	30	27	30
DO (mg/l)	10	8	9	8.2	10.5	8.2	9.6	9	8	7.6	9	7.8	7	7	8.4	7.6
TH (mg/l)	26	42	19	44	28	60	18	42	25	60	20	64	19	36	22	62
TA (mg/l)	27	36	30	28	22	34	18	26	24.3	35	26	24	36	44	24	40
EC (µS/cm)	80	88	59.5	88	78.3	75	63.8	80	88	110	66.8	75	90	120	75	90
TDS (mg/l)	52	57.2	38.68	57.2	50.9	48.75	41.47	52	57.2	71.5	43.42	48.75	58.5	78	48.75	58.5

Table 6. Principal Component Analysis scores of fish abundance, richness and water quality parameters of study streams in different seasons.

Parameters	South-west (SW)		North-east (NE)		Intermediate (IM)		Dry (DY)	
	PCA I	PCA II	PCA I	PCA II	PCA I	PCA II	PCA I	PCA II
Fish abundance	1.656	0.490	0.348	0.817	1.078	0.553	1.655	0.419
Species richness	-2.534	0.406	-2.755	0.321	-2.612	0.299	-2.369	0.227
Air temperature ^{0}C	-0.196	-0.143	0.375	-0.048	0.085	-0.118	-0.098	-0.024
Water temperature ^{0}C	-0.392	-0.093	0.040	-0.043	-0.116	-0.131	-0.215	-0.047
Dissolved oxygen (mg/l)	-2.516	-0.064	-2.653	-0.200	-2.285	-0.086	-2.202	0.176
Total hardness (mg/l)	0.623	-0.824	0.266	-0.878	0.318	-0.530	0.421	-0.698
Total alkalinity (mg/l)	-0.099	-0.043	0.469	-0.157	0.186	-0.058	-0.247	-0.323
Conductivity (µ / mhos)	0.489	0.171	0.651	0.128	0.742	0.086	0.579	0.159
TDS (mg/l)	1.301	0.100	1.526	0.059	1.246	-0.016	1.098	0.111
Variance explained	2.803	0.145	2.899	0.204	2.415	0.091	2.316	0.111
Percentage of variance	93.774	4.842	92.702	6.519	95.456	3.588	94.638	4.549

