



FACTORS GOVERNING DISTRIBUTION OF BENTHIC MACROINVERTEBRATE FAUNA IN THE SPRINGFED HEADWATERS OF DOON VALLEY, INDIA

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Abstract: The benthic macroinvertebrate communities are compared to know their distribution pattern in the headwaters of Asan, Suswa and Tawa streams in Doon valley and to determine environmental variables operational at regional level. Samples were collected during monsoon, winter and summer between July 2011 to June 2012. Total density of the benthic macroinvertebrate community was high in the winter season in Asan and Suswa compared to monsoon in Tawa. Total density was significantly different among the headwaters. The mayfly prevails over caddisfly during winter and summer in the Asan and during summer and monsoon in the Tawa. The share of Planorbidae and Chironomidae were also present noticeably in the Asan during summer, especially the former that attains notable abundance only in the Asan. Chironomidae was most abundant taxa in the Suswa during winter and summer while Caenidae prevails over it during monsoon. CCA revealed that differences in assemblages were driven by water temperature in both Suswa and Tawa streams, while conductivity in the Asan stream, though streams belong to same eco-region.

Keywords: Doon valley, Headwaters, Drivers, CCA, Chironomidae, Conductivity, Water temperature

Introduction

The benthic macroinvertebrate fauna are an important component of aquatic communities in the lotic ecosystem. They play important role in the aquatic food chain as they are primary consumers, many of which process detritus (Nautiyal 2010). The omni- and carnivore fishes use benthic invertebrates as food in streams/rivers. Thus, abundance of benthic invertebrates fauna have a bearing on fish population and commercial fisheries. Their abundance and distribution pattern is very sensitive to habitat characteristics and substratum (Buss et al. 2004; Mishra and Nautiyal 2016), water temperature (Camargo and Voelz 1998), pH (Sandin and Johnson 2004), landuse

(Resh et al. 1988; Nautiyal and Mishra 2012), and riparian vegetation (Silveira et al., 2006). There is scattered information on distributional patterns of benthic macroinvertebrate fauna in the headwaters of various rivers around the world (Murphy and Davy-Bowker 2005; Nerbonne and Vondracek 2001; Usseglio-Polatera and Beisel 2002; Sivaramakrishnan et al. 2005) and also with respect to seasonal variation (Joshi et al. 2007; Burgherr and Ward 2001).

However, in India such studies on the headwater streams are very scarce in the Himalaya (Nautiyal et al. 2013) and central India (Singh et al. 2013; Mishra and Pandey 2019). Therefore, present study is designed to examine the factors governing



the distribution of benthic macroinvertebrate fauna in the headwater stream close to their source in the Doon valley; the Asan, Suswa and Tawa. The study will explain the relationship between the faunal composition and the environmental variables operational at locality and regional level.

Study area

The Doon valley lies between two different mountain chains; high-rise lesser Himalaya Mussoorie range (1800-2800 m a.s.l.) in the north and young topographic relief of frontal Siwalik range with 800 m average elevation characterized by a sudden topographic rise from alluvial plain in the south. The former is characterized by rocks from Proterozoic to lower Cambrian and is separated from Cenozoic Siwalik group and Dun gravels by MBT (Main Boundary Thrust). The Doon Valley is fragile, mainly composed of river alluvium (sand, silt and clay) of recent age while Doon fan gravels composed of boulder, pebble

and gravel and older Dun gravels mainly consists of silt and clay of recent to Pleistocene age (Thakur and Pandey 2004). The streams Asan, Suswa and Tawa selected for the study lie between latitude $30^{\circ}17'49.8''$ to $30^{\circ}4'30''$ N and longitude $77^{\circ}56'48''$ to $78^{\circ}12'24''$ E (Figure 1). The Asan that forms major drainage of western Doon, arises from foot of the Siwalik hills close to Chandrabani temple at 700 m asl and flows westwards. The Suswa originates from the Upper Doon range near Mothrowala and flows eastwards through Chanchak at 580 m a.s.l. to meet Song R. The Tawa stream is a small left-side tributary of the lower Song which originates from the 'Asha Ka Plot, (landmark Golatappar). The headwaters of Asan, Suswa, Tawa were sampled at the stations Baronwala, Mothrowala and Teen Pani, respectively (Figure 1). There is no vegetation cover and hence lack of shading ('open streams') in the Suswa and Asan while the Tawa is a shaded stream by virtue of its proximity to forest nursery.

