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Impact Of Water Current Velocity In Structuring Benthic Macroinvertebrate Community In Ramganga River, India

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Abstract: The objective of this study was to investigate how the speed of water flow affects the composition of benthic macro-invertebrate communities in the Ramganga River, located in the Himalayas. Over a period spanning from October 2014 to March 2015, samples were collected from eight different locations along the river, ranging from its source to its mouth (designated as S1 to S8). A total of 160 samples of invertebrates were collected from each station, covering a spectrum of current velocities. These velocities were classified into five categories: extremely low (type I, 0-15 cms^{-1}), low (type II, 15-30 cms^{-1}), moderate (type III, 30-45 cms^{-1}), moderate (type IV, 45-60 cms^{-1}), and high (type V, >60 cms^{-1}). The mean density of invertebrate fauna exhibited an increase from type I (214.0±104.6) to type III (545.7±361.3), followed by a decrease in type IV (22.8±5.7), and then a subsequent increase in type V (315.6±250.6). However, these fluctuations did not demonstrate a significant relationship. In total, 34 different taxa were identified across all sampling stations. The highest number of taxa (22) was observed in type III, while the lowest (8) was found in type IV. Among these taxa, Glossoscolecidae was most abundant in areas with type I velocity, Simulidae in type II, Leptoceridae in types III and V, and Psephenidae in type IV. Furthermore, Principal Component Analysis (PCA) was employed to elucidate the characteristic taxa associated with each velocity type. The results highlighted that mild velocity (type III) was particularly crucial in fostering maximum density and species richness within the benthic macro-invertebrate communities

Key words: current velocity • ganga river • leptoceridae PCA • ramganga • zoobenthos

Introduction

The regional conditions like physical environment, food resources and interactions with other species influenced the abundance and composition of biological communities (Allan and Castillo 2007). Among the physical environments, the current velocity is one of the important factors to influence macroinvertebrate abundance and distribution in streams (Hart and Finelli 1990; Fenoglio et al 2004). It plays a significant role in shaping benthic communities on substratum (Schoen et al 2013). The impact of current velocity on assemblage patterns of benthic macroinvertebrate fauna was observed in various flowing systems around the globe (Wellnitz et al 2001; Lancaster and Downes 2010).

Benthic macroinvertebrates are sensitive to river current velocity because current velocity is a major determinant of physical habitat in rivers. The current velocity regime changes lead to habitat alterations, changes in species distribution and abundance and loss of native biodiversity. The anthropogenic variation of current velocity is now contributing biodiversity loss across the world especially in freshwater ecosystems and to the degradation of many of the natural goods and services that these ecosystems provide to human communities (Postel and Richter 2003; Poff et al 2007). However, In India, several studies have been conducted on the relationship of benthic macroinvertebrate and environmental variable in Himalayan

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(Nautiyal et al 2015; Mishra et al 2020; Nautiyal and Mishra 2022) and Central Indian rivers (Mishra and Mishra 2011; Nautiyal et al 2017; Pandey and Mishra 2021), but no information is available about current velocity impact on structuring of benthic macroinvertebrate fauna especially in a Himalayan River, the Ramganga. Therefore, this study will provide an interesting knowledge that how current velocity will impact on function of the river ecosystem

Materials and Methods

The river Ramganga originates near Gairsain (Uttarakhand) of Doodha-Toli ranges in the lower Himalayas of Pauri Garhwal at an altitude of about 3,110 m (msl). The river Ramganga is one of the important tributaries of the river Ganga and it brings maximum pollutants from Uttarakhand to the Ganga river. The river Ramganga is a near pristine in the lower Himalaya of the first 100 km, until it reaches foothill where it starts facing challenges including the Kalagarah Dam (Fig 1), abstractions at the Hareoli barrage, sewage and industrial pollution from town/cities (Kashipur, Moradabad, Bareilly). Despite this, when it joins the river Ganga, it restores its water quality up to some extents. Therefore, this river lies in three different categories; very good (pristine to near pristine i.e headwater), moderate (impacted section i.e. town/agriculture) and poor (impacted with urban areas/cities; lower section).

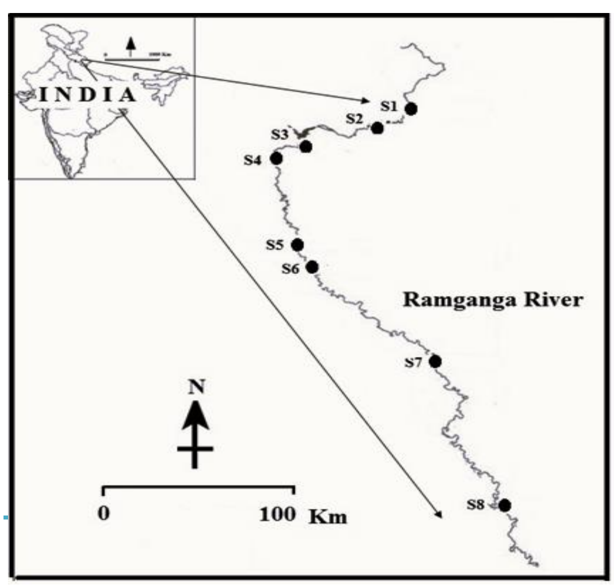

Fig 1: Geographical location of the river Ramganga in India and sampling station on the river Ramganga.

