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Distributional Patterns of Benthic Macro-invertebrate Fauna in the Glacier Fed Rivers of Indian Himalaya

Asheesh Shivam Mishra[1*], Prakash Nautiyal[1] and Vijay Prakash Semwal[2]

[1]*Aquatic Biodiversity Unit, Department of Zoology and Biotechnology, H.N.B. Garhwal University, Srinagar - 246174, Uttarakhand, India*
[2]*Department of Zoology, Govt. P.G. College, New Tehri, Uttarakhand, India*
[*]*E-mail: drasmhnbgu@yahoo.com*

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Abstract
Large-scale distributional pattern for the benthic macro-invertebrate fauna was determined in the glacier fed Himalayan and Trans-Himalayan rivers and streams of India at the elevation range of 2000-3000 m asl. In Trans-Himalaya the family Heptageniidae (Ephemeroptera) alone (Chandra and Bhaga) or in combination with Chironomidae (Diptera) in similar proportions (Chenab) or Diptera alone (Miyar) dominated the assemblages. Its influence seems to extend to Rupin drainage in the Himalaya where Chironomidae alone dominated the assemblages. Except for this Himalayan river. Various families of Trichoptera attained highest abundance in other rivers of the Himalaya. Thus, Leptoceridae in combination with Limnephilidae (Alaknanada at Tapovan) and Heptageniidae and Baetidae (Alaknanada at Mana) is the only instance of similarity in abundant taxa by virtue of same river. The Mandakini was partially similar to Alaknanda by virtue of abundant Limnephilidae. The Bhagirathi was characterized by abundance of Philopotamidae. Thus, assemblages exhibit greater variability in the Himalayan rivers than Trans-Himalayan rivers and are hence entirely different, as also evident from the cluster analysis. This present hypothesis is not applicable to explain the macro-invertebrate assemblages in Himalayan and Trans-Himalayan region.

Key words: Biome, Chenab, High elevation, Himalaya, Insects, Rupin

Introduction
During the past three decades, concepts of the structure and function of stream, ecosystems developed vigorously (Allan, 1959; Ross, 1963; Pahwa, 1979; Vannote *et al*., 1980; Corkum, 1989). The benthic macro-invertebrate distribution was primarily related to the organic energy base, as well as to habitat or biotope preferences (Culp and Davis, 1982; Cushing *et al*., 1983; Wallace, 1988). The knowledge regarding distribution of benthic macro invertebrate fauna in river ecosystems of India is limited and highly fragmentary *viz*., in the Chambal river (Khan and Kulshrestha, 1993), the Khan (Kulshrestha *et al*., 1989), the Ken (Nautiyal and Mishra, 2012; 2013), the Paisuni (Mishra and Nautiyal, 2011), the Tons (Mishra and Nautiyal, 2013), the Cauvery (Sivaramakrishnan *et al*., 1995). In the case of Himalaya too, the knowledge is limited to localities or for certain sections of the river in the lesser

Himalaya; the Ganga river system (Badola and Singh, 1981; Singh and Nautiyal, 1990; Singh *et al*., 1994; Gusain, 1994; Nautiyal *et al*., 1997; Sunder, 1997), Satluj (Julka *et al*., 1999), Jhelum (Engblom and Lingdell, 1999) and Nepal Himalaya (Ormerod *et al*., 1994). The local and regional patterns of distribution of macro-invertebrate fauna close to the snow line or in the Greater or Trans-Himalaya have been scarcely investigated; Mandakini basin (Semwal and Nautiyal, 2009). In view of this, preliminary efforts were made to investigate the large-scale distributional patterns and taxonomic composition of benthic macro-invertebrate communities in the rivers of two adjoining zones of Himalaya; Trans-Himalaya (Himachal Pradesh) and Himalaya (Uttar-akhand). The study proposes to classify the Trans-Himalaya and Himalaya rivers/ locations on the basis of distribution of the macro-invertebrate fauna and examine suitability of 'biome dependency hypoth-esis' (based on family level) to explain large scale distributional patterns in these regions.