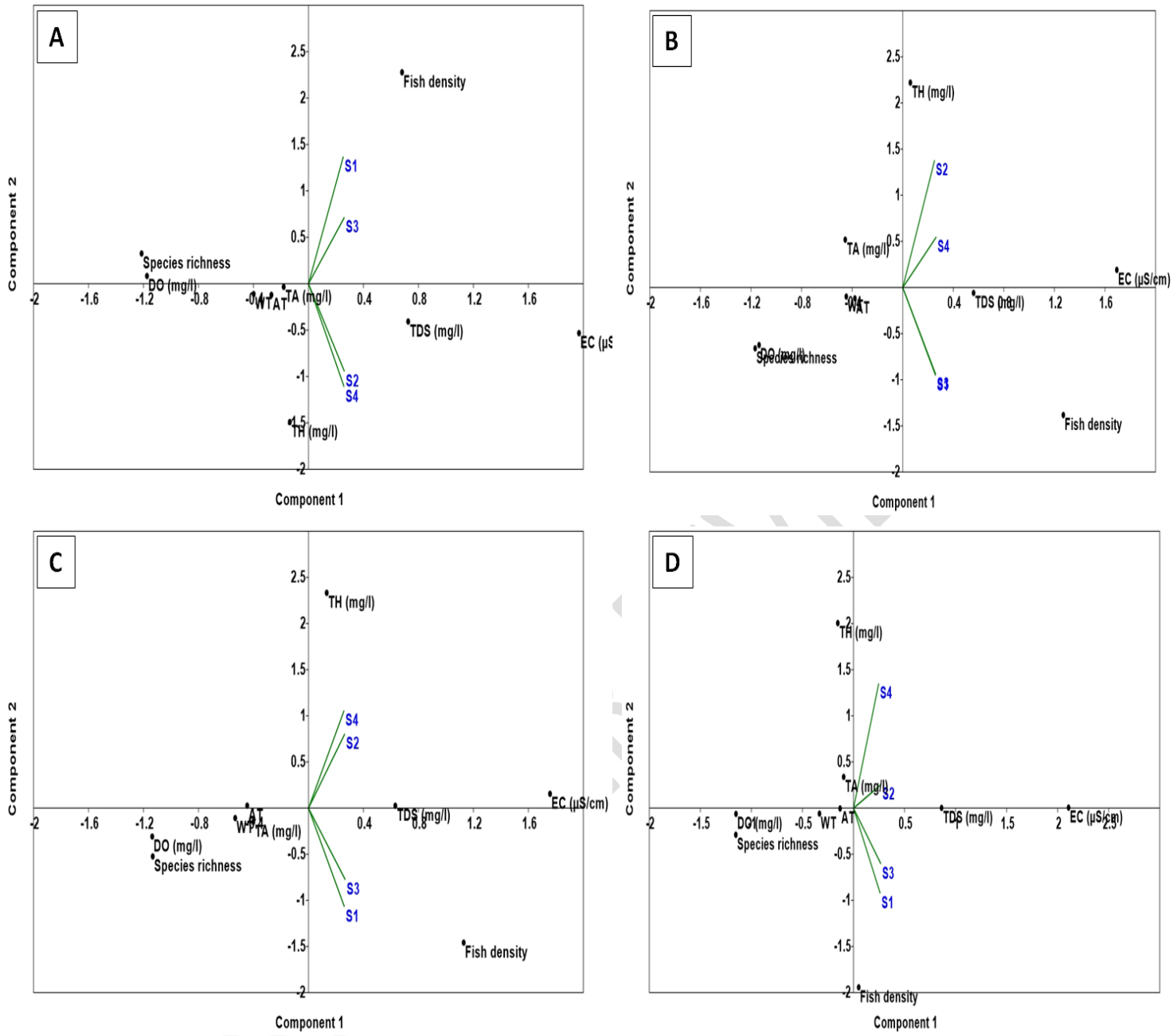

Figure 6. Principal Component Analysis Plot of fish abundance, richness and water quality parameters during four seasons from the study sites of Chittar river, Tamil Nadu (A- South-west monsoon; B- North-east monsoon; C- Intermediate season; D- Dry season).

4. DISCUSSION

In Chittar river tributaries, the fish assemblages encompass mostly cyprinids. Cyprinid dominance and their occurrence in pool habitats are common in Western Ghats streams of Peninsular India. Stream pools provide many niches to invertebrates and fishes due to their heterogeneity of substrate types, varied flow pattern, depth and the availability of food [16]. Riffle dwelling species such as *Bhavania australis* from New falls are also encountered in the present study. Fish species richness generally increases from upstream to lower reaches with varying complexity [17]. The great species diversity upstream of New Falls and Harihara river, however, is owing to the dense bank vegetation and intact natural vegetation in its upstream. Because of water diversion for agricultural purposes, anthropogenic disturbances

such as fish capturing, the presence of invasive species, and unlawful sand mining, downstreams have a lower species richness than upstreams.

The River Continuum Concept, originally postulated for aquatic invertebrates, predicts that there is an upstream-downstream gradient of changing physical conditions and associated biotic changes [18]. Varied environmental conditions such as widespread rainfall (both south-west and north-east monsoons) and cooler climate have played important role in diversity pattern and endemism in the Southern Western Ghats [19]. The diversity of fish species in the present study also fall in line with the earlier findings of other flora and fauna. The species richness of river fauna may be dependent on the accessibility of streams [20].

