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Research Article

ASSESSMENT OF ICHTHYOFAUNAL DIVERSITY AND IDENTIFICATION OF HABITAT SPECIALIST FISHES ALONG ALTITUDINAL GRADIENT IN RIVER MURTI, WEST BENGAL

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ABSTRACT

Despite of being rich in fish biodiversity, the freshwater resources of India are currently experiencing an alarming decline due to several factors. River conservation and management activities in most countries, including India, suffer from inadequate knowledge of the constituent biota. This emphasizes an immediate need for initiating global research to develop alternative conservation planning schemes to protect the biodiversity of these freshwater aquatic systems. So, the present study was aimed at monitoring ichthyofaunal diversity, richness and abundance of river Murti in relation to different habitat types. Fishes were collected from four different sites along altitudinal gradient in river Murti, West Bengal. Key parameters responsible for structuring such habitat types and fish assemblage pattern were also assessed to identify habitat specialist fish fauna. A total of 40 species representing 27 genera, 16 families and 5 orders were collected, where Cyprinidae was found to be the most abundant fish family followed by Channidae and Mastacembelidae and the fish assemblage was found to be most diverse at the plains compared to hilly terrains. Whittaker's β diversity showed highest value between the sites situated at highest and lowest altitude. Four species namely *Neolissochilus hexagonolepis* (McClelland, 1839),*Garra gotyla gotyla* (Gray, 1830), *Acanthocobitis botia* (Hamilton, 1822) and *Danio dangila* (Hamilton, 1822)were found to prefer four different sites and may be termed as habitat specialists. Such thorough understanding of this aquatic system and its biodiversity may assist in decision making and policy framing that lead to sustainable water use practices.

Keywords: Altitudinal gradient, Conservation, Ichthyofaunal diversity, Habitat specialist, Whittaker's β diversity.

INTRODUCTION

Biodiversity plays an indispensable role in ecosystem stabilization, preserving overall quality of the associated environment and understanding intrinsic worth of all species on the earth (Ehrlich and Wilson, 1991). Moyle and Leidy (1992) observed that decision making to reduce confrontational effects of anthropogenic activities and framing policies that promote sustainable use of water resources solely depend on understanding of the aquatic ecosystem and its biodiversity. Lenders *et al.* (1998) established the importance of reference and target images in ecological recovery of riverine systems.

The alteration of aquatic ecosystem is thought to be a major factor in structuring pattern of fish assemblage (Resh *et al.*, 1988; Poff and Ward, 1989) and may be responsible for extinction of numerous species. In this regard, a close association between structural characteristics of the lotic environment and occurrence of fish species has been found. Shelford (1911) identified habitat features as major determinants in distribution and abundance of fish fauna. Later in North America, studies on behaviour patterns of individual fish species along with entire fish assemblages were carried out (Winn, 1958; Smart and Gee, 1979; Baker and Ross, 1981) and the fact that Fish diversity is correlated with habitat complexity of depth, flow and substrate types (Schlosser, 1982) were established. The impact of these habitat attributes in ecosystem functioning and structuring fish assemblages in various streams has been studied in detail at different

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latitudes (Angermier and Karr, 1984; Angermier, 1987; Hugueny, 1989; Degerman and Sers 1992; Pusey *et al.*, 1993; Leveque, 1997).

Extensive literatures on the freshwater fishes of Asia mostly provide emphasis on taxonomy or focus towards the capture fisheries and aquaculture. Qualitative and quantitative estimation of resource and ecology of ichthyofauna remain unassessed in much of Southeast Asia (Welcomme, 1987). Similarly, studies on freshwater fishes in India are concentrated mostly on culture or capture fisheries (Jhingran, 1975) and taxonomy (Jayaram, 1981; Datta and Munshi and Srivastava, 1988; Talwar and Jhingran, 1991; Menon, 1992). Even some scattered works on commercial fisheries remain restricted largely to the major river systems of the Indian subcontinent, specially the Ganges and the Yamuna. Apart from a few studies in south India (Bhat, 2003; Sreekantha, 2007; Shinde 2009; Radhakrishnan and Kurup, 2010) and in Arunachal Pradesh (Bagra and Das, 2010), data on fish assemblage structure in correlation with their habitat prerequisites in Indian streams are lacking.

Despite of harbouring diversified ichthyofauna, the scenario is similar in studies on freshwater fishes of West Bengal, as most of the literatures are restricted to a few well-studied locations only. Some of the valuable abundance data were available for perennial water bodies in Midnapore district (Bhakta and Bandyopadhyay, 2008) and Karalariver in Jalpaiguri district (Patra and Datta, 2010) in West Bengal. Moreover, scarcity of information on distribution, population dynamics, threat status, ecology, behaviour, survival strategy of our valued fish fauna poses a major gap in complete acquaintance of the riverine system, thus causing an alarming decline in freshwater fish biodiversity due to absence of a proper knowledge base (Chaudhuri, 2022). The present study was aimed at monitoring ichthyofaunal diversity, richness and abundance in river Murti in relation to different habitat types. Key parameters responsible for structuring habitat types and fish assemblage pattern along altitudinal gradient were also assessed to identify habitat specialist fish fauna. An understanding of the aquatic system and its biodiversity may assist in making decisions to minimize adverse impacts of anthropogenic activities and frame policies that lead to sustainable water use practices.

MATERIALS AND METHODS

Study Area and Fish Sampling

River Murti originates from the Mo forest (near the Neora Valley National Park) in Darjeeling Himalayas (2211m above sea level or asl) flowing its way along the foothills in Jalpaiguri district and finally meets the Jaldhaka River (102m asl). The area studied lies along altitudinal gradient at a hilly terrain of Rocky Island (27 °00.483′ N 88°48.107′ E) (S1), Samsing (26 °59.014′ N 88°49.291′ E) (S2) where the river reaches the plains and two sites in the plains of North Dhupjhora (26 °50.631′ N 88°49.704′ E and 26 °49.41′ N 88°49.33′ E) (S3 and S4) that is named after the River Murti (Table 1, Figure 1). Although not toodistant from S3, S4 is characterized by its lentic ecosystem offering a completely different aquatic environment unlike the other three sites of the hill stream. Monthly sampling was carried out for 3 years in the river at the sampling sites (for a stretch of 2km) using cast net (mesh size of 1cm and covering an area of about 4.5m²) and gill net (20m in length with 3cm spacing between adjacent knots). The specimens were retrieved from the net and identified morphologically to the lowest taxonomic level (Shaw and Shebbeare, 1937; Day, 1958 and Talwar and Jhingran, 1991). All species names adhere to Fishbase (Froese and Pauly, 2022).

Data Analysis

In order to assess icthyofaunal diversity in the river Murti in association with habitat structure some of the following diversity indices were computed using Past3. These were Shannon-Weaver index (H′) (Shannon and Weaver, 1949), Species evenness or equitability (J′) (Pielou, 1969), Dominance index (D) (Berger and Parker, 1970) and Species richness (Margalef, 1958). Whittaker’s beta dissimilarity was calculated using MS Excel (Van Dyke, 2008). The data was normalized prior to analysis wherever required. The variations in fish assemblage structure at different sites were graphically represented by the application of cluster analysis based on Bray-Curtis similarity index (King, 1964). To overcome sampling errors, non-parametric methods like Jacknife and Bootstrap estimators were used to ascertain actual species richness.The dissimilarity among different habitats in terms of fish assemblage structure and environmental parameters were analysed by Multidimensional Scaling. Principal Component Analysis (PCA) was carried out using PRIMER (Version 6.1.15) to find out principal environmental factors responsible for structuring habitat types.

RESULTS AND DISCUSSION

Four different sites along altitudinal gradient of Murti river were chosen for ichthyofaunal sampling, which resulted in the capture of a total of 40 species representing 27 genera, 16 families and 5 orders (Table 2).Cyprinidae (52.5%) was found to be the most abundant fish family followed by Channidae (10.0%) and Mastacembelidae (5.0%) (Figure 2). The fish assemblage was found to be most diverse (total 35 species) at Site 3 with 17 species belonging to Cyprinidae, 4 species belonging to Channidae, 2 species belonging to Mastacembelidae and 1 species belonging to Nemacheilidae, Cobitidae, Psilorhynchidae, Amblycipitidae, Chacidae, Clariidae, Bagridae, Olyridae, Badidae, Ambassidae, Osphronemidae and Belonidae (Figure 3). The diversity of fish assemblage (total 21 species) was found to be relatively less at Site 4 with 9 species belonging to Cyprinidae, 4 species belonging to Channidae, 2 species belonging to Mastacembelidae and 1 species belonging to Nemacheilidae, Chacidae, Clariidae, Badidae, Ambassidae and Belonidae (Figure 3). In Site 2, the fish diversity (total 17 species) was comparable with Site 4 though species composition was found to be different with 13 species belonging to Cyprinidae and 1 species belonging to Psilorhynchidae, Amblycipitidae, Olyridaeand Erethistidae (Figure 3). Fish species richness was found to be lowest (total 7 species) in Site 1 with 7 species belonging to Cyprinidae.

