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Piscine diversity, Community structure and Distribution patterns of the West Ramganga River: A mid-Himalayan tributary of River Ganga

SHYAMAL CHANDRA SUKLA DAS[1], AMANULLAH KHAN[2], ABSAR ALAM [3], VINEET KUMAR DUBEY[4] and KRIPAL DATT JOSHI[5]

Regional Centre, ICAR-Central Inland Fisheries Research Institute, Allahabad, Uttar Pradesh 211 002 India

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ABSTRACT

The study documents the fish diversity, assemblage structure, distributional pattern and composition at different sampling sites along the stretches of the West Ramganga river of mid-Himalayas between 138 and 777 meters above sea level. Altogether 92 fish species representing 8 orders, 23 families and 64 genera were recorded. The most dominant family was Cyprinidae with 47 species (51%) followed by Bagridae with 7 fish species (8%). *Labeo* was the most dominant genera with 9 species, followed by *Barilius* (6), *Garra* and *Mystus* (4 species each). Species richness showed a trend of rapid decline along the altitude with highest records in the lowland sites, where ~93% of the total fish species recorded were between 138 and 320 masl. The Shannon Wiener Index (H') was found to be maximum at R6 (3.254) followed by R7 (3.24) and R8 (3.074) sites, all constituting the lowland stretch of the river. Species composition showed a distinct assemblage of cold-water specific genera at higher elevation sites based on clustering As per IUCN status, one species each of endangered (*Tor putitora*) and vulnerable (*Schizothorax richardsonii*) category was reported from the river, while 6 species reported, fell into near threatened category (*Tor tor*, *Labeo pangusia*, *Wallago attu, Ompok pabda, Hypophthalmichthys molitrix*, *Bagarius bagarius and Ailia colia*). The high fish species richness in the river Ramganga provides an updated information for the policy makers to plan suitable conservation measures which is currently lacking in most of the threatened freshwater ecosystems especially in the Himalayan river basin.

Key words: Altitude, Assemblage patterns, Fish diversity, Himalaya

In cold water ecosystems, the aquatic species must tolerate the adverse conditions to maintain its stable population for which several physiological and morphological adaptations such as low metabolic rates and hydrodynamic body forms are required (Winemiller *et al.* 2008; Bhatt *et al.* 2012). At present the rivers in the Indian Himalayan region harbour a rich diversity of about 266 fish species, including vast variety of threatened, migratory and endemic species (Nautiyal 2005; Froese and 2019). Currently, the Himalayan rivers are severely vulnerable owing to commissioning of dams for irrigation and electricity generation leading to the endangerment of several freshwater fish species (Joshi 2003; Sarkar *et al.* 2011; Bhatt *et al.* 2012; Joshi *et al.* 2014; Joshi *et al.* 2018). The Himalayan rivers are the preferred choice for hydro-power developers because of assured perennial flow, steep gradients and gorges with stable rocky banks (Joshi 2017a). Moreover, the Himalayan rivers like Indus, Ganga and Brahmaputra are of great importance to aquatic germplasms. The livelihoods and economies are now embarking upon an unprecedented scale of development. The rapid growing anthropogenic disturbance and their consequences is likely to be more complicated in future by several environmental challenges such as rising temperatures, shifts in runoff and precipitation patterns, which may pose a threat to the rich diversity of fish fauna.

River Ramganga is one of the major rivers of the Shiwaliks or Lower Himalaya which originates as two separate streams from Western and Eastern Ramganga and then flows down into the plains independently. The river is impacted due to dam at the uplands and pollution due to domestic waste and industrial effluents in the downstream at lowland areas (Khan *et al.* 2016). The river is considered to be rich in floral and faunal diversity including substantial number of endemic fish species (Joshi 1994; Atkore *et al.* 2011). Few studies have so far been conducted on the fish diversity and distribution covering the smaller portion of the river (Atkore *et al.* 2011). For sustainable utilization and conservation of fishery resources from this river, there is an urgent need to understand fish diversity and