Materials and methods

The present study was restricted to some rivers at several locations ranging in elevation from 2000-3000 m asl in the Himalaya (Alaknanda, Bhagirathi, Manda-kini, Rupin) and Trans-Himalaya (Chandra, Bhaga, Miyar, Chenab) of India. The fauna was sampled seasonally (10 quadrates per stations) in Himalaya during 2005, while Trans-Himalayan streams were sampled intensively (20 quadrates per stations) once in 2011 due to limited access through Rohtang Pass. Total 24 locations were sampled in 8 rivers situated in two different regions of Himalaya (Tab. 1 and Fig. 1). Each river was sampled at different three stations within 200 m stretch depending on the various microhabitat and velocity. One-time intensive sampling is considered appropriate to analyze the distributional patterns of benthic macro-invertebrate assemblages, which reflect real difference among the sites and not seasonal trends (Corkum, 1989). Since distributional patter-ns of species are a function of dispersal mechanism, environmental tolerances and historical factors (Carter *et al*., 1980), the likelihood of a species being present throughout a large geographical area is low.

Sampling procedures at each station involved lifting stones (boulder, cobble, pebble, gravel) and sieving clay and silt from 0.09 m^2 area in different flows (turbulent, swift, slow, placid). The subst-rate was washed to dislodge the fauna, which was preserved in 5% formalin for further analysis. As broad taxonomic classifications are acceptable when the empirical relationships involving benthic invertebrates are to be developed in a large study area (Corkum, 1989), the fauna was identified to family level (Pennak, 1953; Edmondson, 1959; Edington and Hild-rew, 1995). Counts were made to obtain density (indiv. m^{-2}), relative abundance (as %), the taxonomic composition in each river. The rivers were classified based on their counts using by using Cluster analysis (Wards methods 1-Jacard similarity index measure).

Results

The relative abundance of Trichoptera is higher in the Himalaya (Mandakini followed by Alaknanda and Bhagirathi) except Diptera in the river Rupin compared with Ephemeroptera in the Trans-Himalaya

Table 1. Geographical co-ordinates and physico-chemical characteristic of the Himalayan and Trans–Himalayan rivers at different sampling locations.

Ecoregions	Rivers	Stations	Latitude (N)	Longitude (E)	Altitude (m)	Substrate type	WT (°C)	CV (ms^{-1})	pH
Himalaya	**Alaknanda**	Mana	30° 46'	79° 29'	3166	R;B;C	NA	NA	NA
		Tapovan	30° 33'	79° 33'	1637	B;R;C	NA	NA	NA
	Bhagirathi	Harsil	31° 02'	78° 44'	2484	B;C;P	4.3-9.8	2.0-3.3	7-7.21
	Mandakini	Sone prayag	30° 37'	78° 59'	1706	R;B	9.0	1.1	7.2
	Rupin	Dodra	31° 14'	78° 06’	2141	B;R;C	9.5-10	0.29-0.78	7.6-8.2
Trans Himalaya	**Miyar**	Udaipur	32°46'	76°42'	2845	R;B;C	8.5	0.68-2.08	6.7-6.8
	Chandra	Gondhanala	32° 31'	76° 38'	2891	C;B;P;G	5.4	2.6	7.5-8.8
	Bhaga	Tandi	32° 33'	76° 58'	2878	B;C;P;G	4.8	2.5	7.7-7.9
	Chenab	Tandi	32° 33'	76° 58'	2879	B;C;P;G	5.5	2.2	8.4-8.5

(R = Rock, B = Boulder, C = Cobble, P = Pebble, G = Gravel)