A total of 40 species were recorded in river Murti whereas S estimator value is calculated to be 50 by combination of resampling methods namely Jacknife and Bootstrap method which projects an acceptable difference between the observed sampling values and the estimated sampling size (Figure 4).The fish diversity was also analysed from diversity estimators conducted by DIVERSE function in Primer E (Table 3). The Shannon-Weaver index was found to be highest at Site 3 (2.963) and the least at Site 1 (1.792) with progressive declining trend from Site 4 (2.716) to Site 2 (2.592) suggesting the existence of more diverse fish assemblage at the plains compared to hilly terrains. Similarly, S3 was most species rich (4.260) with S4 (2.882), S2 (2.234) and S1 (0.8841) showing progressive declining trend. Species evenness values indicated that species are quite evenly distributed at all the sites as evident from the values ranging from 0.98 at Site 1 to 0.95 at Site 3. Site 3 and Site 4 showed least values of dominance (0.07296 and 0.08005 respectively) while greater species dominance was found in Site 1 and Site 2 (0.1894 and 0.09108 respectively). Whittaker's β diversity at the four sampling sites in river Murti showed highest value between S1 and S4 (1) and lowest value between S3 and S4 (0.429) (Table 4).

The similarity in fish species composition among four different sites along altitudinal gradient was analysed using the Bray-Curtis similarity index to calculate the extent of similarity between pairs of data sets. The similarity in species composition across different sampling sites was shown as a dendogram using the complete linkage method. The hierarchial cluster analysis showed a close resemblance of species composition with lowest similarity coefficient being 50.At that level of similarity site 1 and site 2 were closer than site 3 and site 4 (Figure 5). Whittaker's β diversity showed highest value (1) between S1 and S4 with progressive declining trend between S2 and S4 (0.944), S1 and S3 (0.921), S2 and S3 (0.692), S1 and S2 (0.588) and S3 and S4 (0.429).Therefore variation in species assemblage at different sampling sites was fully perceived.

Figure 1. Course of River Murti with four sampling sites.

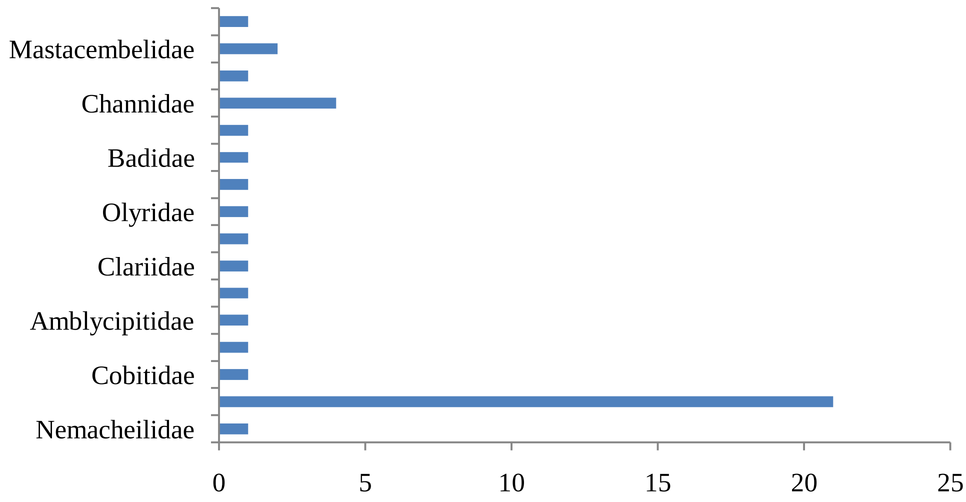

Figure 2. Graph showing species abundance of each fish family in river Murti.

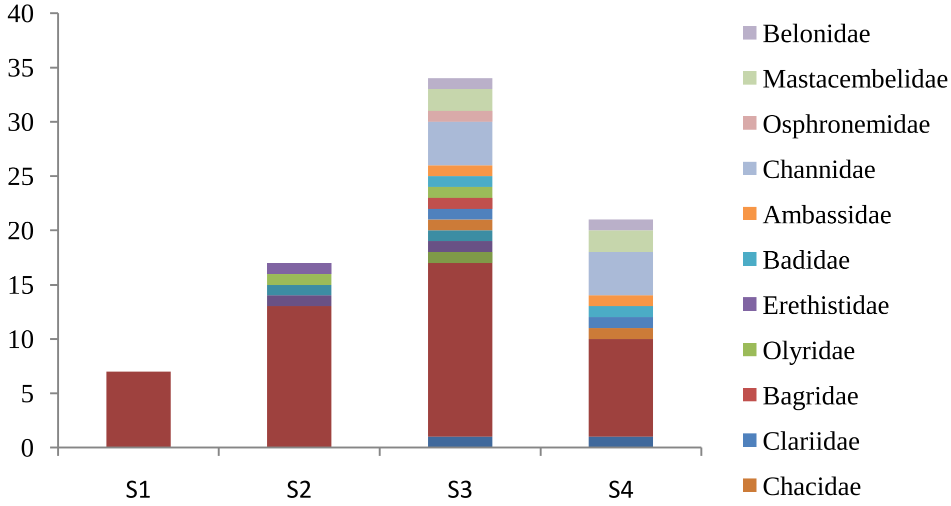

Figure 3. Abundance of existing fish family at different sampling sites in river Murti.

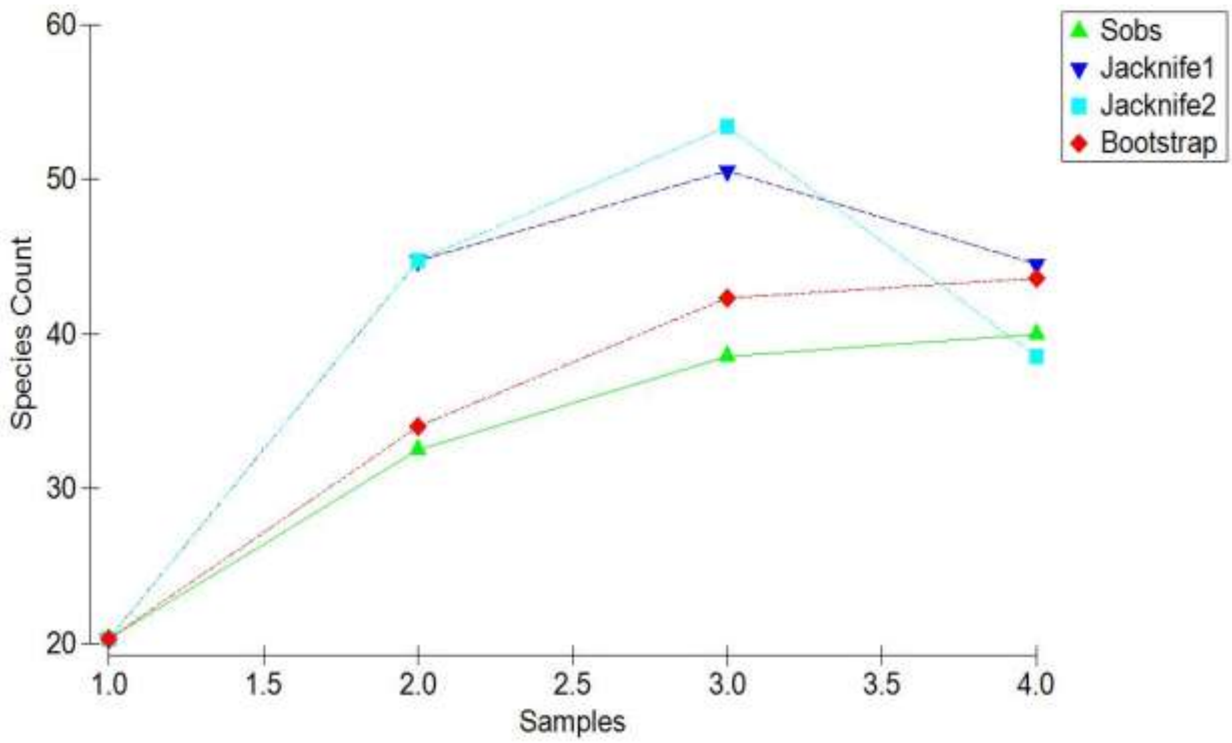

Figure 4. Species accumulation curve.

