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Taxonomic and Trophic Characterization of Benthic Macroinvertebrate Fauna in Headwaters of Eastern Himalaya

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***Abstract*:** A taxonomic and functional feeding group study of benthic macroinvertebrate fauna was conducted in the headwater streams/Kholas of eastern Himalaya *viz.* Rimbi Khola and its tributaries (Nambu Khola, Limbuni Khola and Lingsur Khola). Samples were collected twice in a year during January and February 2017. Standard methods were adopted for the samples collection and identification of benthic macroinvertebrate fauna. The density ranged from 264 to 792 indiv.m^{-2} among Rimbi Khola and tributaries. Seventeen taxa were recorded with highest taxonomic richness in Rimbi Khola compare to the tributaries. Leptoceridae was most abundant taxa in all streams/Kholas followed by Hydropsychidae, Leptophlebidae and Baetidae. CCA identified discharge, current velocity and substratum as most important factors in streams/Kholas, while different characteristics taxa were determined by PCA. These variations in environmental variables and characteristics taxa were attributed to proximate factors in each river. However, trophic characterization indicated that all the streams/Kholas were dominated by shredders. Collectors were second most abundant trophic group in the Rimbi, Limbuni and Lingsur Khola, while scraper in Nambu Khola. Nambu Khola was different from rest of the streams due to variation in dominant trophic groups, because of open stream system and high periphytonic growth.

Keywords: Eastern Himalaya, Discharge, Leptoceridae, Shredders, CCA

The aquatic invertebrates have the ability to clean rivers as they utilize the organic and detritus matter. The benthic invertebrates can be used as a barometer of overall biodiversity in aquatic ecosystems (Chatzinikolaou et al 2006). They are an important and integral part of any aquatic ecosystem as they form the basis of the trophic level. The negative effects of pollution in the community structure can in turn affect trophic relationships. The study of structural composition of benthic macroinvertebrate fauna is governed with various physico-chemical factors such as water quality, sediments quality and biological factors i.e., competition and predation. In view of above global studies, various Indian studies have been conducted in the rivers and streams of different geographical regions like Himalaya (Nautiyal et al 2015, Semwal and Mishra 2019, Mishra and Prasad 2020), the central Highlands (Mishra and Nautiyal 2013, Mishra and Nautiyal 2016, Nautiyal et al. 2017, Mishra and Nautiyal 2017) and in the Western Ghat (Dinakaran and Anbalagan 2010, Santosh et al 2014). Though many studies have been performed in the lesser Himalayan region, but very sparse study is available in the rivers of north east Himalaya and especially in the rivers proposed for hydroelectric project. Therefore, a study was conducted on the Rimbi Khola (a tributary Rangit River basin) at proposed dam site (Rangit-II Hydroelectric project) to determine the structural and functional composition of the benthic invertebrate fauna and this will be a reference study after commencement of hydroelectric project.

MATERIAL AND METHODS

Study area: The Rimbi Khola originates from Lachhmi Pokhari and Lam Pokhari lakes as Chhinjyum Khola and drains the forested areas through Pale Khola on its left bank and Longman Khola on its right bank (Fig. 1). The Rimbi Khola receives water from a number of streams like Nambu Khola, Limbuni Khola and Lingsur Khola before drain in to Rathong Chhu (tributary of the Rangit river Basin).The total catchment area of Rimbi Khola above the proposed dam site is 120 sq km. The catchment is of small size and fan shaped. The Rimbi Khola catchment has a good forest cover and about 8094.95 hectare of the catchment area is covered with forest to the proposed dam site. However, the major part (49.78%) of the total forest land is covered with open forest. The dense forest covers only 17.56% of the total forest around the catchment area to the dam site. The alpine scrub covers 9.37%, while 5.97% is under scrub of the total catchment. A large part (11.17%) of the catchment is under barren/ rocky land and snow/ glaciers covers. There are few lakes viz. Lachhami Pokhari, Lam Pokhari, Sukia Pokhari and Ghuniah Pokhari are famous, covers only 0.16 hectare of the catchment (Anonyms 2009). A rapid survey of the Rimbi Khola and its tributaries was made up and downstream of the

proposed dam site. The sampling was performed at 4 sites (RK1 to RK4) in the Rimbi (Fig. 1). The macroinvertebrate community (with proven indicator value) was sampled for determining density, taxonomic composition, abundances and trophic characterization by using standard methods.