Present address:[1]Scientist (scsdtin@gmail.com),[2]Ex- Senior Research Scholar (amankhanfish@gmail.com), [3]Scientist (absar_alam@rediffmail.com), [4]Ex- Research Associate (vineetkrdubey@gmail.com), Regional Centre, ICAR-Central Inland Fisheries Research Institute, 24-Panna Lal Road, Allahabad. [5]Principal Scientist (kdjoshi.cifri@gmail.com), ICAR-National Bureau of Fish Genetic Resources, Canal Ring Road, Lucknow.

distributional pattern. The documentation of fish species along with their distribution is crucial in formulation of the needed conservation plan. In this backdrop, the present study was carried with the aims (1) to document the current fish diversity and species composition, (2) to assess the similarity in species assemblage across the sampling sites ranged from highland to lowland areas, and (3) to investigate the current threats to the fish fauna and their conservation significance.

MATERIALS AND METHODS

Study area: West Ramganga river arises at an altitude of about 3,110 meters in the southern slopes of Dudhatoli (middle Himalayas) in the Uttarakhand state of India. The river is spring-fed, perennial and receives surface run-off from a catchment area of 32,493 km ^{2}. It lies between 29° 51' N and 80° 11' E. The length of the river from its source to the confluence with the Ganga is approximately 596 km. The study was carried out in 500 km river stretch from Bhikiasain (R1) in Uttarakhand state up to Dabri (R8) in Uttar Pradesh state of India. Ramganga during its course traverses more than 100 km before entering Corbett National Park near Marchula. Inside the park the river traverses about 40 km and comes out at Kalagarh where it enters the plain. A famous Ramganga dam has been constructed 26 km downstream of Kalagarh for irrigation and power generation in 1963–1973. Main tributaries of the river are Palain, Mandal and Sonanadi. It provides water for irrigation to 57,500 ha farm land and generates 198 MW of energy. On the downstream of this river another barrage named Harewali was constructed that diverts most of the water for irrigation and feed the main Ganga at Tighri ghat.

Sampling

Fish diversity of the river: Seasonal sampling of the river Ramganga for collection of fish and fishery data was conducted at 8 selected sites (R1 to R8) along the river (Table 1). The data on piscine diversity was collected through experimental fishing conducted at the selected sites using gill and cast nets of different sizes. Four different bottom-set mono-filamentous gill nets with varying mesh sizes (15 m long × 1.5 m wide; mesh size 12 mm, 16 mm, 20 mm and 24 mm) were used within 100 m reach for 3 hours. In the upland areas, cast nets (5.5 m^2) were casted 30 times at each reach (site) covering about 100 m^2 of river segment allowing 3–5 min settling time at each cast. Sampling was done between May 2014 to January 2015 covering summer, monsoon and winter seasons. Fish species identification was carried out using taxonomic literatures (Talwar and Jhingran 1991; Jayaram 2010).

Data Analysis: The Shannon and Weiner diversity index was calculated to compare the fish species diversity at different sampling locations of the west Ramganga river. The index used is a good representation of species richness across the sampling locations and widely used for prioritization of sites (Clarke and Warwick, 2001). The Diversity Index (Shannon and Weiner Index) was calculated using the formula

$$H' = -\Sigma\{p_i \times \ln(pi)\},$$

where, p_i is the proportion of total samples represented by species i, which is individuals of species i (n) divided by the total number of individuals found (N), ln is the natural log and Ó is the sum of the calculations.

Evenness (E) index

Evenness index is an important component of the diversity index, which measures the relative abundance of different species. The evenness (E) was calculated by using the formula

$$E = H'/InS,$$

where, H', diversity index; S, total number of species.

Silhouette analysis was used to assess the separation distance between the group of sampling sites based on ward and k-means clustering (Borcard *et al.* 2011) which was further represented by a dendrogram. The analysis was done in R version 3.0.2 (R Development Core Team2011). The threat status of all the species was based on IUCN criteria (IUCN 2019).