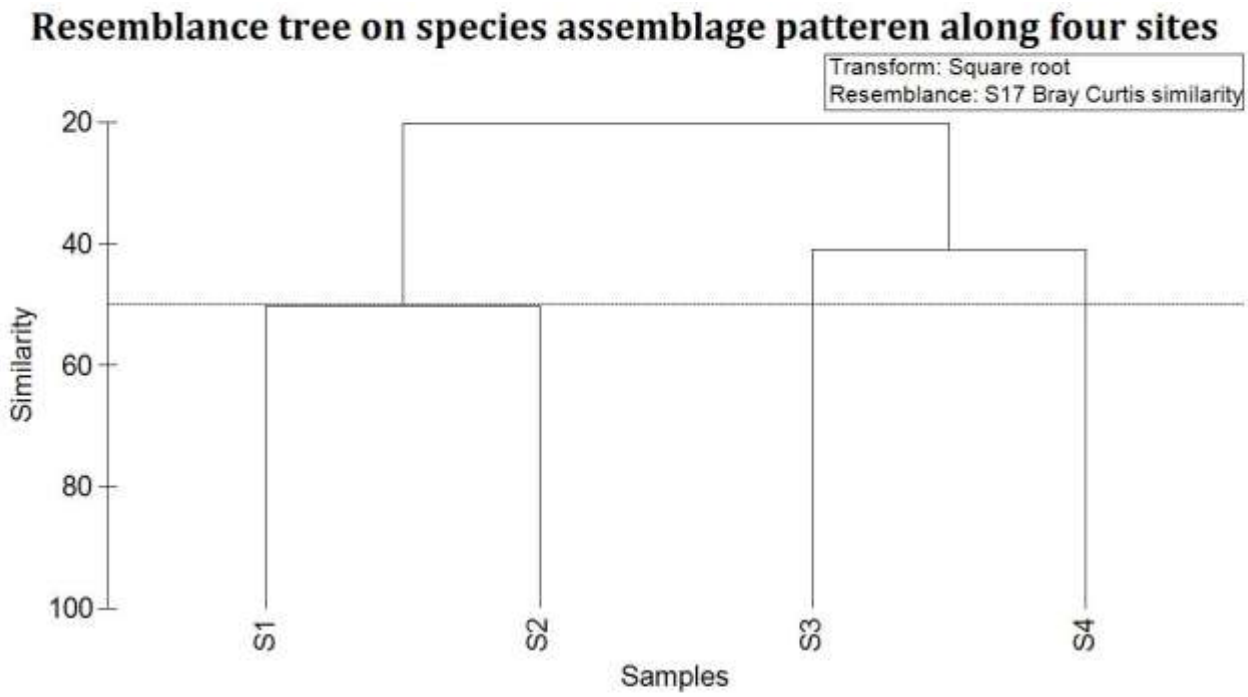

Figure 5. Resemblance tree on species assemblage pattern along four sites in river Murti.

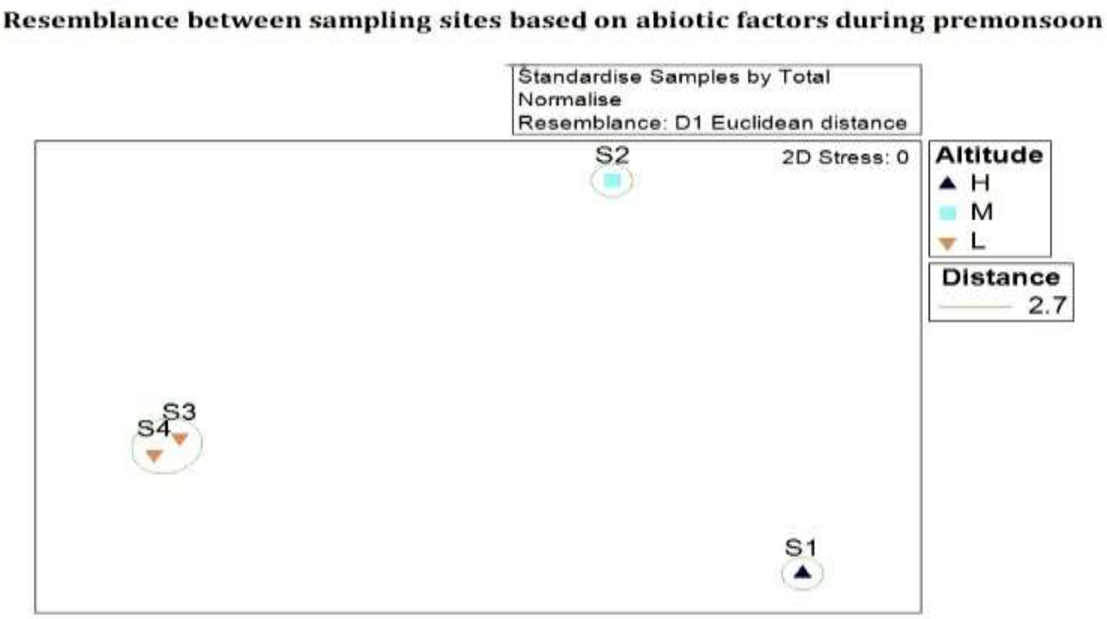

Figure 6. Resemblance between sampling sites in river Murti based on abiotic factors during pre-monsoon.

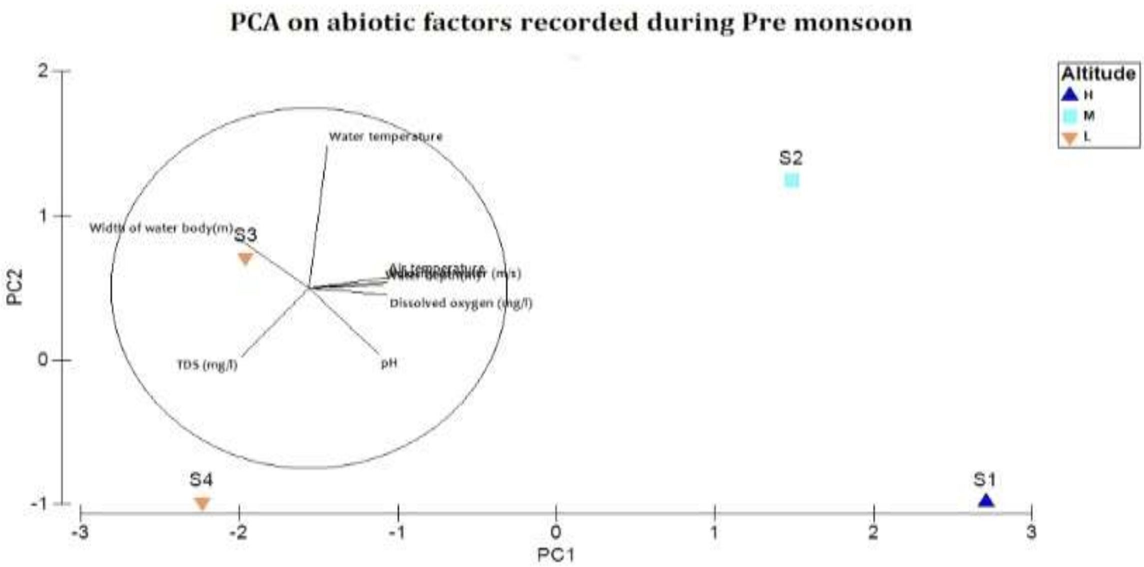

Figure 7. PCA on abiotic factors in river Murti during pre-monsoon.