The extensive samples were collected during the lean season twice in a year (January and February 2017) which is most productive period because of low depth and high penetration of the sunlight, which cause high density of the producers and ultimately the consumers. Twenty quadrates were collected from each sampling locations. The physico-chemical parameters like water temperature (Mextech, multi meter), pH (Hanna portable digital meters) and conductivity (LABTRONICS model – LT23) were recorded at each station. The dissolved oxygen (DO), alkalinity, hardness, nitrate and phosphate were measured by titrimetric Winkler's method (APHA 1992).The sampling rationale, process and analysis were performed by using standard protocol (Mishra and Nautiyal 2011, Nautiyal et al 2017). The standard methods were used to determine trophic category (Ramusino et al 1995, Cummins et al 2005).

RESULTS AND DISCUSSION

The physical and chemical characteristics varied among the station in the Rimbi Khola and its tributaries. The water temperature slightly decreased from RK1 (13.5°C) to RK4 (13°C). However, pH and conductivity increased from 6.9 to 7.3 and 50 to 60 (µC), respectively from RK1 to RK4.The hardness decreased from RK1 (60.15 mg/l) to RK4 (30.08 mg/l). The alkalinity decreased from RK1 (55.04 mg/l) to RK3 (47.87 mg/l) and increased at RK4 (55.04 mg/l). The value of dissolved oxygen was almost same among the stations (Table 1). However, in tributaries the pH, conductivity and hardness were observed to be high in Limbuni Khola

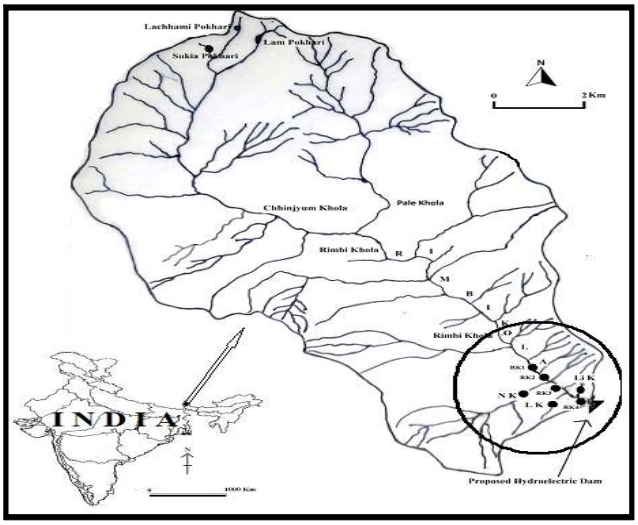

Fig. 1. Location of Rimbi Khola drainage system in India. The encircle portion indicate the sampling point at the Rimbi Khola and tributaries. Acronyms: RK1, RK2, RK3, RK4 –Rimbi Khola stations, NK-Nambu Khola, LK-Limbuni Khola, LiK-Lingsur Khola

Table 1. Geographical locations and physico-chemical characteristic at various stations