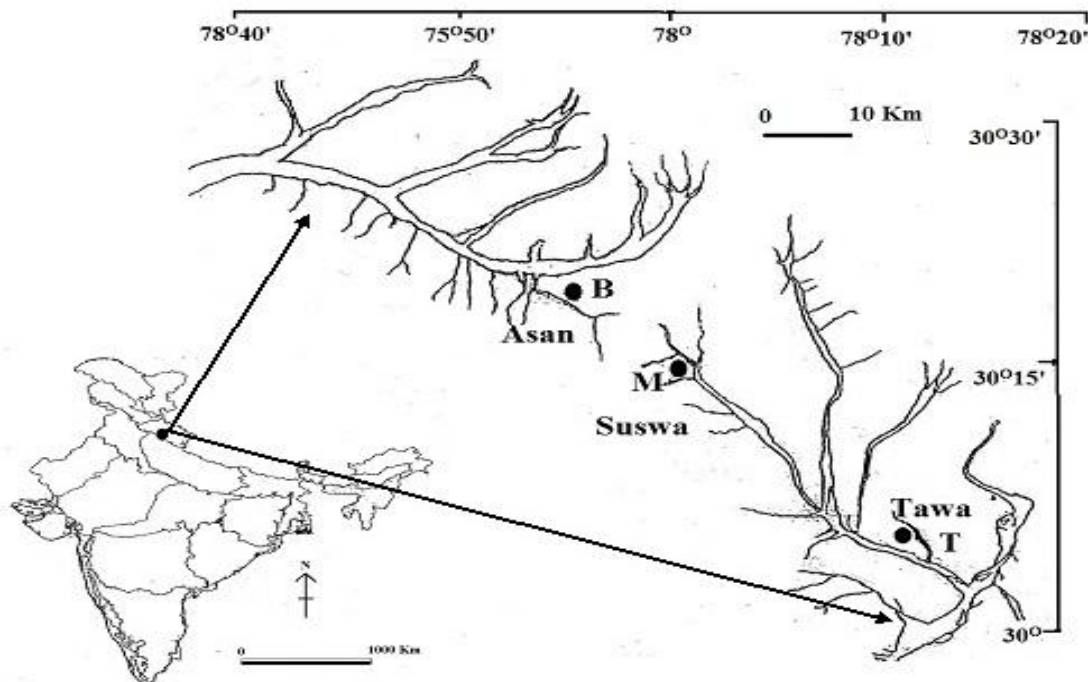


Figure 1: Relative position/location of the upper sections of the Asan, Suswa and Tawa. The sampling stations are Baronwala (B), Mothoronwala (M) and Teenpani (T) in the streams Asan, Suswa and Tawa, respectively in the Himalayan region



Materials and Methods

The streams of Doon Valley were sampled seasonally in the year 2007-2008. The benthic macroinvertebrates were collected from 5 quadrates in a 50 m stretch at each station by using Ekman dredge and kick net sampler depending upon substrate type. The collected samples were preserved in 5% formalin for laboratory analysis (Mishra and Nautiyal 2011a). Significant difference in density among the stations was determined using the Kruskal–Wallis (H) test (PAST software <http://nhm2.uio.no/norlex/past>). Canonical correspondence Analysis (CCA) was used to determine the environmental variables responsible for distribution of benthic macroinvertebrate fauna in headwater of each river (CANOCO ver 4.5; ter

Braak & Smilauer 2002). Similarity and difference among the seasons in all the rivers was determined by cluster analysis via Ward methods (Statistica Ver. 5.0)

Results and Discussion

The physico-chemical characteristics of the river Asan, Suswa and Tawa varied spatially and temporarily. The air temperature ranged from 12.5 to 29.6°C, 12.0 to 30.9°C and 15.5 to 29°C in Asan, Suswa and Tawa, respectively, while water temperature ranged from 18 to 27.3°C, 19.5 to 28.8°C and 18.3 to 25.3°C in Asan, Suswa and Tawa, respectively. However, the current velocity, pH and conductivity were high in the monsoon season and low in summer. Dissolved oxygen also varied with season (Table 1).