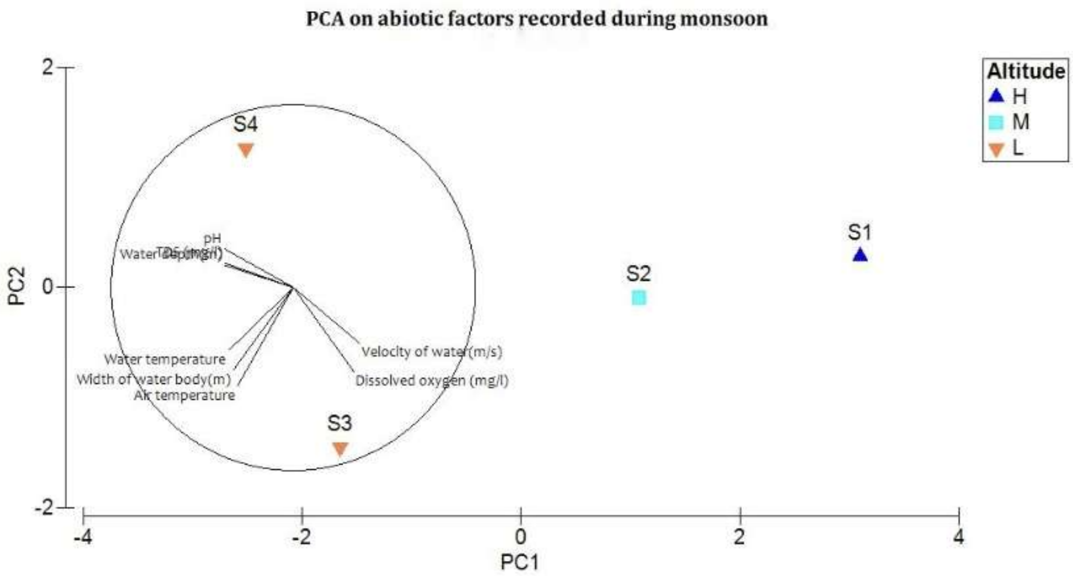

Figure 8. Resemblance between sampling sites in river Murti based on abiotic factors during monsoon.

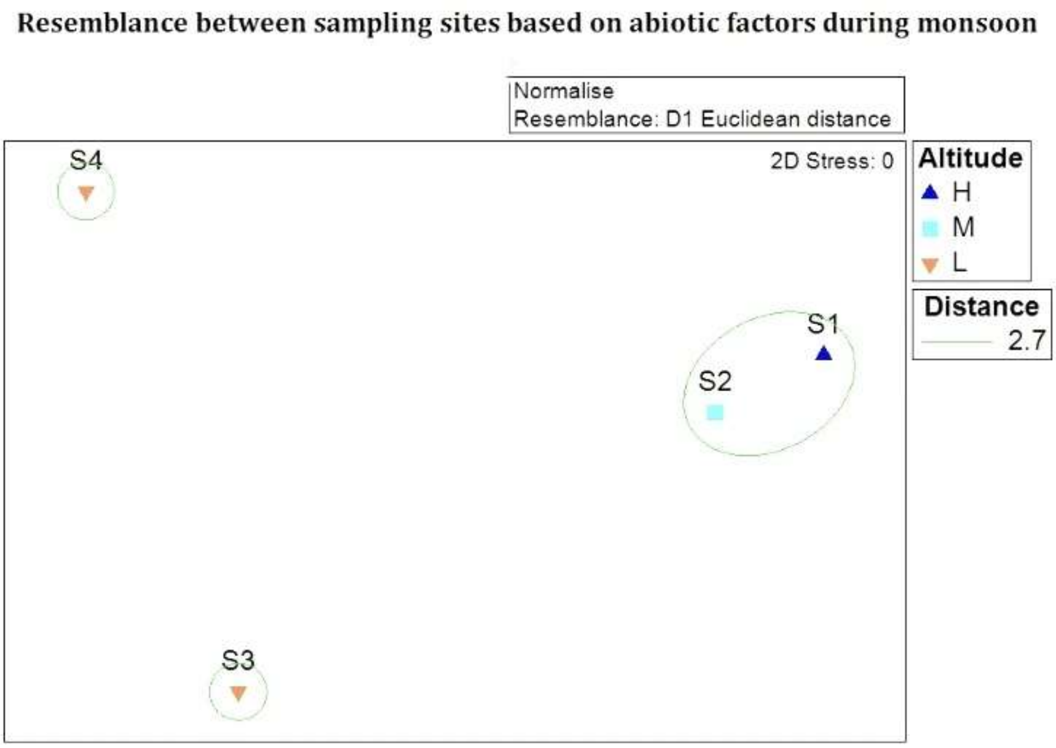

Figure 9. PCA on abiotic factors in river Murti during monsoon.

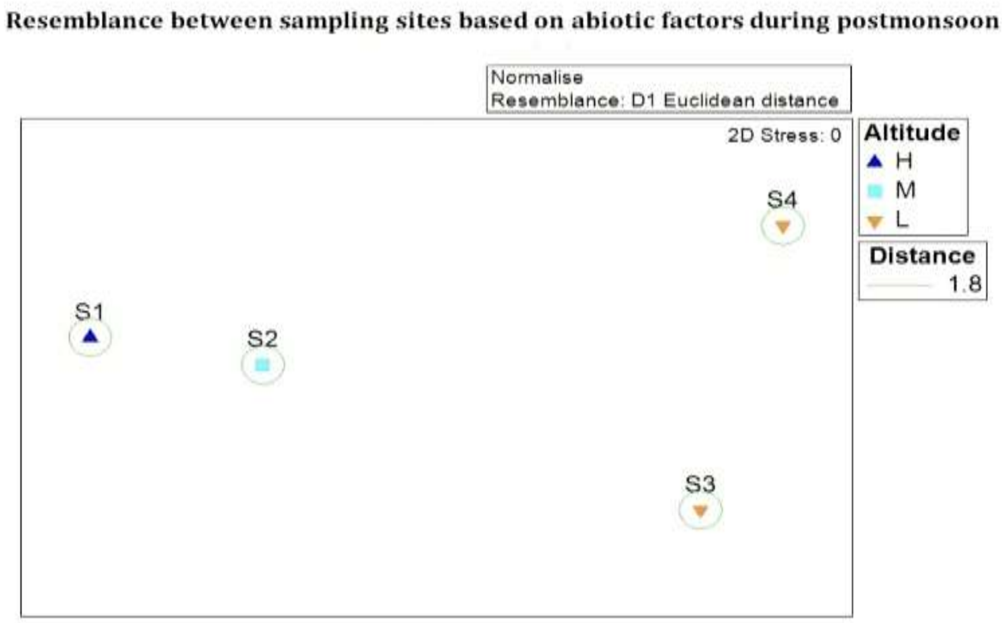

Figure 10. Resemblance between sampling sites in river Murti based on abiotic factors during post-monsoon

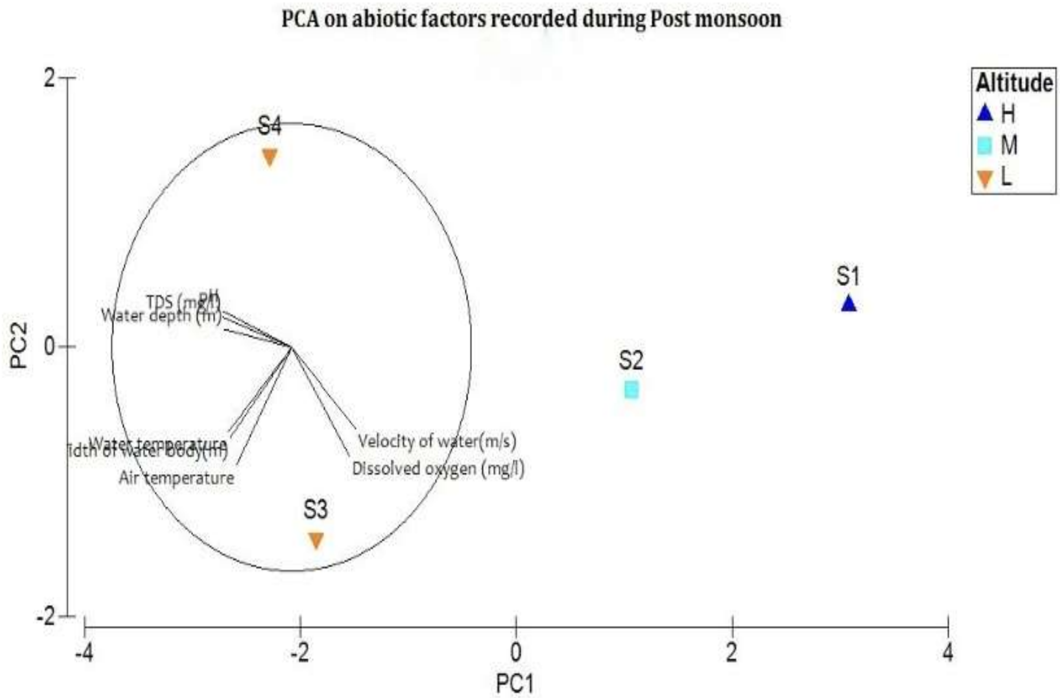

Figure 11. PCA on abiotic factors in river Murti during post-monsoon.