Parameters	Rimbi Khola				Tributaries		
	RK1	RK2	RK3	RK4	NK	LK	Lik
Latitude (°N)	27°19'9.9"	27°21'33.9"	27°18'45"	27°19'58.5"	27°19'10.2"	27°18'41.7"	27°20'5"
Longitude (E)	88°09'37"	88°11'55.4"	88°10'59"	88°13'43"	88°09'38"	88°10'47"	88°13'5.5"
Altitude (m asl)	1432	1405	1275	1040	1454	1345	1180
River depth range (m)	0.35-1.5	0.45-.95	0.20-0.50	0.30-0.70	0.25-0.45	0.15-.45	0.13-0.40
Sampling Depth (m)	0.35	0.45	0.45	0.40	0.25	0.30	0.28
River width (m)	30	30	50	34	20	11.5	18
Width water channel (m)	19	9	20	20	1-8	5	6.3
Transparency (%)	100	100	100	100	100	100	100
Current velocity (ms^{-1})	0.819	0.46	0.936	0.63	0.232	0.621	0.94
Discharge (m^3s^{-1})	2.722	4.055	4.055	5.895	0.408	0.264	0.694
Substratum	R	RBC	RBC	RB	R	RBC	R
WT °C	13.5	12	12	13	12	14.5	15
pH	6.9	6.6	6.9	7.3	6.8	7.2	6.6
Conductivity µC	50	50	65	60	60	80	50
Alkalinity (ppm)	55.038	55.04	45.87	55.04	64.21	55.04	64.21
Hardness (ppm)	60.150	60.15	37.59	30.08	45.11	67.67	37.59

Rimbi Khola (RK 1-RK4), Nimbu Khola (NK), LK (Limbuni Khola), LiK (Lingsure Khola). Acronyms: R- Rock, B- Boulder, C-Cobble

compared to Nambu Khola and Lingsur Khola.

Benthic macroinvertebrate fauna: The benthic macroinvertebrate density increased from RK1 (264 indiv.m^{-2}) to RK2 (506 indiv.m^{-2}) to RK3 (792 indiv.m^{-2}) but suddenly decreased at RK4 (440 indiv.m^{-2}) in the Rimbi Khola. However, among the tributaries, the highest density was observed in Ligsure Khola (737 indiv.m^{-2}) followed by Nambu Khola (682 indiv.m^{-2}) and Limbuni Khola (385 indiv.m^{-2}). Though all these streams belong to 1st order in headwater zone but their total density varied. The variation in the total density among the headwater streams was also evident in USA (Viosca 2007). Total 17 taxa (richness) were recorded, 15 from Rimbi Khola and 12 taxa from tributaries. Out of these, 9 taxa were common between Rimbi Khola and tributaries. The richness was highest in the Rimbi Khola (15) compared Limbuni Khola (8), Lingsur khola (6) and Nambu Khola (Table 2). The highest richness and density in the Rimbi Khola as compared to the tributaries, attributed to increase in the in the stream order, discharge and substrate heterogeneity. The reduction of substrate particle size provides variety of substrate for various taxa (Molokwu et al 2014, Mishra and Nautiyal 2016).

The Leptoceridae was most abundant taxa among all the water bodies. However, in Rimbi Khola, Chironomidae (25%) was second most abundant taxa followed by Baetidae Heptageniidae, Leptophlebiidae while Hydropsychiidae (29%) was second most abundant taxa followed by Heptageniidae (19%) in the tributaries (Fig. 2). The faunal assemblage patterns varied in Rimbi Khola as Leptoceridae-Chironomidae-Leptophlebiidae (RK1), Leptoceridae - Heptageniidae (RK2), Leptoceridae (RK3)and Leptoceridae-Baetidae-Heptageniidae-Chironomidae (RK4), but almost same in the tributaries i.e. in Nimbu Khola (LPR-HP-HY), Limbuni Khola (LPR-HY-HP) and Lingsur Khola (LPR-HY). The abundance of Leptoceridae at all the stations of Rimbi Khola and also in tributaries was attributed to the identical temperature profile as the ambient temperatures are moderated by subtropical humid climate. The fluctuations are also minimized in the snow fed streams as they receive constantly cold waters. Similarly, the taxa Heptageniidae was persist in most of the assemblages among the stations of Rimbi Khola and tributaries, was attributed to decline of water depth, favour more growth of bottom flora. Trichoptera were abundant in the streams of Mandakini basin in west Himalaya (Nautiyal et al 2015).