Cyprinids dominate the assemblage's structure as they occupy all possible habitats in the Western Ghats streams due to their high adaptive variability. In the present study, four of the documented species, *Devario aequipinnatus*, *Garra mullya*, *Dawkinsia filamentosa*, and *Rasbora daniconius* have extensive distribution in the Indian region and they are communal and abundant species in the Western Ghats streams [21]. Such widespread distribution and their high abundance propose that most of these species are proficient in enduring an extensive range of environmental conditions [22]. Larger numbers of individuals are commonly found in pool habitat with fewer, smaller individuals in shallow, unstable riffle habitat. However, the importance of habitat has already been identified as the primary basis for the organization of biological communities. Variations in species diversity at sampling stations suggested that changed environments supported fewer biological communities, whereas less disturbed sites were characterized by a diversified fish fauna in a range of environments, as the current study clearly demonstrated. Several studies have examined the structure of the fish community as well as an upstream and downstream gradient in order to forecast species richness based on measures such as altitude, order, stream gradient, and distance from the source [23]. Relationship with habitat diversity and fish diversity in New falls and Harihara river streams follows a similar pattern of habitat concept. Bedrock, boulders, and leaf litter with woody debris contribute to habitat complexity and are important components of fish habitats in headwater streams of Southern Western Ghats. As habitat degradation accelerates on a worldwide scale, maintaining species richness and biodiversity has emerged as a critical concern in conservation biology [24].

Despite the above, water physiochemical properties play a significant role in promoting fish diversity in freshwater habitats [25]. There have been several changes in the fish community, which may have an impact on the other components of the river ecosystem, including physical, chemical, and biological properties, either directly or indirectly [26]. According to Basavaraja et al. [27], seasonal variations in water quality indicators such as water temperature, pH, electrical conductivity, DO, BOD, and turbidity were investigated. Total hardness has been measured, and the state of freshwater fish richness and abundance has been determined. Hence, these studies indicates thatlower values of alkalinity and hardness in Harihara river upstream and higher values of alkalinity and hardness in downstream indicate the agricultural activities in the buffer zones. There is a great mixing of over runoff water from agricultural fields in this stream. Natural and anthropogenic impute for the higher alkalinity and TDS has already been documented [28]. Similar findings have also been available in upstream of New falls (Site 1). [29] has found a positive correlation of a particular fish assemblage with conductivity and total dissolved solids. In the present study similarly the conductivity and TDS have a strong association with fish abundance and fish density to all the seasons at study sites of S1 and S3.

Moreover, the physical stability, as well as anthropogenic behaviors such as overexploitation and the discharge of various types of contaminants, have a crucial component in the decreasing of fish diversity [30]. Although, the removal of substrates through illegal sand mining in the stream may have been responsible for the change in

channel flow at downstream of New falls and the Harihara river. Uncontrolled exploitation of surface waters results in a long-term decrease of the available water volume for fish habitation. There is an enormous mixing of overflow water from agricultural fields in this stream. The practice of dry season fish harvesting should be banned to save the native fauna. Our paper thus provides an initial step for a comprehensive study on the river fish fauna in the concerned study area in association with water quality and conservation studies.

5. CONCLUSION

In this study has revealed a database of freshwater fish diversity with their ecological structures in two tributaries of the Chittar river based on investigations at four sites from different seasons, which will serve as an authentic baseline for further management and conservation of biological diversity. Here, the assemblage structure of fishes has been substantially dominated by cyprinid family species. However, the distribution of fish species in relation to habitat features and physico-chemical parameters in upstream sites 1 and 3 comprised with bedrock and boulders, but in downstream sites 2 and 4, sand and leaf litter followed by boulders were the predominant substrates in all seasons. Despite this, the physicochemical parameters TDS and conductivity exhibit a substantial relation with fish species abundance and richness at S1 and S3 sampling sites, except in downstream study localities. In the present investigation was suggested as essential for the development of a sustainable management strategy for the downstream sampling locations. A faunal survey and regular monitoring have indeed been implemented as crucial for the conservation of freshwater fish species.

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