Eight stations (S1 to S8) were selected for conducting this study (Table 1). These stations were selected based on sampling approach on variation in the substrate type and landuse. The sampling area is too large and covering two states, therefore one-time intensive sampling (20 quadrates were sampled in a 200 m stretch of the river at each station and each quadrate was placed in a different microhabitat created by current velocity and depth) in the dry-period was considered appropriate for such studies (Corkum, 1991). The composition of macroinvertebrate fauna remains relatively stable in the dry period than in floods (Ormerod et al. 1994; Jüttner et al. 2003). The substrate type and land use pattern varied along the length of the river (Table 1). The invertebrate samples were collected from margin of the river to the maximum approachable depth (7cm, 20cm, 35cm, 45cm, 55 cm) at five different categories of current velocity (EMCON current meter) extreme low, type I, 0-15 cms^{-1}; low, type II,15-30 cms^{-1}; mild, type III, 30-45cms^{-1}; moderate, type IV, 45-60 cms^{-1}; and high, type V, >60 cms^{-1}). The land-use is agriculture and also the wetland areas. Among the stations, the main river channel was fragmented due to production of sand bars in the mid-channel attributed to floods at S7.

Table 1. Geographical locations and physical features of the sampling station in the river Ramganga. Acronyms: Ag-Agriculture, B-Boulder, C-Cobble, P-Pebbles, S-Sand, S-Si-Sand-Silt, SIBWD- Savage input, bathing, washing, dying, BBWNOMV- Banks with boulders with no or occasional marginal vegetation, S-Si RSV- S –Si with rooted/submerged vegetation

Sr. No.	Stations	Latitude (ON)	Longitude (OE)	Altitude (masl)	River Width m)	Landuse	Substratum
1.	Bhikiasain (S1)	29° 63' 49"	79° 26' 667"	777	75-100	BBWNOM V	P >B >C > S>Si
2.	Marchula (S2)	29° 73' 112"	79° 25' 46"	560	30-40	BBWNOM V	C>B>P>S
3.	D/S Afzalgarh Barrage (S3)	29°49 ' 069"	78° 75' 552"	320	30-50	Ag	C-P>S
4.	D/S Hareoli Barrage (S4)	29° 41' 924"	78°61' 932"	230	30-40	Ag	S-Si RSV
5.	Agvaanpur (S5)	28° 56' 55.8"	78°43' 26.1"	192	30-40	Ag	S-Si RSV
6.	Katghar (S6)	28°49' 22.1"	78°47 '58.6"	189	70	SIBWD	S–Si
7.	Chaubari (S7)	28°17' 14.9 "	79°22' 10.3"	160	70	Ag	S > Si
8.	Dabri (S8)	27°29' 51.9 "	79°41' 45.8"	138	80-150	Ag	S-Si.

In India, Bhattacharyya et al (2000) reported five physiographic regions like Northern Mountains (temperature ranged 5-27^{O}C), The Great Plains (temperature ranged 6-48^{O}C), Peninsular India (temperature ranged 9-40^{O}C), Peninsular Plateau (temperature ranged 15-41 ^{O}C), Coastal Plains (temperature ranged 14 - 40^{O}C) and the Islands (temperature ranged 20-32^{O}C). The seasons are mainly categorized in to winter (November to February), summer/pre-monsoon (March to June) and monsoon (July to October). The benthic macroinvertebrate samples were collected during October 2014 to March 2015.

Total 160 samples were collected from 8 different stations along the river length from headwater to mouth. Lifting of stone (stony substratum) and sieving substrate (clay and silt bottom; mesh size 0.05 mm) methods were adopted for collection of invertebrate samples from 0.09 m-^{2} area (Mishra and Nautiyal 2011). The collected samples were preserved in 4% formalin solution and identified to family (as higher resolution identification is time consuming) by using standard keys (Edmondson, 1959; Edington and Hildrew, 1995; Nesemann et al., 2004; Nautiyal and Mishra 2013).

The counts data of benthic macroinvertebrate fauna were computed to determine density and taxonomic composition. The significant difference in density between two current velocity types were determined by using nonparametric methods (Mann-Whitney test-U test; PAST *ver* 4.03). The density was standardized by area and analyzed using linear regression (Schoen et al 2013). The MS office Excel was used to log-transformed the density data for improving the homogeneity of variance. Principal correspondence Analysis (PCA) was applied to determine the characteristic taxa with respect to variable velocity types CANOCO ver. 4.1 (terr Braak, 2002).