Trophic characterization: The trophic categories of benthic macroinvertebrate fauna among the headwater streams indicated that shredders were most dominant category in all the streams; Rimbi Khola (58.5%), Nambu Khola (70%), Limbuni Khola (Fig. 3). However, the second dominant category was gathering collectors in the Rimbi Khola (27%) followed by Lingsur Khola (11%), Scrapers (18%) in Nambu Khola and filtering collectors (35%) in Limbuni Khola. The dominance of shredders among the streams was attributed to availability of food as coarse particulate organic matter

Table 2. Taxonomic richness and distribution of benthic macroinvertebrate fauna in the Rimbi Khola and its tributaries

Taxa	Rimbi Khola	Tributaries		
		Nambu Khola	Limbuni Khola	Ligsur Khola
Taxonomic richness	15	5	8	6
Brachycentridae			+	
Hydropsychiidae	+	+	+	+
Hydroptilidae	+			
Leptoceridae	+	+	+	+
Limnephilidae	+			
Psychomyiidae	+		+	
Baetidae	+	+		+
Ephemerellidae	+	+		
Heptageniidae	+	+	+	+
Leptophlebiidae	+		+	+
Chironomidae	+			
Simulidae	+			+
Tabanidae	+			
Perlidae	+		+	
Psephenidae	+			
Hemiptera	+			
Lepidoptera			+	

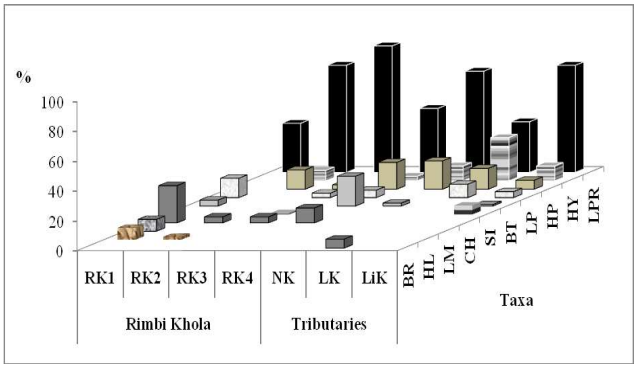

Fig. 2. Taxonomic compositions of abundant benthic macroinvertebrate taxa (5%) at different stations in Rimbi Khola and tributaries. Acronyms: BR-Brachycentridae, HL-Helidae, LM-Limnephildae, CH-Chironomidae, SI-Simulidae, BT-Baetidae, LP-Leptophlebiidae, HP-Heptagenidae, HY-Hydropsychidae, LPR-Leptoceridae. The rest are similar as Figure 1.

(CPOM). The detritus feeders (caddis fly) were abundant in the streamlets discharging into the Rimbi as they flow through forested area. Functionally, the abundance of gathering collectors is known to utilize fine particulate organic matter (FPOM) which is available after the degradation of CPOM. The collectors (gathering + filtering) were observed to be most abundant trophic group in the Rimbi and its two tributaries (Limbuni and Lingsur), while in tributary of Rimbi Khola (Nambu khola), scraper was second most dominant group. The variation in second dominant trophic group of Nambu Khola from rest of the streams was due to presence of open stream system, which allows the penetration of sun rays for periphytonic growth.

The grazing and detritus food chains exist in the headwaters of the Bhagirathi river (Nautiyal 2010). The abundance of shredders was also evident in the headwaters

Table 3. Canonical correspondence analysis along with taxon –environmental correlation

Axes	1	2	3	4	Total inertia
Eigenvalues	0.346	0.254	0.186	0.101	0.999
Taxon-environment correlations	1.000	1.000	1.000	1.000	
Cumulative percentage variance of taxon data	34.6	60.0	78.6	88.8	
Sum of all eigenvalues					0.999
Sum of all canonical eigenvalues					0.999
Conditional Effects					
Variables	λ-Value	P-value	F-Value	% Variation	
Discharge	0.21	0.268	1.33	24	
Current velocity	0.24	0.204	1.77	21	
Substrate	0.18	0.266	1.48	18	
Conductivity	0.14	0.378	1.19	14	
pH	0.14	0.324	1.62	14	
Sampling depth	0.09	.000	0.00	9	