Table 1: Temporal variation in the physico-chemical characteristic in different rivers of and Doon valley. Abbreviation: R-Rock, B- Boulder, C- Cobble, P- Pebble, G- Gravel, Si- Silt, S – Sand, Cl- Clay, AT-Air Temperature, WT-Water Temperature, DO-Dissolved oxygen, CV-Current Velocity, C-Conductivity

Parameters	Asan	Suswa	Tawa
Station	Baronwala	Mothoronwala	Teen Pani
Landuse	Agriculture+Plantation	Agriculture +village	Forest
Latitude (°N)	30°17.83''	30°15.95''	30°4.50''
Longitude (°E)	77°56.8'	78°01.46'	78°12'.405''
Altitude (m)	562	573	341
River width (m)	12	32	15.5
Depth (m)	0.15-0.37	0.20-0.56	0.10-0.60
Distance from the sources (km.)	5	3	5
Substrate type	P> C> G> B	C >P> B>S	C> B>P
AT (°C) (Min. - Max.)	12.5-29.6	12-30.9	15.5-29
W T (°C) (Min. -Max.)	18-27.3	19.5-28.8	18.3-25.3
C V (ms ⁻¹) (Min. - Max.)	0.33-0.52	0.25-0.51	0.33-0.50
D O (mg l ⁻¹) (Min. - Max.)	6-12.5	5-12.1	6.5-12.8
pH (Min. - Max.)	6.7-7.4	6.6-7.2	6.7-7.5
C (μS ⁻¹) (Min. -Max.)	270-710	580-670	280-500
Total density	11.6	10	11.5
K-W Test (Observed. H)	14.41		
K-W Test (Observed. H) Among the streams	14.41		

*Table H (0.05)=5.99

The mean benthic macroinvertebrate density (indiv.m⁻²) varied with respect to seasons in the Asan (winter 2680, summer 414, monsoon 718),

the Suswa (winter 3585, summer 891, monsoon 1019) and the Tawa (winter 438, summer 935, monsoon 167). Highest density was observed in



the winter season in the Asan and Suswa while monsoon in Tawa. The density was significantly different among the seasons in each stream and also among the streams (Table 1). In the Central Indian headwaters viz. Ken, Paisuni and Tons rivers, the mean density was significantly different (Mishra and Nautiyal 2011a). Singh et al (2013) also observed the significant difference in the density in the headwaters of Vindhayn streams. Viosca (2007) observed variation in the total density among the headwater streams in USA.

Taxonomic composition: The composition of benthic macroinvertebrate fauna seasonally varied in each river. Total 18 taxa (family) were observed from the rivers Asan, Suswa and Tawa. In the Asan river, Baetidae (53%) was most abundant taxa followed by Hydropsychidae (29%) and others during the winter season. However, Hydropsychidae, Planorbidae each contribute

similar share (23%) and others during summer season, and in the monsoon Hydropsychidae (46%) was most abundant taxa followed by Baetidae (40%) and others. In the Suswa, Chironomidae was predominant taxa than others in the winter (85%) and summer seasons (76%), Caenidae (15%) was the other dominant in summer season. In the monsoon season Caenidae (54%) was most abundant taxa followed by Chironomidae (35%) and others. In case of Tawa, Baetidae (32%) was most abundant taxa followed by Hydropsychidae (20%) and Limnephilidae (15%) and others, and in summer season Glossosomatidae (28%) was most abundant taxa followed by Heptageniidae (19%) and Baetidae (16%), however, in the monsoon season Baetidae (50%) was most abundant followed by Hydropsychidae (20%) and others (Table 2).