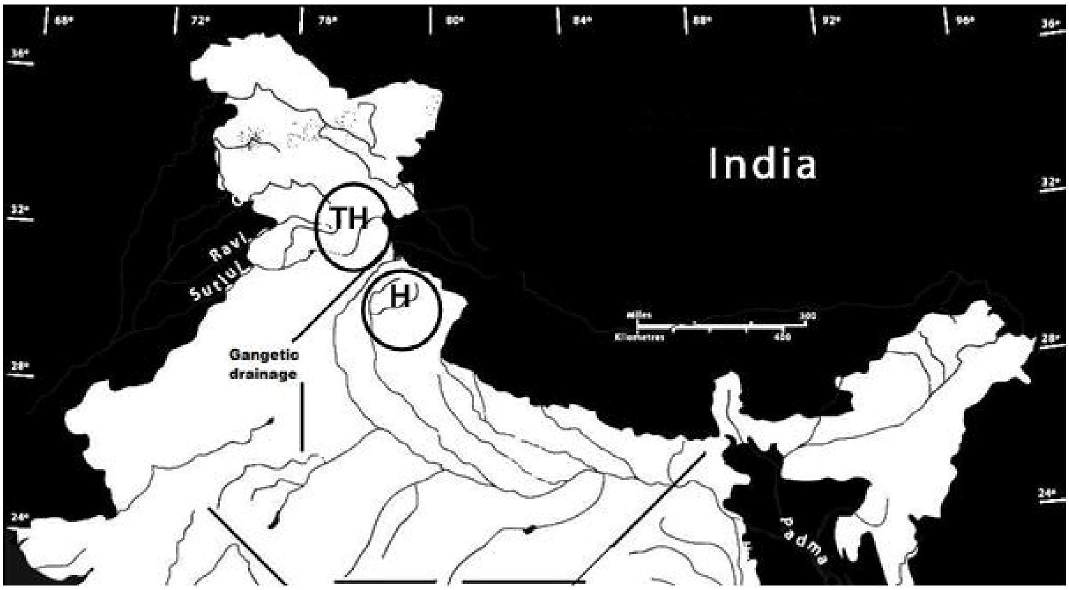

Figure 1. Encircled portion in the map indicates the area of present study in the Himalayan and Trans-Himalayan Eco-region. (TH = Trans-Himalaya, H = Himalaya)

(Chenab >, Chandra >, Bhaga > Miyar) (Figs. 2, 3). Ephemeroptera figures as next important macro-invertebrate group in the Himalaya (Fig. 2).

Seven taxa (families) are present in the different rivers/stations of Trans- Himalaya and Himalaya belonging 3 insect orders viz. Ephemeroptera, Trichoptera and Diptera. Out of these 7 taxa, 2 belong with Ephemeroptera, 3 with Trichoptera and 2 with Diptera (Tab. 2). In the Himalayan rivers, Leptoceridae, Heptageniidae and Baetidae are equally abundant in the river Alaknanda at Mana, and Leptoceridae and Limnephilidae at Tapovan. Philopotamidae is abundant taxon in the Bhagirathi while

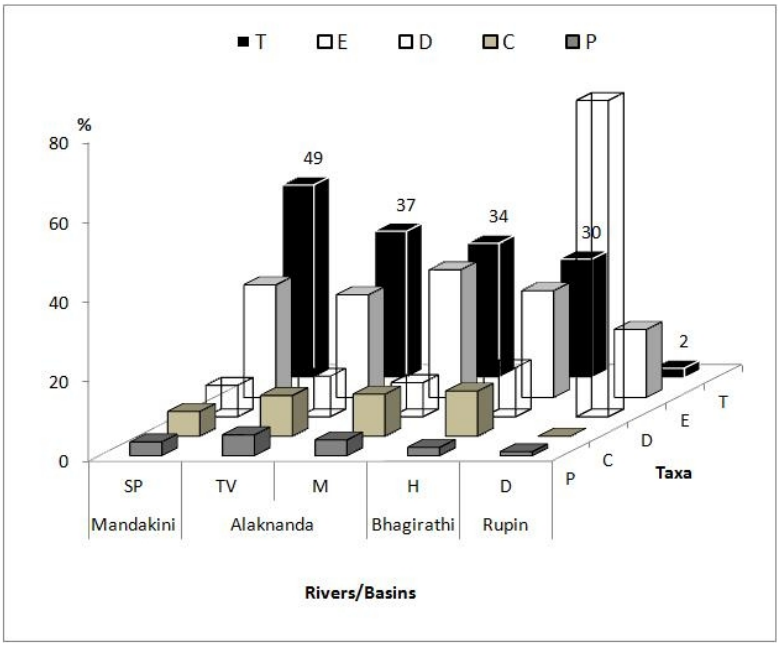

Figure 2. Percentage compositions of dominant taxonomic groups (orders) in the rivers of Himalaya Eco-region. (SP = Soneprayag, TV = Tapovan, M = Mana, H = Harsil, D = Dodra)

Table 2. Percentage composition of abundant taxa (> 7%) in the rivers of Trans and Himalaya. The taxa in others category (rest insect fauna and molluscs) are having < 7% composition.