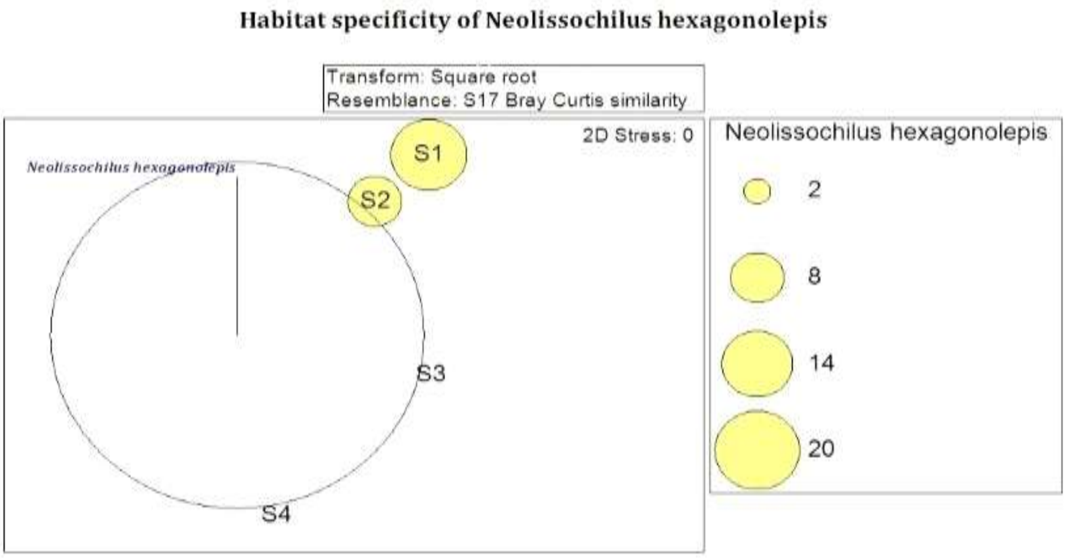

Figure 12. Habitat specificity of *Neolissochilus hexagonolepis.*

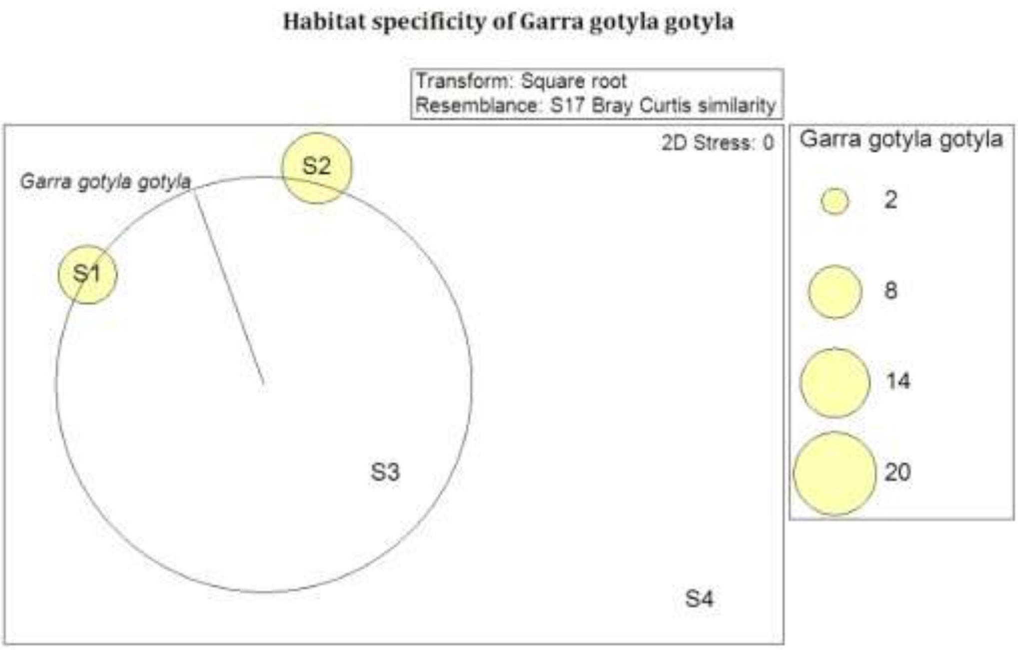

Figure 13. Habitat specificity of *Garra gotyla gotyla.*

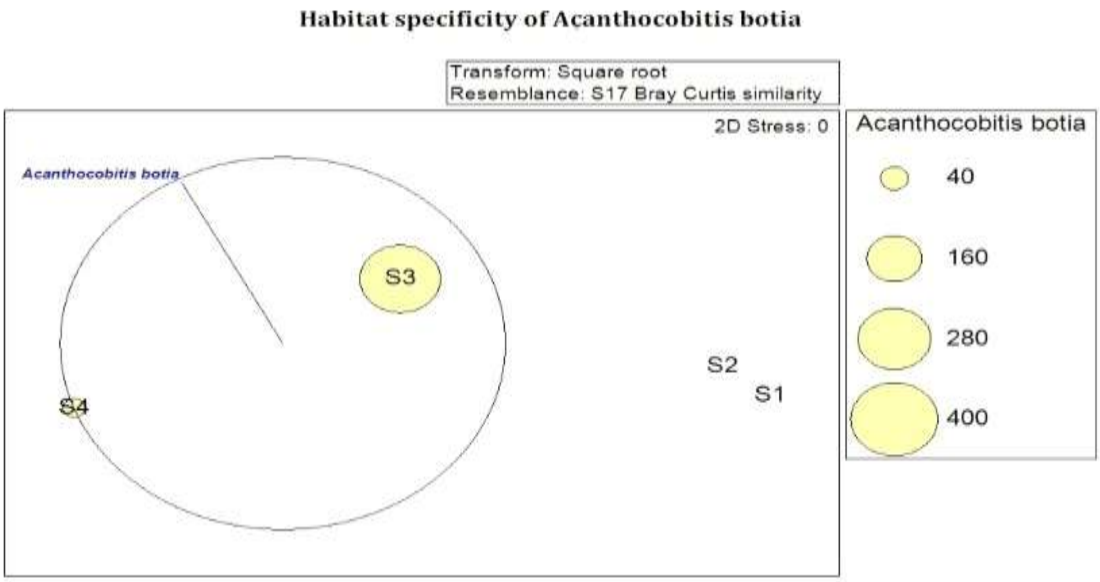

Figure 14. Habitat specificity of *Acanthocobitis botia.*

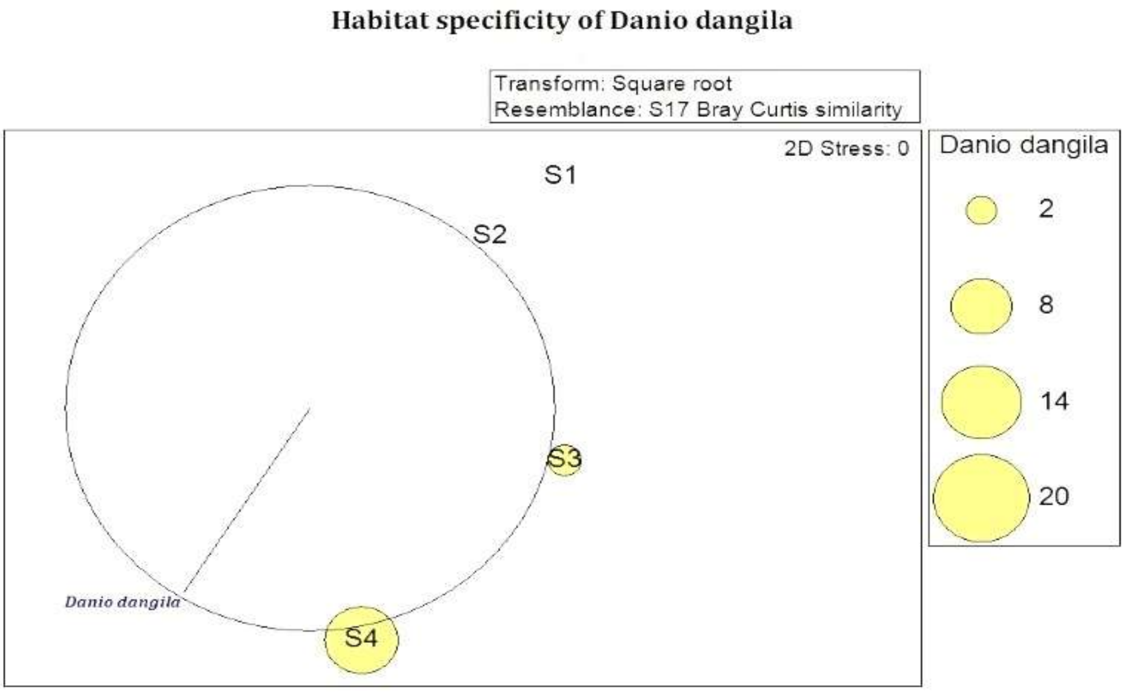

Figure15. Habitat specificity of *Danio dangila.*

Euclidean distance was measured between four sampling sites throughout the year (broadly categorized as pre-monsoon, monsoon and post-monsoon). During pre-monsoon S3 and S4 was found to be similar, whereas S1 and S2 were different (Figure 6). PCA (Principal Component Analysis) indicated the principal factors responsible for such variation. Velocity of water, dissolved oxygen, air temperature, width of water body were shown to be responsible for 76.6% of the variation, while water temperature, pH and TDS contributed 16.7% among the rest (Figure 7). Monsoon showed a close relation in habitat structure of S1 and S2 with S3 and S4 being significantly different (Figure 8). Velocity of water, water temperature and pH accounted for 82.5% of the variation, whereas dissolved oxygen, air temperature, width of water body and TDS was found to be liable for 15.8% of the same (Figure 9). Variation among all the four sites was revealed during post-monsoon (Figure 10). pH was found to be responsible for 80.2% of the variation while velocity of water, dissolved oxygen, air temperature, water temperature and width of water body accounted for 17.7% among the rest (Figure 11). Four species namely *Neolissochilus hexagonolepis* (McClelland, 1839), *Garra gotyla gotyla* (Gray, 1830), *Acanthocobitis botia* (Hamilton, 1822) and *Danio dangila* (Hamilton, 1822)were found to prefer S1, S2, S3 and S4 respectively and thus may be designated as habitat specialists (Figure 12, 13,14 and 15).

Table 1. Location and Physico-chemical characteristics in the sampling sites of the river Murti.

Sampling sites	Latitudes (North)	Longitudes (East)	Altitudes, at river bed (m asl)	River Width (m)	River Depth (m)	Velocity of water (ms^{-1})	Dissolved Oxygen (mgl^{-1})	pH	Substratum
S1	27 °00.483′	88°48.107′	516	16	1.1	1.1	9.2	7.1	Sand, gravel, boulders and bedrocks
S2	26 °59.014′	88°49.291′	402	18	0.9	0.9	8.9	7.4	Sand, gravel, boulders and bedrocks
S3	26 °50.631′	88°49.704′	137	25	1.4	0.5	8.5	7.5	Sand, gravel, and bedrocks
S4	26 °49.41′	88°49.33′	130	20	1.2	0.2	7.9	7.8	Sand and gravel

Table 2. Fish fauna found in river Murti along with their order, family and threat status.

Order	Family	Genus	Species	Threat Status (According to BCPP-CAMP, 1998)
Cypriniformes	Nemacheilidae/ Balitoridae	*Acanthocobitis*	*botia*	Lower Risk- near threatened
Cypriniformes	Cyprinidae	*Barilius*	*barila*	Vulnerable
Cypriniformes	Cyprinidae	*Barilius*	*bendelisis*	Lower Risk- near threatened
