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LONGITUDINAL PATTERNS OF BENTHIC MACROINVERTEBRATE FAUNA IN RIVER DHASAN, CENTRAL INDIA

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ABSTRACT

This study reveals the distributional patterns and relationship of benthic macroinvertebrate assemblages to their environments in a lesser known river Dhasan (a tributary of river Bentwa) of Central India. Extensive sampling was done (20 quadrates per station) in winter season (December 2018 to February 2019). The total mean density of river decreased from S1 to S4 (except S2) and differed significantly among the stations. A total of 15 taxa (family) were observed among all the stations. Among these, Caenidae was most abundant taxon at S1 while Thiaridae was abundant from S2 to S4. The assemblages forming taxa varied from S1 to S4. Longitudinally, the abundance of Caenidae and Viviparidae declined from S1 to S4, but Chironomidae and Gomphidae increased from S1 to S4. Similarly, the abundance of Tabanidae and Thiaridae also increased from S1 to S4, but decline at S3. Canonical correspondence analysis indicated current velocity as the most important variable for faunal distribution. Functionally, the river was separated in two zones; heterotrophic (S1 to S3) to autotrophic (S4). The abundance of collectors and gathers resulted in heterotrophic condition while scrappers for autotrophic condition. Hence, two ecological zones are evident in the river Dhasan.

Keywords: Caenidae, CCA ordination, Peninsular plateau, river continuum concept, thiaridae, trophic status

INTRODUCTION

Benthic macroinvertebrates are commonly used for integrated quality assessment of rivers which have widely been reported and described (Mason and Parr, 2003; Romachandra *et al*., 2005; Varnosfaderany *et al*., 2010). They are widely regarded as one of the best biological indicators for assessing the impact of water pollution on rivers and streams (Turak and Waddell, 2001). They also represent an important functional link between basal resources, such as algae and detritus and upper trophic levels such as fish (Ikomi *et al*., 2005; Dıaz Villanueva *et al*., 2012). The distribution of benthic macroinvertebrates is largely related to surrounding environmental factors (Benbow *et al*., 2003). The changes in benthic community structure were often assessed by examining taxonomic compositions along the stream continuum (González *et al*., 2003). Spatial variations have been attributed to habitat characteristics (Boyero, 2003).

Currently very few rivers are pristine, and most have a long history of alteration. However, high impact due to human activities have caused many changes in the communities and biodiversity of river fauna (Nedeau *et al*., 2003). Increasing anthropogenic pressure on lotic systems has captured public attention because of water quality deterioration and health problems (Arienzo *et al.*, 2001; Jiongxin, 2004). Various studies on the distributional patterns of benthic macroinvertebrate fauna have been conducted in many rivers/streams from different parts of the world (Silveira-Mesa, 2010; Ezekiel *et al.*, 2011; Dray *et al.*, 2012; Silveira-Manzotti *et al*., 2016). In India similar studies have been conducted in Himalayan ecoregion (Nautiyal *et al*., 2004; Nautiyal *et al*., 2015; Semwal and Mishra, 2019), central highlands ecoregion (Nautiyal and Mishra, 2012; Mishra and Nautiyal 2013; Nautiayl *et al*., 2017; Mishra and Pandey, 2019) and western ghat (Kubendran and Ramesh, 2016).

Various types of mountainous terrains and climatic ecoregions exist in India with each ecoregion having many streams and rivers of different orders which meet the requirements of irrigation, domestic supply and power generation to narrow the demand-supply gap. The river Dhasan is used for similar purposes. Dhasan is a perennial river originating from Raisen district (Madhya Pradesh, India) and travels more than 350 km before joining the river Betwa near Jigni town (Uttar Pradesh, India) in Peninsular plateau Vindhayn region (*https://www.theindianwire.com /environment/ken-betwa-link-project-a-light-in-the-dark-or-a-threat-to-the-nature-308845/*). Since river Dhasan is utilized for several societal purposes and a barrage is constructed in the lower section of river which disrupts the continuum of river, so affects the distributional pattern of benthic macroinvertebrates. Therefore, river Dhasan was selected for the present study to assess river health by using macroinvertebrate fauna in light of river continuum concept of Vannote *et al.* (1980).