Variable indicates percentage of variation cause in the distribution of benthic macroinvertebrate fauna

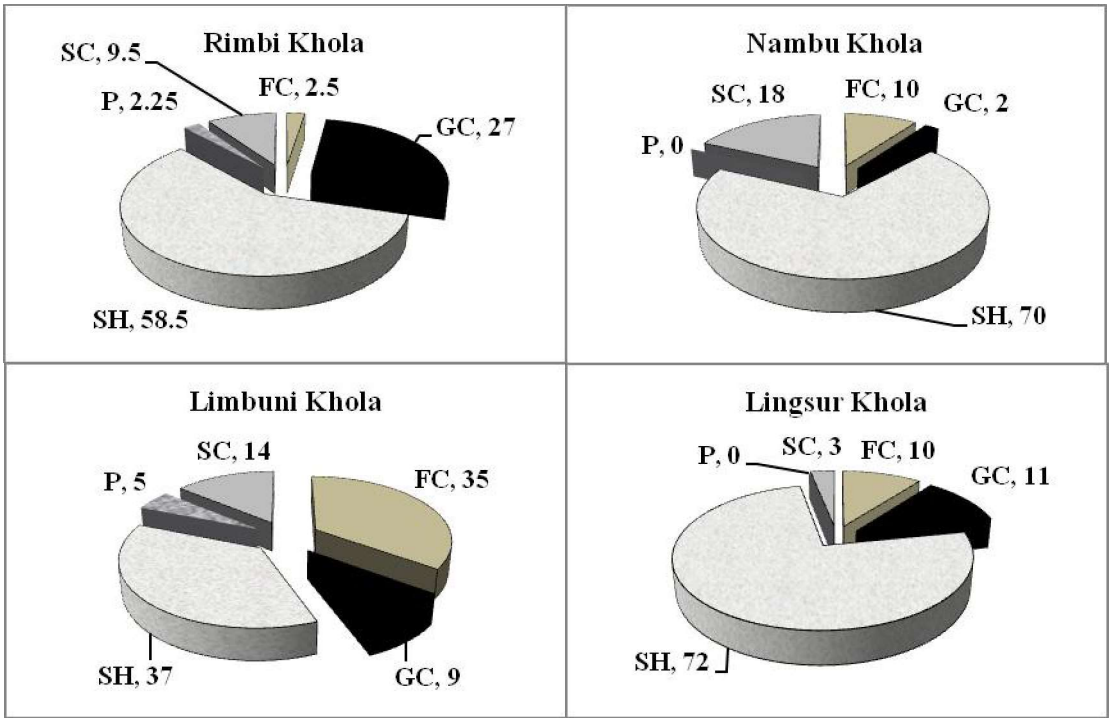

Fig. 3. Percentage of functional feeding groups (FFG) in the river Rimbi Khola and its tributaries. Acronyms: SH-Shredder, SC-Scraper, GC-Gathering Collector, FC-Filtering Collector, P-Predator

of Vindhyan river, the Paisuni (Mishra and Nautiyal 2011). According to the River Continuum Concept (RCC, Vannote et al 1980), the streams/rivers is categorized into headwaters (orders 1-3), medium-sized streams (4-6), and large rivers (>6). The Rimbi Khola and its tributaries were shredder dominated belong to 1-2 order and represent the headwater category. The predominance /dominance of shredders support to RCC model.