Rivers	Stations	HP	BA	PH	LE	LI	CH	SI	Others
Himalaya									
Alknanda	Mana	8	8	3	8	4	2	2	65
	Tapovan	6	8	3	9	9	3	3	59
Bhagirathi	Harsil	6	7	8	2	3	3	3	68
Mandakini	Sonprayag	7	10	6	5	27	2	2	41
Rupin	Dodra	16	1	-	-	1	27	52	03
Trans-Himalaya									
Miyar	Udaipur	30	11	-	-	-	33	10	16
Chadra	Gondhala	61	38	-	-	-	-	-	01
Bhaga	Tandi	47	41	-	-	-	-	-	12
Chenab	Tandi	22	34	-	-	-	34	-	10

(BA = Baetidae, CH = Chironomidae, HP = Heptageniidae, PH = Philopotamidae, LE = Leptoceridae, LI = Limnephilidae, SI = Simulidae)

Limnephilidae in Mandakini. In the Rupin, Simulidae was most abundant taxa followed by Chironomidae and Heptageniidae. However, in case of Trans-Himalaya, Chronomid and Heptageniidae are abundant in the Miyar, while Heptageniidae is most abundant in the rivers Chandra and Bhaga (Tab. 2).

Cluster analysis indicates that the rivers under comparison form two major clusters; Himalaya and Trans-Himalaya. However, spatially, all locations group in to two clusters of representing Himalaya and one of the Trans-Himalaya. Among two clusters of the Himalaya one cluster contains some stations of the Miyar nallah in a Trans-Himalayan rivulet.

Discussion

Ephemeroptera (E), Trichoptera (T), Diptera (D) and Plecoptera (P) are major components of the benthic community (Hynes, 1970; Singh *et al.,* 1994; Nautiyal *et al.,* 2004). In the rivers at higher elevation, these (E, T, D, P) along with coleopteran account for > 80% of the benthic macro-invertebrate community. These are also known as components of high mountain streams fauna and have been reported in glacial headwaters of the Akbura river the Tien shan Mountains in middle asia at 3670 m asl despite water temperature ≤ 1.5°C (Ward, 1994). The rivers of west Himalaya at higher elevation are glacier fed and dominated by the Trichopterans; Leptoceridae and Limnephilidae in these rivers and they are functionally collectors and scrapers. By virtue of low nutrient concentration near the origin and headwater zone, the algal (primarily diatom) density (Nautiyal *et al.,* 1997) and hence their biomass and the primary production is low. The streams are thus largely heterotrophic in this zone and tend to become autotrophic towards the middle and lower zones near the foothills (Welcomme, 1985; Cotta Ramusino *et al*., 1995). Headwater streams are heavily influenced by riparian vegetation, which is responsible for large - scale inputs of allochthonous nutrients while at the same time hindering autotrophic production by shading (Welcomme, 1985). Owing to allochthonous nutrients in the headwaters the detritus feeding Trichoptera which function as shredders, gatherers and collectors are predominant. Semwal and Nautiyal (2009) reported equal proportion of Ephemeroptera and Trichoptera in the Kakra Gad at higher elevation (2440 m asl) at headwater zone of the Mandakini basin. This is quite contrary to the observation that the relative abundance of Ephemeroptera exceeds Trichoptera in glacierfed Himalayan rivers; the Bhilangana (Mohan and Bisht, 1991), the Ganga near foothills at Hardwar (Nautiyal *et al.,* 1997), the Bhagirathi (Nautiyal *et al.,* 2007). Ward (1994) also observed that Ephemeroptera proceed Trichoptera in the Alpine glacier fed streams.

In the Trans-Himalayan region, forest is a major land use along with agriculture, village, town and city. The banks of the Trans-Himalayan rivers are devoid of canopy due to lack of dense forest occurs like west Himalaya, which facilitates light penetration leading to increase in periphytonic biomass, thus accounting for abundance of Heptageniidae that function as scrapers. Along with periphyton the fine particulate organic matter is also present in the river due to upstream processing of the coarse particulate organic matters (CPOM; Vannote *et al.,* 1980). Thus, collectors are also present in the river as second abundant components. However, in the Rupin, river banks have canopy, the source of CPOM from vegetation on the slopes. The CPOM converts in to fine particulate organic matters (FPOM) due to instream processing possibly by shredders, thus accounting for the abundance of collectors (Diptera).