MATERIALS AND METHODS

Physiography of the sampling stations

The river Dhasan was sampled at four different stations (Fig. 1). The geographical details, landuse and other related details are given Table 1. Agriculture is major landuse at each station, except mouth zone where forest landuse prevails. "Parichha dam" is located at its lower zone to meet the requirements for agriculture and drinking water.

Johariya Sheikh (S1): Johariva Sheikh is located near Sagar Madhya Pradesh (MP), India at an altitude of 490 masl, 23°47'49.5" N latitude and 78°33'36.1" E longitude. The river depth at S1 was 18-65 cm with fragmented flow especially during dry periods (winter & summer seasons). The river bottom composed mainly of cobbles and pebbles.

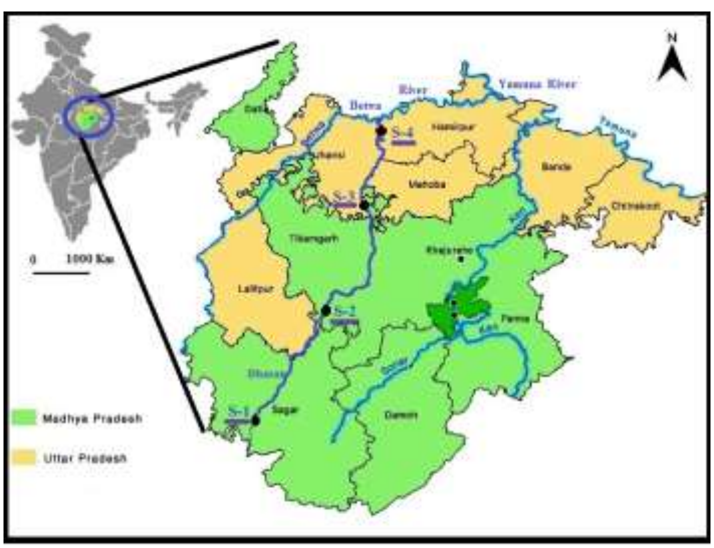

Fig. 1: Geographical location of the river Dhasan in India and sampling stations (S1 to S4) on the river Dhasan

Badagaon (S2): Badgaon station is located in Tikamgarah district, MP, India, at an altitude of 316 masl, 24°33'14.4" N latitude and 79°02'24.7" E longitude. The river depth at S2 was 30-180 cm. The river flow nearly ceases during winter and summer seasons and disrupts river continuum by developing small pools. The river bed is made up of rocks, boulders, cobbles and pebbles.

Deori (S3): This station is unique as its water is regulated by Pahari Dam located at Deori near Jhansi district Uttar Pradesh (UP) India. The station is located at an altitude of 198 masl,

$23^{O}13'58.9"$ N latitude and $79^{O}17'19.6"$ E longitude. The Pahari Dam is only water storage dam replaced by old structure to new spillway. The capacity of this dam is 46.0 million cubic meter (CBM) and used for irrigation purpose. At this station, river became deep with 10-15 m in upstream of the dam and 30-50 cm deep in downstream section of river. The river flow is only observed in downstream of dam. The river bed is composed of clay-silt, boulders, cobbles and pebbles.

Jigani (S4): It is located in Hamirpur district (UP, India) at an altitude of 123 m asl, $25^{O}44'30.5"$ N latitude and $79^{O}23'38.04"$ E longitude. The station S4 is situated near to confluence point with Betwa river. The river was 7.5 m deep at center but shallow at banks. The bed of river was sandy (red coarse sand) with little of clay.

Sampling

The benthic macroinvertebrate fauna were collected longitudinally from 4 pre-selected stations (S1 to S4) in stream ecosystems of central India. The macroinvertebrate fauna tend to increase just after the termination of monsoon [in September] and attain highest during winter in December-January. The discharge gradually reduces from February to mid June and as weather becomes hot in summer. The shallow parts of plateau streams tend to dry, resulting in desiccation. The streams become restricted to deeper pools. Hence, more species are expected in post-monsoon, especially during December-February. Expectedly the density and species richness decrease in summer as the number of habitats and microhabitats get reduced when shallow parts become shallow or dry up. Therefore, sampling was performed in winter season during December to February in 2018-2019.