Role of environmental variables and characteristic taxa: Factors governing distribution of invertebrate fauna in Rimbi Khola and its tributaries were explored through CCA. The cumulative percentage variance of taxon - environmental variation for CCA axes 1 and 2 was 44.4 and 21.6 %, respectively. Among the array of variables, discharge, current velocity, substrate (and conductivity were most important variables responsible for invertebrate distribution (Table 3). The taxa associated with discharge were Chironomidae, Baetidae, Leptophlebidae, while Heptageniidae - Leptoceridae were associated with current velocity and Hydropsychidae with substrate (Fig. 4). In the lesser Himalayan river, forest type, land use and substratum were most important factors for invertebrate distribution (Nautiyal et al. 2015). Current velocity was most important variables in the rivers of Vindhyan mountain region (Mishra and Nautiyal 2011). In PCA, the eigen values for axis 1 (λ_1=0.513) and 2 (λ_2=0.164) explained cumulative variance in taxonomic composition and taxon-environmental

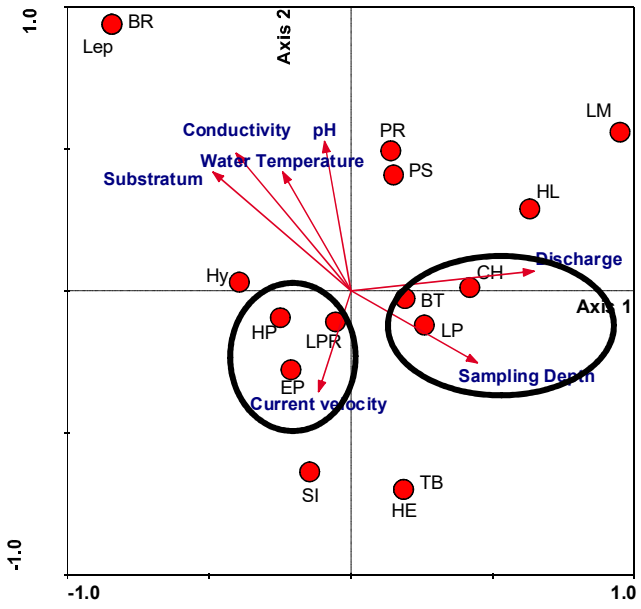

Fig. 4. Relationship between benthic macroinvertebrate fauna and environmental variables. Acronyms: PS-Psephenidae, EP-Ephemerellidae, TB-Tabanidae, PR-Perlidae. The rest are similar as Figure 2.

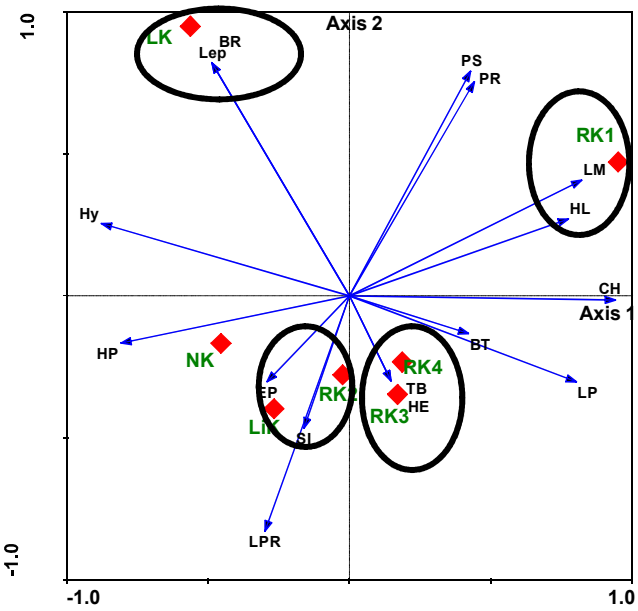

Fig. 5. Characteristics benthic macroinvertebrate taxon at each station of Rimbi Khola and tributaries. The rest are similar as Figure 2. .

relationships in the stream and caused 51.3 and 16.4% variation in the taxon-site relationship, respectively. The characteristic taxa varied at different stations like Limnephilidae - Hydroptilidae at RK1, Tabanidae - Helidae at RK3 and RK4, Brachycentridae – Lepidoptera at LK and Ephemerilidae at LiK (Fig. 5).

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