RESULTS AND DISCUSSION

A total of 5,580 fish individuals were collected during the investigation that belonged to 92 species, 64 genera, 23 families and 8 orders. Family Cyprinidae predominated the

Table 1. Description of the sampling sites and diversity indices along the stretches of the W. Ramganga river.

Sampling sites	R1	R2	R3	R4	R5	R6	R7	R8
Name of the site	Bhikiasain	Marchula	Afzalgarh	Hareoli	Agwanpur	Katghar	Chaubari	Dabri
Location	29°63'49" N, 79°26' 66" E	29°73'11"N, 79°25' 46" E	29°49'69" N, 78°75' 55"E	29°41' 92"N, 78°61' 93"E	28°56' 55"N, 78°43' 26"E	28°49' 22"N, 78°47'59"E	28°17' 15"N, 79°22'10"E	27°29' 52"N, 79°41'46"E
	Highland		*Middle*			*Lowland*		
Altitudinal levels	>777 m	560 m	320 m	230 m	192 m	189 m	160 m	<138 m
Number of individuals	477	38	1070	688	198	2025	534	550
Number of families	3	2	13	16	14	15	15	12
Number of genera	10	7	33	37	31	40	29	29
Number of species	18	9	41	42	37	48	33	34
Diversity								
Shannon (*H'*)	2.142	1.758	2.504	2.776	3.193	3.254	3.240	3.074
Evenness (J)	0·68	0.61	0.30	0.48	0.42	0.39	0.49	0.45

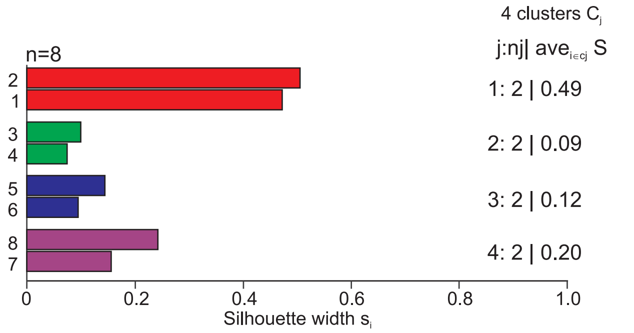

Fig. 1. Silhouette plot of the four groups based on ward clustering (Sampling sites 1 to 8)

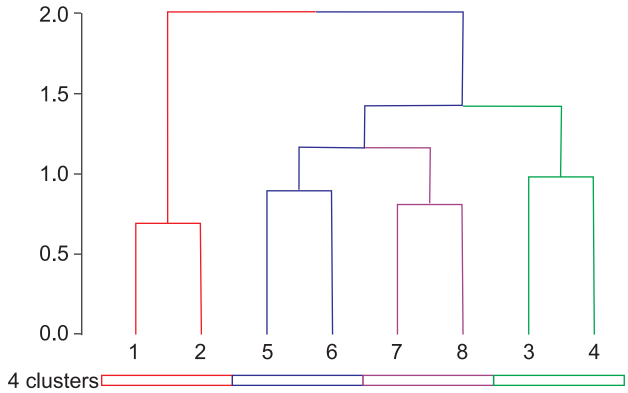

Fig. 2. Dendrogram of four clusters of fish species among different sampling sites (1 to 8).

collection with a total of 47 species (51%) followed by Bagridae with 7 species (8%). *Labeo* was the most dominant genera with nine species, followed by *Barilius* with six and *Garra* and *Mystus* with four species each. Approximately 25 species were recorded at least twice in the sampled river (Table 2). Out of the total species, four were exotic (*Cyprinus carpio*, *Ctenopharyngodon idella*, *Hypophthalmichthys molitrix* and *Hypophthalmichthys nobilis*). Among the exotic, *Cyprinus carpio* dominated the catch in the main River Ganga and its tributaries namely Yamuna, Ken, Betwa, and Sone (Joshi *et al.* 2014, Joshi *et al.* 2016, Joshi *et al.* 2017). The exotic fishes recorded in