The physicochemical parameters like air temperature, water temperature (digital thermometer, Mextech multimeter), transparency (Secchi disc), water current velocity (ENCON current meter), pH (model HI 96107), dissolved oxygen, nitrate and phosphate (APHA, 1998) were measured at each station. The substrate predominance at each sampling station was estimated visually. If the river bed was extensively littered with cobble substrate followed by boulders and gravels, then substrate type was recorded as C: B: G. Substrate names and their categories were determined through Wentworth classification of substratum particle size (*http://fwcb.cfans.umn.edu/courses/fw8459/ Private/SubstrateandHyporheos08-2.pdf*).

The benthic macroinvertebrate fauna were collected by lifting stone method (stony substratum) and sieving substrate method (clay and silt bottom; mesh size 0.05 mm) from 30 cm^2 area. The samples were preserved in 5% formalin and identified to family level (Edmondson, 1959; Edington and Hildrew, 1995; Nesemann *et al*., 2004). The counts data were computed for determining density, abundance assemblages (taxa >10%) and the functional feeding groups (Cotta Ramusino *et al.*, 1995; Mishra and Nautiyal, 2013). The Kruskal-Wallis test (H-test) was used to determine the statistical differences in densities among the stations (Henderson, 2003). Canonical correspondence analysis, an ordination technique (ter Braak, 2002; CANOCO ver. 4.5.), was used on log-transformed data using Monte Carlo Permutation tests and forward selection to identify the impact of environmental variables on the taxonomic composition of benthic macroinvertebrate fauna in river Dhasan.

RESULTS AND DISCUSSION

The physicochemical characteristics of river Dhasan varied from S1 to S4. The increasing trends were observed for air temperature (27.0-32.7^{O}C), water temperature (15.0-20.8^{O}C) and pH (7.0-8.12). The current velocity ranged from 0.0 to 0.04 ms^{-1} at S1, 0.6 to 1.0 ms^{-1} at S2, 0.3 to 0.6 ms^{-1} at S3 and 0.8 to 1.2 ms^{-1} at S4 (Table 1). The transparency was observed up to 0.65 m at S1, S2 and S4, while 0.48 m at S3. Nitrates decreased from S1 (0.731 mg L^{-1}) to S2 (0.687 mg L^{-1}), then increased in S3 (0.755 mg L^{-1}) and again decreased in S4 (0.713 mg L^{-1}). However, dissolved oxygen (11.3-9.0 mg L^{-1}) and phosphate (0.102-0.084 mg L^{-1}) decreased longitudinally from S1 to S4

Table 1: Geographical locations and physicochemical characteristics at various station in river Dhasan, Ken and Tons.

Stations/Parameter	Johariya Sheikh (S1)	Badagaon (S2)	Devri Dam (S3)	Jigani (S4)	H-test
Latitude (^{O}N)	23.79711	24.55406	25.23274	25.74187	
Longitude (^{O}E)	78.56006	79.04024	79.28493	79.39395	
Altitude (masl)	492	319	183	126	
Land use	Ag	Ag-V	D-Ag	F-V	
Substratum	C>G>St	B>C>P>G	Cl>G>B	S-St	
River width (m)	36	162	482	528	
Sampling depth (m)	0.32-0.38	0.30-0.37	0.45-0.58	0.48-0.60	
Transparency (m)	0.59-0.61	0.52-0.60	0.45-0.48	0.58-0.65	
Current velocity ms^{-1})	0-0.04	0.6-1.0	0.3-0.6	0.8-1.2	
Air temperature (^{O}C)	27-27.8	28-28.5	30.2-30.5	32.5-32.7	
Water temperature (^{O}C)	15-15.5	17-17.8	18-18.7	20-20.8	
Dissolved oxygen (mg L^{-1})	11.3	10.2	9.8	9	
Nitrate (mgl^{-1})	0.731	0.687	0.755	0.713	
Phosphate (mgl^{-1})	0.102	0.1	0.092	0.084	
pH	7.0-7.12	7.5-7.52	7.0-7.4	8-8.12	
Mean density ± SE (m^{-2})	480.7± 31.37	586.3± 30.32	369.6 ± 36.37	414.7 ± 20.21	16.44*

*Significant at 5 %; H at 3 df = 7.81; Acronyms; B - Boulders, C - Cobbles, P - Pebbles, S - Sand, St - Silt, Velocity, Ag - Agriculture, V-Village, D-Dam