Cypriniformes	Cyprinidae	*Barilius*	*vagra*	Vulnerable
Cypriniformes	Cyprinidae	*Opsarius*	*barna*	Lower Risk- near threatened
Cypriniformes	Cyprinidae	*Opsarius*	*tileo*	Lower Risk- near threatened
Cypriniformes	Cyprinidae	*Cabdio*	*morar*	Lower Risk- near threatened
Cypriniformes	Cyprinidae	*Danio*	*dangila*	Not evaluated
Cypriniformes	Cyprinidae	*Danio*	*rerio*	Lower Risk- near threatened
Cypriniformes	Cyprinidae	*Devario*	*aequipinnatus*	Lower Risk- near threatened
Cypriniformes	Cyprinidae	*Devario*	*devario*	Lower Risk- near threatened
Cypriniformes	Cyprinidae	*Crossocheilus*	*latiuslatius*	Data Deficient
Cypriniformes	Cyprinidae	*Labeo*	*bata*	Lower Risk- near threatened
Cypriniformes	Cyprinidae	*Garra*	*annandalei*	Not evaluated
Cypriniformes	Cyprinidae	*Garra*	*gotylagotyla*	Vulnerable
Cypriniformes	Cyprinidae	*Garra*	*kempi*	Vulnerable
Cypriniformes	Cyprinidae	*Pethia*	*phutunio*	Lower Risk- least concern

Cypriniformes	Cyprinidae	*Puntius*	*terio*	Lower Risk- near threatened
Cypriniformes	Cyprinidae	*Puntius*	*vittatus*	Vulnerable
Cypriniformes	Cyprinidae	*Neolissochilus*	*hexagonolepis*	Not evaluated
Cypriniformes	Cyprinidae	*Neolissochilus*	*hexastichus*	Not evaluated
Cypriniformes	Cyprinidae	*Neolissochilus*	*stracheyii*	Not evaluated
Cypriniformes	Cobitidae	*Lepidocephalichthys*	*guntea*	Not evaluated
Cypriniformes	Psilorhynchidae	*Psilorhynchus*	*balitora*	Not evaluated
Siluriformes	Amblycipitidae	*Amblyceps*	*mangois*	Lower Risk- near threatened
Siluriformes	Chacidae	*Chaca*	*chaca*	Not evaluated
Siluriformes	Clariidae	*Clarias*	*batrachus*	Vulnerable
Siluriformes	Bagridae	*Mystus*	*bleekeri*	Vulnerable
Siluriformes	Olyridae	*Olyra*	*longicaudata*	Not evaluated
Siluriformes	Erethistidae	*Pseudolaguvia*	*foveolata*	Not evaluated
Perciformes	Badidae	*Badis*	*badis*	Not evaluated
Perciformes	Ambassidae	*Chanda*	*nama*	Not evaluated
Perciformes	Channidae	*Channa*	*marulius*	Lower Risk- near threatened
Perciformes	Channidae	*Channa*	*orientalis*	Vulnerable
Perciformes	Channidae	*Channa*	*punctata*	Lower Risk- near threatened
Perciformes	Channidae	*Channa*	*stewartii*	Not evaluated
Perciformes	Osphronemidae	*Trichogaster*	*fasciata*	Lower Risk- near threatened
Synbranchiformes	Mastacembelidae	*Macrognathus*	*pancalus*	Lower Risk- near threatened
Synbranchiformes	Mastacembelidae	*Mastacembelus*	*armatus*	Not evaluated
Beloniformes	Belonidae	*Xenentodon*	*cancila*	Lower Risk- near threatened

Table 3. Diversity indices at the four sampling sites in river Murti.

Sampling sites	Shannon-Weaver index (H′)	Species evenness (J′)	Dominance index (D)	Species richness
S1	1.792	0.979	0.1894	0.8841
S2	2.592	0.977	0.09108	2.234
S3	2.963	0.955	0.07296	4.260
S4	2.716	0.965	0.08005	2.882

Table 4. Whittaker's β diversity at the four sampling sites in river Murti.