Table 2. Occurrence of fish species at different altitudinal levels and sampling sites (R1-R8) in the river West Ramganga

Name of the Fish species	Sampling sites								Status
	R1	R2	R3	R4	R5	R6	R7	R8	
	Altitudinal levels								
	>777 m	560 m	320 m	230 m	192 m	189 m	160 m	<138 m	
Order-Cypriniformes									
Family-Cyprinidae									
1. *Cyprinus carpio* (Linnaeus, 1758)				+	+	+	+		EO
2. *Crossocheiluslatius latius* (Hamilton, 1822)	+	+							LC
3. *Labeo dyocheilus* (McClelland, 1839)	+	+				-			LC
4. *Labeo pangusia* (Hamilton, 1822)								+	NT
5. *Labeo calbasu* (Hamilton, 1822)				+	+	+		+	LC
6. *Labeo gonius* (Hamilton, 1822)					+				LC
7. *Labeo rohita* (Hamilton, 1822)						+			LC
8. *Labeo boggut* (Sykes, 1839)			+						LC
9. *Labeo boga* (Hamilton, 1822)							+	+	LC
10. *Devario devario* (Hamilton, 1822)				+	+	+	+	+	LC
11. *Labeo bata* (Hamilton, 1822)						+		+	LC
12. *Labeo angra* (Hamilton, 1822)			+		+	-		+	LC
13. *Bangana dero* (Hamilton, 1822)			+			+			LC
14. *Cirrhinus reba* (Hamilton, 1822)			+			+		+	LC
15. *Cirrhinus mrigala* (Hamilton, 1822)				+					LC
16. *Ctenopharyngodon idella* (Valenciennes, 1844)					+	+			NE,EO
17. *Hypophthalmichthys molitrix* (Valenciennes,1844)						+			NT, EO
18. *Tor putitora* (Hamilton, 1822)	+	+	+						EN
19. *Tor tor* (Hamilton, 1822	+								NT
20. *Tor mosal* (Hamilton- Buchanan)	+								
21. *Garra mullya* (Sykes, 1839)	+	+		+	+	+			LC
22. *Garra gotyla* gotyla (Gray, 1930)	+	+							LC
23. *Garra lamta* (Hamilton, 1822)	+								LC
24. *Garra annandalei* (Hora, 1921)	+								LC
25. *Esomus danricus* (Hamilton, 1822)				+	+	+		+	LC
26. *Chela cachius* (Hamilton, 1822)			+	+				+	LC
27. *Laubuca laubuca* (Hamilton, 1822)			+	+			+		LC
28. *Puntius sophore* (Hamilton, 1822)			+	+	+	+		+	LC
29. *Pethia conchonius* (Hamilton, 1822)			+	+		+	+	+	LC
30. *Pethia ticto* (Hamilton, 1822)	+		+	+	+	+			LC

Contd...