(Table 1). Patel and Datar (2014) observed water temperature (22-22.4^{O}C), pH (7.5-7.7) and dissolved oxygen (7.8 mg L^{-1}) in another central Indian river, Betwa during winter season. The current velocity was low in headwater (S1 & S2) in comparison to lower (S3) and mouth zone (S4). The rivers of central highlands ecoregion are characterized by low velocity and low discharge especially in lean seasons (summer and winter) which may be attributed to the hot climatic conditions and low mountain gradient (Mishra and Nautiyal, 2011; Mishra and Nautiyal, 2013; Nautiyal *et al.*, 2017). However, in other geographical zone like Himalaya, the headwaters have very fast current velocity (Nautiyal *et al.*, 2013).

The taxonomic richness of benthic macroinvertebrate fauna declined from S1 to S4 (13 taxa at S1 and S2, 11 at S3, 9 at S4). The total mean density increased from S1 (480.7±31.37) to S2 (586.3±30.32) and decrease to S3 (369.6±36.37) again increase at S4 (414.7±20.21). The mean densities among the stations are significantly different (Table 1). The gradual decline in density was attributed to the reduction of substrate size from boulder to sand, while the highest density at S2 was attributed to more substrate heterogeneity (boulders, cobbles, pebbles & gravels). Paul and Meyer (2001) and Mishra and Nuatiyal (2016) observed the impact of substrate size on the density of benthic macroinvertebrate fauna. The lowest density at S3 was attributed to water regulation by Pahari Dam/Geori Dam. Bahuguna *et al.* (2004) reported similar observation in river Ganga at Haridwar due to Bhimgoda barrage.

A total 15 taxa (family) were observed at all the stations. Among these Caenidae were most abundant taxa at S1 (20.4%) while Thiaridae was abundant on remaining stations at S2 (26.1%), S3 (24.4%) and S4 (40.1%). The benthic invertebrate assemblages varied at S1 (CE- TH-CO-AM-VI), S2 (TH-CE-CH), S3 (TH-CH-CE-CO-BA) and S4 (TH-CH-CO) [Table 2]. The high abundance of Caenidae at S1 may be attributed to the dominance of small stony substrate (cobbles) and slow water velocity. The adjacent agriculture landuse at S1 provided fine particulate organic matter (FPOM) in the river which helps in increasing the level of FPOM resulting in dominance of Caenidae. Thiaridae preferred soft substratum (clay-silt) thus the abundance level of Thiaridea increased highest at S4 compared to S2 and S3. Nautiyal and Mishra (2012) also reported high abundance of Caenidae at cobble dominated station in the Ken river. Similar observation was also reported in a Brazilian river, the Lules (Mesa 2010).

Table 2: Taxonomic richness, assemblages and composition of benthic macroinvertebrate fauna in the river Dhasan at various stations

Taxa	S1	S2	S3	S4
Taxonomic richness	13	13	11	9
Assemblages (10%)	CE-TH-CO-AM-VI	TH-CE-CH	TH-CH-CE-CO-BA	TH-CH-CO
Caenidae	20.4	20.3	12.2	-
Baetidae	9.6	8.8	10.4	-
Chironomidae	4.8	11.3	14.0	18.6
Simulaidae	0.2	2.4	6.8	-
Tabanidae	3.4	3.8	-	5.6
Dysticidae	1.6	3.4	3.6	-
Elmidae	2.5	0.9	2.4	-
Gomphidae	-	1.9	3.9	5.6
Agrionidae	-	-	-	1.9
Crustacea	1.8	0.9	-	2.7
Viviparidae	10.1	7.9	7.4	2.9
Thiaridae	16.0	26.1	24.1	40.1
Ambleceridae	13.0	3.4	3.3	5.0
Corbiculidae	14.0	9.0	11.9	17.8
Unidentified	2.5	-	-	-