	S1	**S2**	**S3**	**S4**
S1				
S2	0.588			
S3	0.921	0.692		
S4	1	0.944	0.429	

Hora (1952) and Menon (1954) addressed the general ichthyofaunal distribution account of the Himalaya Mountains primarily based on surveys, performed through the Eastern Himalayan region of India (e.g., Hora, 1921; Shaw and Shebbeare, 1937) and the western Himalayas. The present study described fish assemblage structure in the river Murti exhibiting altitudinal zonation and documented fish species distribution. Cyprinid fishes are overall dominant in the river Murti following the same pattern found in most of the other North-Eastern Himalayan rivers like Teesta (Chakrabarty and Homechaudhuri, 2013), Brahmaputra (Biswas and Boruah, 2000), Gandaki(Edds,1993) etc. The ichthyofaunal diversity as well as species richness were found to be higher in the lower reaches of river Murti (S3 and S4) compared to the upper ones (S1 and S2) whereas dominance followed the reverse trend. Fish diversity differs largely with altitude within a river due to characteristic turnovers in environmental drivers (Acharjee and Barat, 2013; Chakrabarty and Homechaudhuri, 2013). Sisorid catfishes, Hill stream loaches show major adaptation strategies with flowing waters by modification and development certain body parts into adhesive disc and papillae(Das and Nag,2004) whereas cyprinid fishes mostly exhibit streamlined body shape, prominent snout and tubercles, keratinization of lips etc.(Ojha and Singh,1989;Railsback*et al.*, 1989;Mittal andMittal,2002). Physiological adaptations like increased rate of erythropoiesis in presence of higher amount of dissolved oxygen may also operate as one of the key parameters to restrict distribution of different fish species in swift flowing rivers (Chaudhuri *et al.*, 2017a and Chaudhuri *et al.*, 2017b). The results of the present study have supported the needs of morphological and physiological adaptations in the lotic aquatic ecosystems of these hilly regions with projected the trend of less species diversity and richness with dominance of specialized species.

A large scale of environmental drivers modulates the whole species adaptation and assemblage pattern in hill streams of the Himalayas (Bhatt *et al.*, 2012; Acharjee and Barat, 2013). These factors (water temperature, pH, elevation, dissolved oxygen, water depth, velocity and width of water body) might cumulatively contribute to some major variables upon which species assemblage largely deviate from one site to others in these characteristic hill streams and major rivers like Teesta (Bhatt *et al.*, 2012). In the present study water temperature, velocity of water, dissolved oxygen, width of water body, pH and TDS were found to be the crucial environmental drivers responsible for structuring significantly different habitats along altitudinal gradient in river Murti all over the year. During pre-monsoon, the decreased amount of water in S3 causes reduction in velocity of water as well as dissolved oxygen. As S3 and S4 both are located at the lower reach of the river, the water temperature and width of water body at these two sites does not differ much. Hence they may look similar during pre-monsoon whereas S1 and S2 continues to be dissimilar since difference in altitude maintains variance in water temperature, velocity of water, dissolved oxygen and width of the water body. Conversely heavy rainfalls at monsoon causes an immense increase in velocity of water along with dissolved oxygen and may make the upper reaches of the river (S1 and S2) look similar. S3 gets enormous water to repossess its lotic water ecosystem and maintains difference from S4 where the water remains comparatively stagnant although increased in amount. After the monsoon ends, the velocity of water and dissolved oxygen show a slight drop in value at S2 compared to S1. Hence all the four sites remain different with their characteristic habitat structure contributed by the said environmental factors.

Beta dissimilarity depicts a clear idea about nested ness of a species assemblage pattern and similarly its turnover along them (Legendre and De Cáceres, 2013). Several beta diversity components could be used for community assemblage analysis. Beta-diversity is likely to get different along the longitude universally due to geographic gradients. In this study we choose to focus on Whittaker beta dissimilarity value along with Bray-Curtis similarity to address habitat choices of inhabiting species (Bojsen and Barriga, 2002;Legendre *et al.*, 2005).The highest beta dissimilarity was found between S1 and S4, the uppermost and lowermost sampling site selected in river Murti, with no shared species among the two sites indicating maximum possible variation in species assemblage pattern and pointing out towards habitat specificity of the fish fauna. The values of beta dissimilarity remained consistently high for S2-S4 and S1-S3 which gradually lowered in S2-S3 and relatively low values were obtained for S1-S2 and S3-S4 suggesting that upper and lower reaches are greatly dissimilar while difference between two sites of both upper (S1 and S2) and lower reaches (S3 and S4) are less. The results were supported by Bray-Curtis similarity analysis which accounted that S1 may show similarity in terms of species composition with S2 and the same is pertinent between S3 and S4. Similar pattern of variation among the four sites was observed in Euclidean distance also, demonstrating the fact that altitudinal gradient along with other key environmental drivers pose distinction in habitat structure, thus causing variance in species assemblage pattern.

Habitat specialists (that were clearly inclined towards a specific habitat and were most abundant in the same) were identified for each of the four sites. These were *Neolissochilus hexagonolepis* in S1, *Garra gotyla gotyla* in S2, *Acanthocobitis botia* in S3 and *Danio dangila* in S4. The fact that *N. hexagonolepis* was also found in S2, *G. gotyla gotyla* in S1, *A. botia* in S4 and *D. dangila* in S3 may be justified as S1 and S2 shows similarity in habitat structure during monsoon and S3 and S4 were similar in pre-monsoon.

CONCLUSION

The river Murti provides refuge to a diverse fish population but is under continuous threat of habitat alterations because of unsustainable use of resources, increased anthropogenic activity and tourism. The present study demonstrated that a combination of physiochemical variables may be responsible for structuring habitat pattern characterizing altitudinal zonation of fish assemblage in this swift flowing river system. The knowledge of habitat specialist fish species along with their physiological and morphological adaptations may be the key to conserve such precious habitats.

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REFERENCES

Acharjee, M.& Barat, S. (2013). Ichthyofaunal diversity of Teesta River in darjeelinghimalaya of west bengal, India. *Asian Journal of Experimental Biological Sciences*, *4*(1), 112-122.

Angermeier, P.L. (1987). Spatiotemporal variation in habitat selection by fishes, in smack Illinois streams, In Matthews, W. J. And D. C. Heins (eds), *Community and Evolutionary Ecology of North American Stream Fishes*. Univ. Oklahoma Press, Norman: 52-60.

Angermeier, P.L. and Karr, J.R. (1984). Relationships between woody debris and fish habitat in a small warmwater stream. *Transactions of American Fisheries Society*, *113*, 716-726.

Bagra, K. and Das, D.N. (2010). Fish diversity of river Siyom of Arunachal Pradesh, India: a case study. *Our Nature, 8*, 164-169.

Baker, J.A. and Ross, S.T. (1981). Spatial and temporal resource utilizationby south eastern cyprinids. *Copeia*, 178-189.

Berger, W.H. and Parker, F.L. (1970). Diversity of planktonic foraminifera in deep sea sediments. *Science*, *168*, 1345-1347.

Bhakta, J.N. and Bandyopadhyay, P.K. (2008). Fish diversity in freshwater perennial water bodies in Midnapore district of West Bengal, India. *International Journal of Environmental Research*, *2*(3), 255-260.

Bhat, A. (2003). Diversity and composition of freshwater fishes in river systems of Central Western Ghats, India. *Environmental Biology of Fishes*, *68*, 25-38.

Bhatt, J. P., Manish, K., &Pandit, M. K. (2012). Elevational gradients in fish diversity in the Himalaya: water discharge is the key driver of distribution patterns. *PLoS One, 7*(9), e46237.

Biswas, S., &Boruah, S. (2000). Fisheries ecology of the northeastern Himalayas with special reference to the Brahmaputra River. *Ecological Engineering, 16*(1), 39-50.

Bojsen, B., &Barriga, R. (2002). Effects of deforestation on fish community structure in Ecuadorian Amazon streams. *Freshwater Biology, 47*(11), 2246-2260.

Chakrabarty, M., &Homechaudhuri, S. (2013). Fish guild structure along a longitudinally-determined ecological zonation of Teesta, an eastern Himalayan river in West Bengal, India. *Arxius de Miscel· lània Zoològica, 11*, 196-213.

Chaudhuri, A. (2022). Delineating species boundary through DNA barcodes of some fishes inhabiting river Murti in the foothills of Darjeeling Himalayas. *International Journal of Advanced Research in Biological Sciences*, *9*(9), 1- 16.