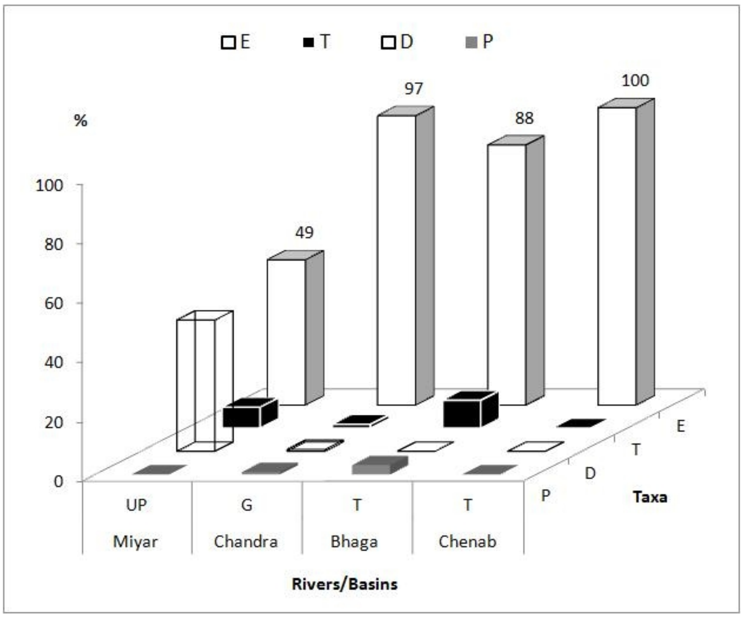

Figure 3. Percentage compositions of dominant taxonomic groups (orders) in the rivers of Trans-Himalaya Eco-region. (UP = Udaipur, G = Gondhala, T = Tandi)

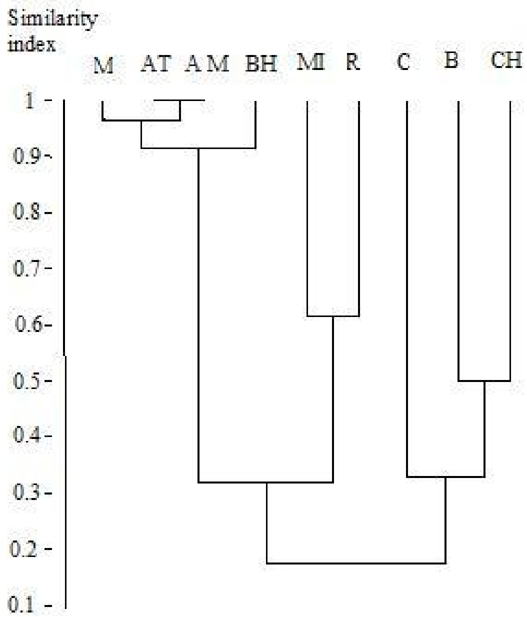

Figure 4. Cluster analysis indicates that the rivers having similar abundant taxa form one group/cluster in the Himalayan and Trans-Himalaya Eco-region. (M = Mandakini, AT = Alaknanda-Tapovan, AM = Alaknanda Mana, BH = Bhagirathi Harsil, MI = Miyar, R = Rupin, C = Chandra, B = Bhaga, CH = Chenab).

In Trans-Himalaya the family Heptageniidae (Ephemeroptera) alone (Chandra and Bhaga) or in combination with Chironomidae (Diptera) in similar proportions (Chenab) or Diptera alone (Miyar) dominated the assemblages. Its influence seems to extend to Rupin drainage in the Himalaya where Chironomidae alone dominated the assemblages. Except for this Himalayan river. Various families of Trichoptera attained highest abundance in other rivers of the Himalaya. Thus, Leptoceridae in combination with Limnephilidae (Alaknanada at Tapovan) and Heptageniidae and Baetidae (Alakna-nada at Mana) is the only instance of similarity in abundant taxa by virtue of same river. The Mandakini was partially similar to Alaknanda by virtue of abundant Limnephilidae. The Bhagirathi was chara-cterized by abundance of Philopot-amidae. Thus, assemblages exhibit greater variability in the Himalayan Rivers than Trans- Himalayan Rivers and are hence entirely different.

The cluster analysis reveals that the rivers of these two Himalayan zones (Himalaya and Trans-Himalaya) are different. Based on similarity in taxonomic composition, there is more similarity within rather than among the two ecoregions especially within Trans-Himalaya.

The association of the rivers of one zone can be explained through 'biome dependency hypothesis' (Ross, 1963; Corkum, 1989). This hypothesis predicts that similar assemblages of macro-invertebrate are most likely to occur at sites along river, if the drainage basin occupies the same biome. It seems that the dissimilarity of abundant fauna in the rivers of two different ecoregion is influenced by geographical factors i.e., terrain, latitude and soil type. The abundant taxon was not absolutely similar among the rivers of Himalaya unlike to Trans- Himalaya. Thus 'biome dependency hypothesis is applicable only to the Trans- Himalaya but not in the Himalaya. The reasons for this need further investigation. This present hypothesis is not applicable to explain the macro-invertebrate assemblages in Himalayan and Trans-Himalayan region.

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