Longitudinally, the abundance of benthic macroinvertebrate fauna varied from S1 to S4. The abundance of Caenidae and Viviparidae declined longitudinally from S1 to S4 (Fig.2). However, Baetidae revealed slight decline from S1 to S2, and increase at S3 but again decrease at S4 (Fig.2). In case of Chironomidae and Gomphidae, the abundance increased from S1 to S4 (Fig.2). The abundance of Simulidae and Dysticidae indicated increasing patternfrom S1 to S3 and decrease at S4 (Fig.2). Longitudinally, the abundance of Tabanidae and Thiaridae enhanced from S1 to S4 but sudden declined at S3 (Fig. 2). However, the abundance of Elmidae declined from S1 to S2 and increased at S3 but absent at S4. The abundance of Ambleceridae and Corbiculidae declined from S1 to S2 then increased from S2 to S4 (Fig. 2). The reduction of substrate size from S1 (cobble) to S4 (sand) resulted in declining the abundance of Caenidae, Baetidae, Viviparidae and Ambleceridae. Simultaneously, the abundance of Thiaridae, Chironomidae and Corbiculidae increased from S1 to S4, as the percentage of soft substratum (sand-silt) increases (Death, 2003).

Table 2: Canonical correspondence analysis indicated the taxa and environmental relationship and the percentage variation of environmental variables.

Axes	1	2	3	4	Total inertia
Eigen values	0.165	0.091	0.024	0.013	0.655
Species-environment correlations	0.962	0.885	0.785	0.689	
Cumulative % variance of taxa data	25.2	39.0	42.7	44.7	
Cumulative % variance of taxa-environment relation	52.1	80.9	88.5	92.5	
Sum of all eigenvalues					0.655

<u>Percentage variation of Environmental variable</u>

Environmental variables	λ -Value	%	p-value	F-value
Current velocity	0.16	50	0.002	11.83
Longitude	0.08	25	0.002	7.83
Land use	0.03	9.375	0.016	2.06
Transparency	0.01	3.125	0.176	1.46
Latitude	0.01	3.125	0.502	0.96
Sample depth	0.01	3.125	0.322	1.14
pH	0.01	3.125	0.662	0.79
Water temperature	0.01	3.125	0.944	0.44

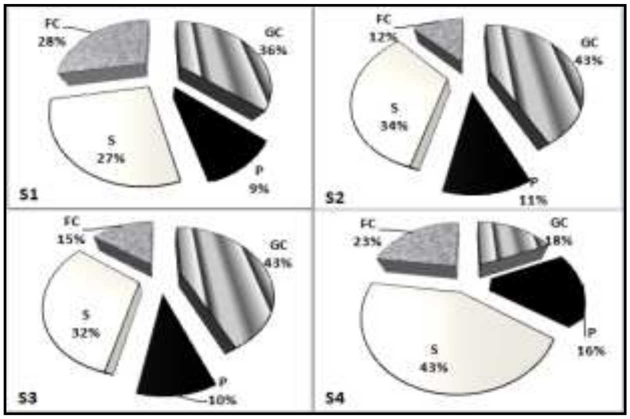

Fig. 3: Characterization of functional feeding groups (FFG) of benthic macroinvertebrate fauna in river Dhasan at stations S1 to S4. Acronyms: S - Scrapper, GC - Gathering collector, FC - Filtering collector, P - Predator

The river Dhasan was separated in to two sections; 1) gathering collectors (S1 -to S3) and 2) scrapper (S4) based on functional feeding groups of the benthic macroinvertebrate fauna. The gathering collectors longitudinally increased from S1 (36%) to S3 (43%) but sudden decrease at S4 (18%). However, scrapper and predator increased from S1 to S4 (Fig. 3). The abundance of gathering collector was attributed to abundance of stony (hard) substratum which allows breaking of course particulate organic matter (CPOM) in to FPOM due to water current velocity. Longitudinally, the also observed the higher abundance of Chironomidae in soft substrate (sand-silt). The high abundance of