Chaudhuri, A., Gangopadhyay, K. and Homechaudhuri, S. 2017(a). Understanding Haematopoiesis as survival strategy in two characteristic habitat specialist fishes inhabiting a hill stream environment. *Journal of Environmental Biology*, *38*, 477-482. doi: 10.22438/jeb/38/3/MS-245.

Chaudhuri, A., Gangopadhyay, K. and Homechaudhuri, S. 2017(b). A quantitative and qualitative evaluation of haematopoiesis in three habitat specialist fishes, *Acanthocobitisbotia*, *Devarioaequipinnatus* and *Bariliusbarna* from a hill stream environment. *International Journal of Zoology and Applied Biosciences*, *2*(5): 218-226.

Das, D., & Nag, T. C. (2004). Adhesion by paired pectoral and pelvic fins in a mountain-stream catfish, Pseudocheneissulcatus (Sisoridae). *Environmental biology of fishes*, *71*(1), 1-5.

DattaMunshi, and Srivastava, M.P. (1988). *Natural history of fishes and syatematics of fresh water fishes of India.*Narendra Publishing House, Delhi.

Day, F. (1958). *The Fishes of India*, *Vols 1 and 2*, William Dawson, London.

Degerman, E. and Sers, B. (1992). Fish assemblages in Swedish streams. *Nordic Journal of Freshwater Research*, *67*, 61-71.

Edds, D. R. (1993). Fish assemblage structure and environmental correlates in Nepal's Gandaki River. *Copeia*, 48-60.

Ehrlich, P.P. and Wilson, E.O. (1991). Biodiversity studies: science and policy. *Science*, *253*, 758-762.

Froese, R. and D. Pauly. Editors. (2022). FishBase. World Wide Web electronic publication. www.fishbase.org, (06/2022).

Harrison, S., Ross, S. J., & Lawton, J. H. (1992). Beta diversity on geographic gradients in Britain. *Journal of Animal Ecology*, 151-158.

Hora, S.L. (1921) .On some new or rare species of fish from the Eastern Himalayas. *Records of the Indian Museum*, *22*, 731-736.

Hora, S.L. (1952). Recent Advances in Fish Geography of India. *The Journal of the Bombay Natural History Society*, *51*, 170-188.

Hugueny, B. (1989). West African rivers as biogeagraphic islands: species richness of fish communities. *Oecologia*, *79*, 236-243.

Jayaram, K.C. (1981). The freshwater fishes of the India, Pakistan, Bangladesh, Burma and Srilanka: A Handbook, 1st ed. Zoological Survey of India, Calcutta. Pp 475.

Jhingran, V.G. (1975). Fish and Fisheries of India. Hindustan Publishing Corporation (India), Delhi.

King, C.E. (1964). Relative abundance of species and MacArthur's model. *Ecology*, *45*, 716-727.

Legendre, P., & De Cáceres, M. (2013). Beta diversity as the variance of community data: dissimilarity coefficients and partitioning. *Ecology letters*, *16*(8), 951-963.

Legendre, P., Borcard, D., & Peres-Neto, P. R. (2005). Analyzing beta diversity: partitioning the spatial variation of community composition data. *Ecological Monographs*, *75*(4), 435-450.

Lenders, H.J.R., Aarts, B.G.W., Strijbosch, H. and van der. Velde, G. (1998). The role of reference and target images in ecological recovery of river systems: Lines of thought in the Netherlands, In: New Concepts for Sustainable Management of River Basins (eds. Nienhuis, P.H., Leuven, R.S.E.W. and Ragas, A.M.J.). Backhuys Publishers, Leiden, 35-52.

Leveque, C. (1997). Biodiversity dynamics and conservation, the freshwater fish tropical Africa. Cambridge University Press, Cambridge: 438 pp.

Margalef, R. (1958). Information theory in ecology. *General Systematics*, *3*, 36-71.

Menon A.G.K. (1992). Conservation of fresh water fishes of peninsular India, unpublished report, Ministry of Environment and forest, Govt of India, 136pp.

Menon, A.G.K. (1954). Fish geography of the Himalayas. *Proceedings of National Academy of Sciences, India*, *20*(4), 467-93.

Mittal, S., & Mittal, A. (2002). Characterisation of glycoproteins in the secretory cells in the operculum of an Indian hill stream fish Garralamta (Hamilton)(Cyprinidae, Cypriniformes). *Fish Physiology and Biochemistry*, *26*(3), 275-288.

Moyle, P.B and Leidy, R.A. (1992). Loss of Biodiversity in Aquatic Ecosystems: Evidence from Fish Fauna, In Fielder, P. L. And S. K. Jain (eds), Conservation Biology: theTheory and Practice of Nature Conservation, Preservation and Management.Chapman and Hall, London, 127-169.

Ojha, J., & Singh, S. (1992). Functional morphology of the anchorage system and food scrapers of a hillstream fish, Garralamta (Ham.)(Cyprinidae, Cypriniformes). *Journal of Fish Biology*, *41*(1), 159-161.

Patra, A.K and Datta, T. (2010). Diversity of Cypriniformes fish fauna in Karala river, a tributary of Teestariver at Jalpaiguri district of West Bengal, India. *Research Journal of Biological Sciences*, *5* (1), 106-110.

Pielou, E.C. (1969). An Intrduction to Mathematical Ecology. Wiley, New York.

Poff, N.L., and J.V. Ward, (1989). Implication of stream flow variability and predictability for lotic community structure: a regional analysis of stream flow patterns. *Canadian Journal of Fisheries and Aquatic Science*, *46*, 1805-1818.

Pusey, B.J., Arthington, A.H. and Road, M.G. (1993). Spatial and temporal variation in fish assemblage structure in the May river, south-eastern Queensland: the influence of habitat structure. *Environmental Biology of Fishes*, *37*, 355-380.

Radhakrishnan, K.V. and Kurup, B.M. (2010). Icthyodiversity of Periyar tiger reserve, Kerala, India. *Journal of Threatened Taxa*, *2*(10), 1192-1196.

Railsback, S., Holcomb, B., &Ryon, M. (1989). A computer program for estimating fish population sizes and annual production rates: Oak Ridge National Lab., TN (USA).

Resh, V.H., Brown, V., Covich, A.P., Gurtz, M.E., Li, H.W., Minshall, G.W., Reice, S.R.,bSheldon, A.L., Wallace, J.B, and R. Wissmar, (1988). The role of disturbance in stream ecology. *Journal of the North American Benthological Society*, *7*, 433-455.

Schlosser, I.J. (1982). Fish community structure and function along two habitat gradients in a headwater stream. *Ecology Monograph*, *52*, 395-414.

Shannon, C.E.and Weaver, W. (1949). A Mathematical Model of Communication. University of Illinois Press, Urbana.

Shaw, G.E. and Shebbeare, E.O. (1937). The fishes of North Bengal. *Journal of Royal Asiatic Society of Bengal*, *III*, 1-137.

Shelford, V.E. (1911). Ecological succession: stream fishes and the method of physiographic analysis. *Biological bulletin*, *21*, 9-35.

Shinde, S.E., Pathan, T.S., Raut, K.S., Bhandare, R.Y. and Sonawane, D.I. (2009). Fish Biodiversity of Pravara River at PravaraSangam District Ahmednagar, (M.S.) India. *World Journal of Zoology*, *4*(3), 176-179.

Smart, H.J. and Gee, J.H. (1979). Co-existence and resource partitioning in two species of darters (Percidae), *Etheostomanigrum* and *Percinamaculata*. *Canadian Journal of Zoology*, *57*, 2061-2071.

Sreekantha, M.D. Chandran, S., Mesta, D.K., Rao, G.R., Gururaja, K.V. and Ramchandra, T.V. (2007). Fish diversity in relation to landscape and vegetation in central Western Ghats, India. *Current Science*, *92*(11), 1592-1603.

Talwar, P.K. and Jhingran, A. (1991). Inland fishes of India and adjacent countries. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 2 volumes: xix + 1158 pp.

Van Dyke, F. (2008). Conservation Biology: Foundations, Concepts and Applications. *Springer*, 478.

Welcomme, R.L. (1987). Riverine and swamp fisheries. *Archiv fur Hydrobiologie – Algological Studies*, *28*, 237-238.

Winn, H.E. (1958). Comparative reproductive behaviour and ecology of 14 species of darters (Pisces: Percidae). *Ecology Monograph*, *28*, 155-1