Name of the Fish species	Sampling sites								Status
	R1	R2	R3	R4	R5	R6	R7	R8	
	Altitudinal levels								
	>777 m	560 m	320 m	230 m	192 m	189 m	160 m	<138 m	
31. *Osteobrama cotio* (Hamilton, 1822)			+				+	+	LC
32. *Cabdio morar* (Hamilton, 1822)			+	+	+	+	+	+	LC
33. *Barilius gatensis* (Valenciennes, 1844)	+								LC
34. *Barilius vagra* (Hamilton, 1822)	+	+							LC
35. *Barilius bendelisisv* (Hamilton, 1807)	+	+	+						LC
36. *Barilius barna* (Hamilton, 1822)	+		+	+					LC
37. *Amblypharyngodon mola* (Hamilton, 1822)			+	+				+	LC
38. *Salmophasiap phulo* (Hamilton, 1822)			+						LC
39. *Hypophthalmichthys nobilis* (Richardson, 1845)			+	+					DD
40. *Gibelion catla* (Hamilton, 1822)					+	+			LC
41. *Chagunius chagunio* (Hamilton, 1822)			+		+	+	+		LC
42. *Raiamas bola* (Hamilton, 1822)	+		+						LC
43. *Securicula gora* (Hamilton, 1822)			+						LC
44. *Salmophasia bacaila* (Hamilton, 1822)					+	+		+	LC
45. *Barilius barila* (Hamilton, 1822)			+		+	+		+	LC
46. *Bariliuss hacra* (Hamilton, 1822)			+	+					
47. *Schizothorax richardsonii* (Gray, 1832)	+	+							VU
Family—Psilorhynchidae									
48. *Psilorhynchus balitora* (Hamilton, 1822)	+								LC
Family—Cobitidae	+								
49. *Botia lohachata* (Chaudhuri, 1912)				+		+		+	NE
50. *Lepidocephalichthys guntea* (Hamilton, 1822)			+	+	+	+			LC
Family—Nemacheilidae									
51. *Acanthocobitis boti*a (Hamilton, 1822)	+	+	+		+		+		LC
52. *Paraschistura montana* (McClelland, 1838)				+					NE
53. *Aborichthys elongates* (Hora, 1921)				+		+	+		LC
Order—Clupeiformes, Family—Clupeidae									
54. *Gudusia chapra* (Hamilton, 1822)			+					+	LC
Family—Engraulidae									
55. *Setipinna phasa* (Hamilton, 1822)							+		LC
Order—Osteoglossiformes, Family—Notopteridae									
56. *Notopterus notopterus* (Pallas, 1769)				+					LC
Family—Siluridae									
57. *Wallago attu* (Bloch & Schneider, 1801)			+	+	+	+	+	+	NT
58. *Ompok pabda* (Hamilton, 1822)				+					NT
59. *Sisor rabdophorus* (Hamilton,1822)	+	+	+	+					LC
Family—Bagridae									
60. *Sperata seenghala* (Sykes, 1839)			+	+	+	+	+	+	LC
61. *Sperata aor* (Hamilton, 1822)	+	+	+	+	+				LC
62. *Mystus vittatus* (Bloch, 1794)			++	+	+	+	+	+	LC
63. *Mystus cavasius* (Hamilton, 1822)					+	+	+		LC
64. *Mystus tengara* (Hamilton, 1822)				+					LC
65. *Mystus bleekeri* (Day, 1877)			+	+	+	+	+	+	LC
66. *Rita rita* (Hamilton,1822)					+				LC
Family—Erethistidae									
67. *Erethistes pusillus* (Müller & Troschel, 1849)	+		+						LC
Order—Beloniformes, Family—Belonidae									
68. *Xenentodon cancila* (Hamilton, 1822)			+	+	+	+	+	+	LC
Order—Siluriformes, Family—Sisoridae									
69. *Glyptothorax telchitta* (Hamilton, 1822)						+	+	+	LC
70. *Gogangra viridescens* (Hamilton, 1822)						+			LC
71. *Glyptothorax pectinopterus* (McClelland, 1842)					+	+	+		LC
72. *Gagata cenia* (Hamilton, 1822)						+	+		LC

Contd...