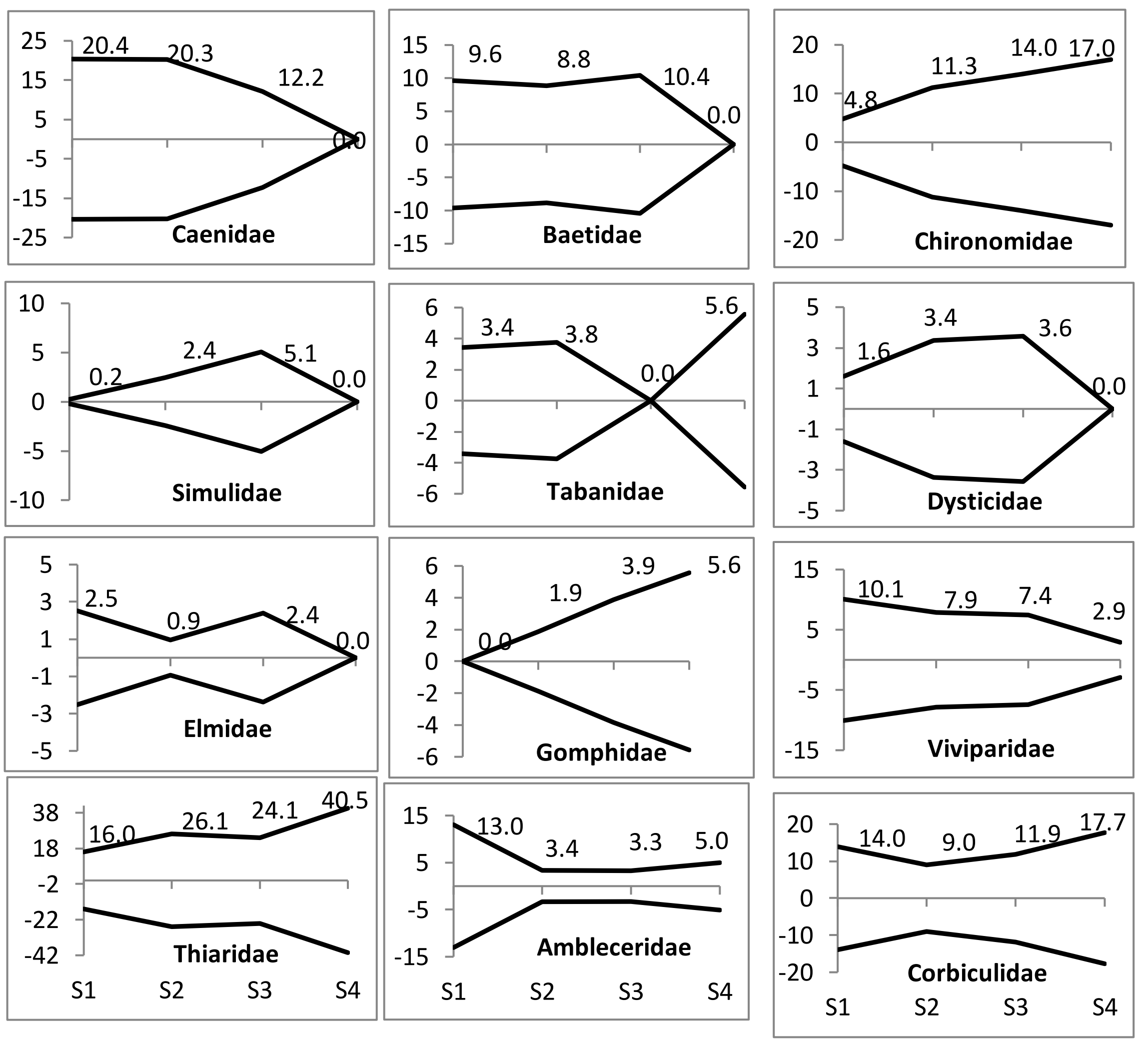

Fig. 2: Longitudinal variations in the abundance of benthic macroinvertebrate fauna in river Dhasan from S1 to S4

of mollusca (Thiaridae and Corbiculidae) was attributed to abundance of chemical fertilizers (calcium and phosphorous) in the river from adjacent land use, especially agriculture land. Mishra and Nautiyal (2013) observed abundance of Thiaridae in a another central highlands river the Tons. Schreiber *et al.* (2003) suggested that *Potamopyrgus antipodarum* (Gastropoda) populations may increase in the response to increased food resources that result from agriculture disturbances by human disturbance (Kerans *et al*., 2005) in the Australian streams. dominance of collector functional feeding group is also reported in tropical rivers (Hyslop and Hunte-Brown, 2012) and subtropical rivers (Jiang *et al.*, 2011; Mishra and Nautiyal, 2011). Nautiyal, (2010) also reported similar result in an Indian Himalaya river Bhagirathi. The abundance of scrapper at S4 was attributed to deposition of FPOM on soft substrate along with algal growth. Thus, the river as a unit indicated two sections- headwater to lower section (heterotrophic) and mouth section (autotrophic). The presence of heterotrophic condition in ¾ part of the river was due to extensive agriculture and anthropogenic activity (dam). Stone and Wallace (1998) also reported abundance of autotrophic condition at mouth zone.