Table 2 Temporal variation in taxonomic composition (as %) of the benthic macroinvertebrate fauna at family level. Acronyms: S- summer, M-monsoon and W-winter

Family	Asan			Suswa			Tawa		
	W	S	M	W	S	M	W	S	M
Perlidae	-	-	-	-	-	-	2	3	4
Caenidae	-	5	-	2	17	54	-	-	8
Leptophlebiidae	1	5	2	-	-	-	-	7	-
Heptageniidae	4	11	2	-	-	-	9	19	9
Baetidae	53	12	40	-	-	-	32	16	50
Siphonuridae	-	4	-	-	-	-	-	2	-
Ephemerellidae	1	-	-	-	-	-	1	2	1
Leptoceridae	-	1	1	-	-	-	-	-	-
Limnephilidae	-	-	-	-	-	-	15	-	-
Hydropsychidae	29	23	46	6	-	8	20	13	20
Glossosomatidae	-	-	1	-	-	-	11	28	4
Chironomidae	3	10	5	85	76	35	3	6	4
Simuliidae	7	-	3	4	-	3	1	-	-
Psephenidae	1	-	-	-	-	-	1	4	-
Corixidae	-	1	-	-	-	-	-	-	-
Salifidae	-	1	-	1	5	-	5	-	-
Planorbidae	1	23	-	2	1	-	-	-	-
Lymnaeidae	-	4	-	-	1	-	-	-	-



But for Diptera during winter and summer in the Suswa, the Asan and Tawa lack predominance and exhibit contrasting pattern of abundance. The abundances of Ephemeroptera (mostly Baetidae) and Trichoptera (Hydropsychidae) parallel each other, though the mayfly prevails over caddisfly during winter and summer in the Asan and during

summer and monsoon in the Tawa. In other seasons the reverse is true in these streams. The share of Mollusca as Planorbidae and Diptera as Chironomidae is also notable in the Asan during summer, especially the former that attains notable abundance only in the Asan.

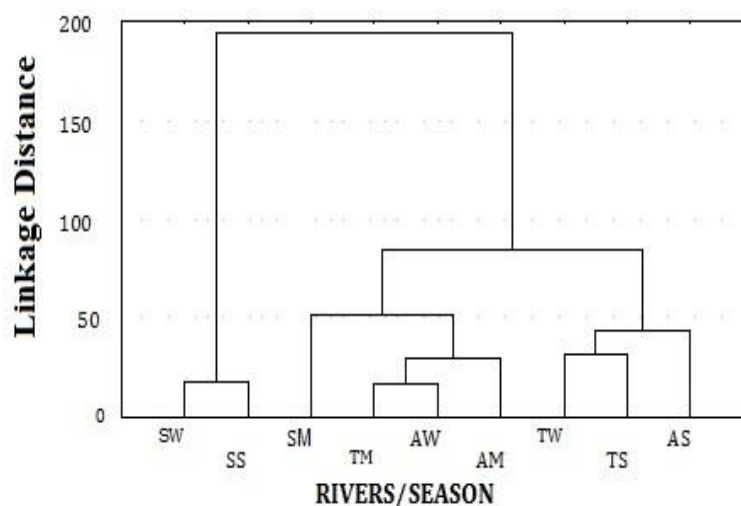


Figure 2: In the Doon region the Asan and Tawa have similar abundance in summer and monsoon but differ in winter. The faunal composition of Suswa is very different from other streams of the Doon region. Only during monsoon there is some similarity among them. **Acronyms:** The acronym used in the dendrogram is a combination of stream and season. The first letter stand for stream and the second for season except the Tawa (1st 2 letters stand for its name). A- Asan, S - Suswa, TA - Tawa,. W - winter, S-summer, M monsoon.

Diptera (Chironomidae) predominate the Suswa during winter and summer while the mayfly Caenidae prevails over it during monsoon (Table 2). In the Himalayan rivers, Trichopterans were dominant taxa in the headwater section of the lesser Himalayan spring-fed streams (Nautiyal et al. 2015). However, in the spring-fed Himalayan streams, Ephemeroptera (may flies) was dominant taxon in the Khanda Gad (Kumar and Dobriyal 1996) and the Gaula in the Kumaun region (Sunder 1997). Ephemeroptera was most abundant taxa in the headwater stream of Doon valley (Nautiyal et al. 2013). In central Indian rivers Mishra and Nautiyal (2011b) reported higher abundance of Trichoptera in the headwater section of Vindhyan river, Paisuni The temporal change was observed in the abundant taxa viz. Ephemeroptera, Trichoptera, Diptera and mollusca in headwater rivers of central India (Singh et al.