Name of the Fish species	Sampling sites								Status
	R1	R2	R3	R4	R5	R6	R7	R8	
	Altitudinal levels								
	>777 m	560 m	320 m	230 m	192 m	189 m	160 m	<138 m	
73. *Bagarius bagarius* (Hamilton, 1822)						+	+	+	NT
Family—Schilbeidae									
74. *Ailia colia* (Hamilton, 1822)					+	+	+	+	NT
Order- Perciformes									
Family-Ambassidae									
75. *Chanda nama* (Hamilton, 1822)			+	+	+	+	+	+	LC
76. *Parambassis ranga* (Hamilton, 1822)			+	+	+	+	+	+	LC
Family: Nandidae									
77. *Nandus nandus* (Hamilton, 1822)			+	+	+				LC
Family: Osphronemidae									
78. *Trichogasterfasciata* (Bloch & Schneider, 1801)			+	+				+	LC
Family: Channidae									
79. *Channa marulius* (Hamilton, 1822)			+	+					LC
80. *Channa striata* (Bloch, 1793)			+	+					LC
81. *Channa punctata* (Bloch, 1793)			+	+			+	+	LC
Family-Gobiidae									
82. *Glossogobius giuris* (Hamilton, 1822)				+	+	+	+	+	LC
Order-Synbranchiformes									
Family-Mastacembelidae									
83. *Mastacembelus armatus* (Lacepede, 1800)			+	+		+			LC
84. *Macrognathus pancalus* (Hamilton, 1822)			+	+		+	+		LC
Family-Claridae									
85. *Clarias batrachus* (Linnaeus, 1758)				+	+				LC
Family-*Heteropneustidae*									
86. *Heteropneustes fossilis* (Bloch, 1794)				+		+			LC
Family-Schilbeidae									
87. *Ailiichthys punctata* (Day, 1872)			+					+	DD
88. *Eutropiichthys murius* (Hamilton, 1822)					+	+	+	+	LC
89. *Eutropiichthys vacha* (Hamilton, 1822)						+		+	LC
90. *Clupisoma garua* (Hamilton, 1822)					+	+			
91. *Neotropius atherinoides* (Bloch, 1794)			+		+				LC
Order- Mugiliformes									
Family-Mugilidae									
92. *Sicamugil cascasia* (Hamilton, 1822)			+		+		+	+	LC

LC, least concern; EN, endangered; VU, vulnerable; DD, data deficient; NT, near threatened; EO, exotic in India.

the present investigation may spread and pose a threat to the endemic fish species in near future (Alam *et al.* 2015). The greatest species richness was found in lowlands at sites (R3-R8) <320 m and the lowest in the highlands at sites (R1and R2) >500 m (Table 1). About 93% of the total number of species recorded occurred between <320 and 138 m. Above this, the species addition was very slow (Table 1).

The freshwater fish diversity of 92 species documented in this study is far more as compared to previous studies (Atkore *et al.* 2011) in a segment of the studied river which also followed a well documented pattern of monotonic decrease in species richness and increase in taxonomic uniqueness with increase in elevation (Lomolino 2001; Rahbek 2005; Jaramillo-Villa *et al.* 2010; Súarez *et al.* 2011). The fish fauna of W. Ramganga river was much diverse (93%) at lower altitudes <320 which was replaced by entirely different community of coldwater fishes at higher altitudes. Similar findings were also recorded in studies of other Himalayan rivers (Atkore *et al.* 2011; Bhatt *et al.* 2012). However, despite several differences in fish species richness along with the altitudinal gradients, it is not yet clearly understood how the specific environmental factors, viz. topographic, geographic and climatic conditions in montane ecosystem affect the species loss and gain. In higher altitudes, basin area, water volume, velocity and temperature parameters are suggested to be the main causative factor which act as barriers to colonization of specific species at lower elevations in the other Himalayan Rivers (Atkore *et al.* 2011, Bhatt *et al.* 2012).