The CCA ordination revealed that cumulative percent variance of taxon-environment relation for axes 1 and 2 was 52.1and 29.8%, respectively, with eigen values of 0.165 and 0.091 (Canonical eigen value, 0.655). Of the 15 environmental variables, current velocity (50%) was most important variable causing distribution of benthic macroinvertebrate fauna, followed by longitude (25%) and land use (9.37%) [Table2]. Most taxa were associated with axis 1 except Ambleceridae, Crustacea, Simulidae and Gomphidae. The taxon-environmental relationship indicated that Thiaridae was highly associated taxon with current velocity, while Corbiculidae, Tabanidae and Agrionidae were associated with dissolved oxygen. Similarly, Baetidae and Simulidae were associated with substratum (Fig. 4). Current velocity was most important factors causing distribution of benthic macroinvertebrate fauna in the central Indian river, the Dhsana. In a central Indian river the Paisuni, Mishra and Nautiyal (2011) also reported similar observations. Singh *et al.* (2010) reported substratum as major variable in the Himalayan ecoregion. The current velocity, substrate size, conductivity and abundance of aquatic plants were the core factors in the some other subtropical rivers of the world (Miserendino and Pizzolon, 2003; Buss *et al.*, 2004).

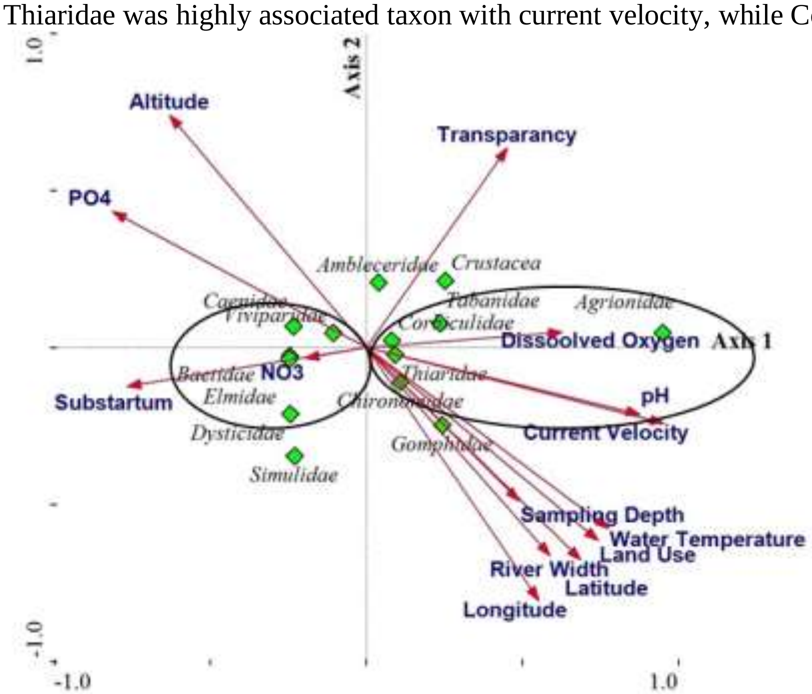

Fig. 4: Canonical correspondence analysis (CCA): The multi-variate analysis indicates the relationship between benthic macroinvertebrate taxa and environmental variables in river Dhasan. Taxon and stations are indicated by arrows and diamond shape, respectively. Current velocity is the most important variable causing 50% longitudinal variation in taxonomic composition from S1 to S4, followed by longitude (20%) and landuse (9.4%).

Conclusions: This study concluded that benthic macroinvertebrate fauna indicated taxonomic variation along the length of the river the Dhasan. Functionally, the river reflected two trophic zones; 1) heterotrophic and 2) autotrophic. The ¾ upper part of the river act as heterotrophic role while remaining ¼ part act as autotrophic role. The current velocity emerged as a major environmental factor for the distribution of benthic invertebrate fauna. The present study also indicated that River Continuum concept (RCC) is not applicable in the river Dhasan.

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