2013). The cluster analysis grouped the rivers with season into three group. The summer and winter season of the Suswa stream group together and form a separate cluster, showing entirely different faunal composition in these seasons. The Suswa shows similarity with the Asan in monsoon and winter season and the Tawa during monsoon only. However, the Asan and Tawa are similar in summer and additionally in winter also (Figure 2) The canonical correspondence analysis indicated that in the Asan river eigen values for CCA axis 1 ($\lambda_1=0.341$) and 2 ($\lambda_2 =0.115$) indicated 66.2 and 88.6% of taxon-environmental relationships. Conductivity (62.7%) was most important factor for variation in the taxonomic composition followed by water temperature (25.5%) and current velocity (11.5%). The associated taxa differed with respect to variation in seasons and variables (Table 3, Figure 3a). Similarly, in the



Suswa river, the eigen values for CCA axis 1 ($\lambda_1=0.137$) and 2 ($\lambda_2 =0.118$) explained 42.1 and 78.4% of taxon-environmental relationships. Water temperature (40.6%), current velocity (37.6%) and dissolved oxygen (18.8%) were most significant factors causing variation in the

taxonomic composition. The benthic macroinvertebrate taxa also varied with respect to season and variables (Table 3, Figure 3b).

Table 3: Temporal variation in benthic macroinvertebrate fauna with respect to environmental variables in canonical correspondence analysis.

S. No.	River	Season	Environmental Variables	Associated Taxa
1.	Asan	Summer	Conductivity	Caenidae, Lymnaeidae and Hirudinea
		Monsoon	Current velocity	Hydropsychidae, Baetidae and Glossosomatidae
		Winter	pH and Water temperature	No taxa
2.	Suswa	Summer	No variable	No taxa
		Monsoon	Water temperature	Baetidae
		Winter	Current velocity	Hydropsychidae and Simuliidae
Dissolved oxygen	Hirudinea, Lymnaeidae, Chironomidae, Caenidae			
3.	Tawa	Summer	Water temperature	Ephemerellidae, Heptageniidae during
		Monsoon	Current velocity and Conductivity	Baetidae, Hydropsychidae, Perlidae and Caenidae
		Winter	No Variables	No Taxa