A total of eight species (8.6%) comprising *Wallago attu*, *Xenentodon cancila, Sperata seenghala, Parambassis ranga, Mystus vittatus, Mystus bleekeri, Cabdio morar* and *Chanda nama* were recorded from six sampling sites and were distributed below <320 m, i.e. middle to lowland altitudes. The reverse scenario was observed at the highest elevations (>560 m) where six species (6.5%) *Barilius gatensis, Garra annandalei, Garra lamta, Psilorhynchus balitora, Tor mosal,* and *Tor tor* were only distributed at 777 m and restricted to only one sampling site of highland altitude. As per IUCN status, *Tor putitora* was endangered (EN), 6 species (*Tor tor*, *Labeo pangusia*, *Wallago attu, Ompok pabda, Hypophthalmichthys molitrix*, *Bagarius bagarius* and *Ailia colia*) were near threatened (NT) and *Schizothorax richardsonii* was listed as vulnerable (VU). The silhouette analysis based on ward and k-means clustering produced 4 clusters with an average silhouette width of 0.22 (Fig. 1.). The sites R1 and R2 showed highest average of 0.49 and sites R3 and R4 showed the lowest 0.09 silhoutee width. The four clusters were then produced as a dendrogram to delineate the differences between the sampling sites (Fig. 2.). Though less in number, the fish species present in the high altitude zone (R1 and R2) are valuable since they have adaptations for living in torrential waters. Thus, it is important for conservation strategies to focus more on their habitat requirements and assemblage in restricted areas. This will support a large number of cold water specialist species that are restricted to isolated sections of the river. The restricted distribution depicts their physiological and morphological adaptations, including body shapes to reduce water resistance, suction cup like appendages for clinging to bedrock surfaces and waterfalls, and ability to hide under large sized boulders or reside in shallow waters habitats during floods and drought in the harsh highland Himalayan environments. Further, sites below 320 m, i.e. R3 to R8 were dominated by fish species of the families Cyprinidae, Siluridae, Belonidae, Ambassidae and Bagridae and associated with a range of habitat types, viz. step and backwater pools, rocky and fine substrates and large river width.

The study clearly revealed that the changes in the composition of functional groups along the elevation gradient are similar to the changes in habitat characteristics with increasing elevation (Fu *et al.* 2004, Graham *et al.* 2014). However, some coldwater genera of *Acanthocobitis, Paraschistura, Botia* and *Garra* depicted long range of distributions from lowland areas to higher altitudes. Changing environmental conditions in the tropical rivers due to anthropogenic and natural factors is greatly influencing fish assemblage patterns of the freshwater species. A baseline study by Sarkar *et al.* (2011) described a significant shift in distribution of several cold water genera from the upper cold water region towards the plains in river Ganga which was possibly due to changes in the hydrology as well as increase in water temperature due to changing climatic conditions. Vass *et al.* (2009) also reported an increase in annual mean minimum water temperature in the upper cold-water stretch of the river (Haridwar) by 1.5°C (from 13°C during 1970–1986 to 14.5°C during 1987–2003) and by 0.2–1.6°C in the aquaculture farms in the lower stretch in the Gangetic plains.

The results of this study assume more significance because of the ongoing large scale development including water discharge, habitat fragmentation, illegal fishing and damming with multiple dam projects are being planned in the Himalayan rivers (Joshi 2007; Pandit 2009; Joshi *et al.* 2016; Joshi 2017a and 2017b; Joshi *et al.* 2017). Therefore, studies need to be conducted to develop a knowledge management system with current diversity patterns and spatial distribution data for the Himalayan rivers. In addition, such information would be critically important in understanding the effects of environmental change on the various fish species through range shifts of endemic species and range expansions of invasive fish species only when proper compiled data of past and present distribution are available (Vass *et al.* 2009). Some of the fish species like *Schixothroax plagistomus, Schistura rupecula, Puntius chelynoides, Balitora brucei, Channa gachua and Pseudechenes sulcatus,* earlier reported from this river by Joshi (1994) were not found in our study.

Owing to diverse aquatic habitats from up to downstream, the river Ramganga harbor rich fish diversity comprising coldwater to warm waters. The presence of restricted range specialized species in the upper coldwater region along with some threatened species makes it more vulnerable in view of ongoing climatic and anthropogenic disturbances. The result presented herein provides an updated checklist of the available fish fauna in the west Ramganga River which is currently threatened due to ongoing development and illegal fishing activities. The rich diversity of threatened and commercially important fishes offers new information to plan suitable conservation measures which is currently lacking in most of the threatened freshwater ecosystems specially in Himalayas. Further, inclusive studies are needed to determine the ongoing interaction of climate, physico-chemical factors and human land use on fish community structure.

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