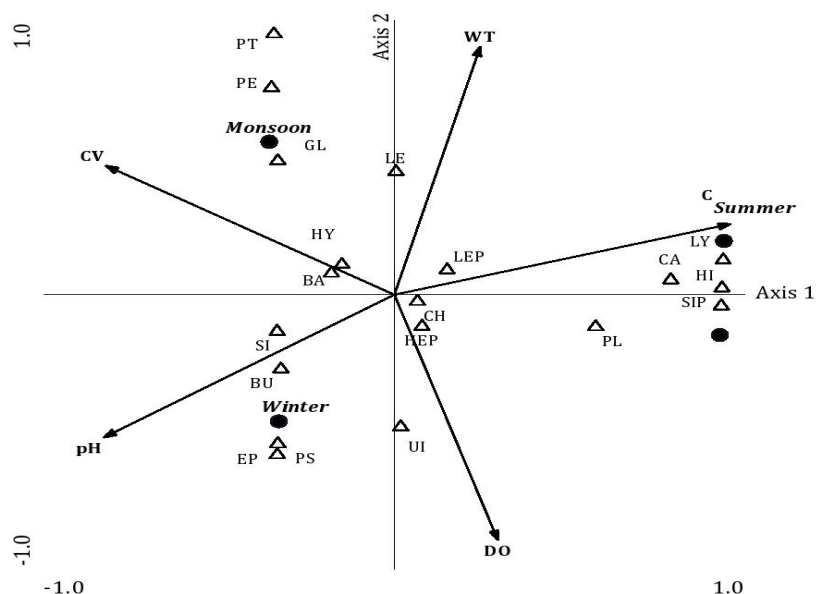


Figure 3a



Figure 3b

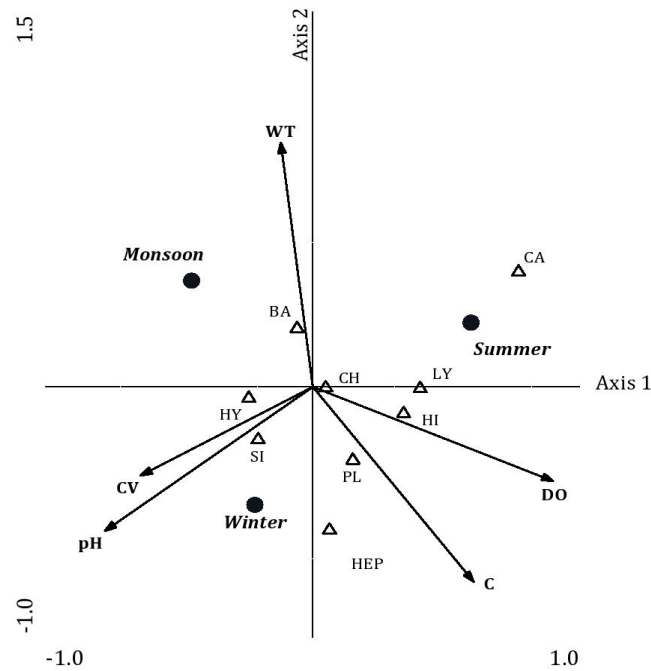


Figure 3c

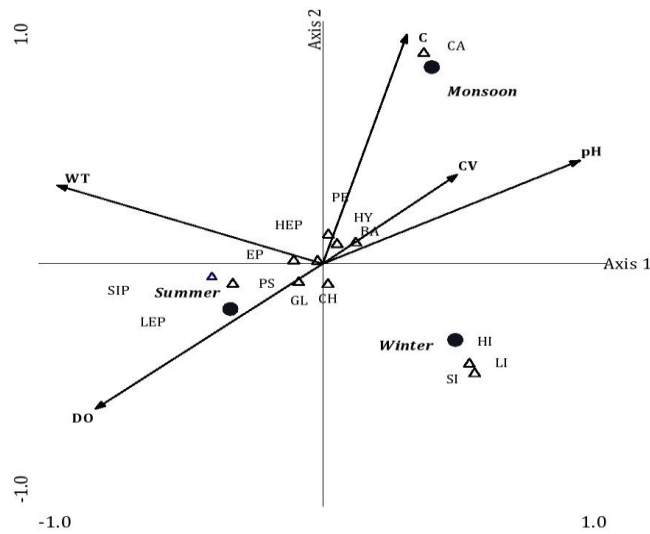


Figure 3 a-c: Ordination analysis for temporal variation in environmental variables causing variation in taxonomic composition in Asan, Suswa and Tawa in Doon valley. Arrows stand for environmental variables, triangles for taxonomic groups, black circles for seasons. **Acronyms:** Dissolved oxygen (DO), Conductivity (C), Current velocity (CV), Water Temperature (WT), Substratum (S). Caenidae (CA), Leptophlebiidae (LEP), Baetidae (BA), Heptageniidae (HEP), Siphonuridae (SIP), Ephemerellidae (EP), Perlidae (PE), Ptilodactylidae (PT), Psephenidae (PS), Hydropsychidae (HY), Glossosomatidae (GL), Leptoceridae (LE), Limnephilidae (LI), Chironomidae (CH), Simuliidae (SI), Helidae (HE), Hirudinea (HI), Planorbidae (PL), Lymnaeidae (LY), Bulimidae (BU), Unidentified (UI).



In the Tawa river, the eigen values for CCA axis 1 ($\lambda_1 = 0.226$) and 2 ($\lambda_2 = 0.148$) explained 54.3 and 89.9% of taxon - environmental relationships. Water temperature (50%) followed by conductivity (38.1%) and current velocity (11.9%) emerged as most important factors causing variation in the taxonomic composition. The invertebrate taxa varied with respect to environmental variables and season (Table 3, Figure 3c). Rai et al. (2019) found that pH and DO were the two most important variables explaining the variation in macroinvertebrate assemblages. Nautiyal et al. (2015) reported that slope, forest type, stream order and land use, slope were the important variables in the headwaters of Himalayan Mountain. In the headwater sections of central Indian rivers, substratum and current velocity were important viable governing distribution of invertebrate fauna (Mishra and Nautiyal 2017).

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