Results and Discussion

The mean density along with standard error of each invertebrate taxon varied accordingly with change of current velocity category among the stations from S1 to S8. The mean density increased from type I (214.0±104.6) to type II (378.2±206.5) to type III (545.7±361.3) but sudden decreased in type IV (22.8±5.7) and again increased in type V (315.6±250.6). Fig 2 indicated no significant relationship (p >0.05) between benthic macroinvertebrate density and current velocity categories *viz* Type I ($F_{1,6}$ = 0.029, p = 0.870, r^2= 0.004), Type II ($F_{1,6}$ = 0.073, p = 0.795 r^2 = 0.012), Type III ($F_{1,6}$ = 0.682, p = 0.440, r^2 = 0.102), Type IV ($F_{1,6}$ = 4.57, p =

0.076, $r^2 = 0.432$) and Type V ($F_{1,6} = 4.156$, $p = 0.087$, $r^2 = 0.409$). The maximum density of benthic macroinvertebrate fauna observed in type III and least density was observed in the type IV velocity.

Total 34 taxa (families) were recorded in the river Ramganga from S1 to S8 among all five different types of velocities. The taxonomic richness varied among the various types of velocity. The maximum number (22) taxa observed in type III velocity, while the lowest number (8) was observed in type IV (Table 2). The maximum number of taxa was observed in mild type III velocity (30-45cm^{-1}). This is because of increased current velocity from slow to mild can provide benthic organisms with resource by increasing delivery rates of particulate food for filter-feeders (Sircom and Walde 2011) and allow the colonization of macroinvertebrate grazers (Schoen et al 2013). However, Sircom and Walde (2011) concluded that enhanced resources increase taxonomic richness as well as also expand niche space. Niche expansion allows the colonization of the invertebrates and increases the abundance. However, in moderate (45-60 cms^{-1}) and high >60 cms^{-1}) velocities the availability of food resources diminishes which affect the richness and abundance of the organisms.

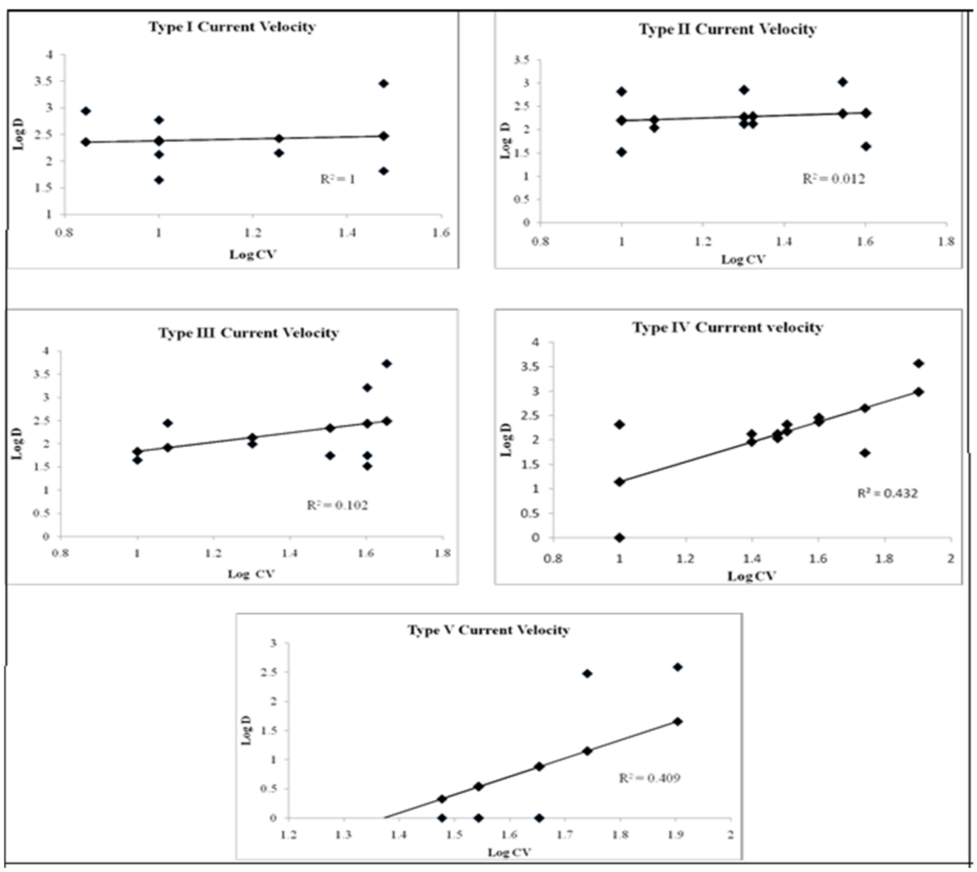

Fig 2: The effect of various current velocity types on the density of benthic macroinvertebrate communities in the river Ramganga. The regression analysis indicated positive relationship with invertebrate density and current velocity types

Among the total 34 taxa, Glossoscolecidae was most abundant in type I velocity, Simulidae in type II, Leptoceridae in type III and V, while Psephenidae in type IV (Table 2). The assemblages pattern (>10%) of benthic macroinvertebrate fauna also differed in various types of velocities; type I (Glossoscolecidae -Chironomidae), type II (Simulidae-Hydropsychidae-Chironomidae), type III (Leptoceridae-Simulidae), type IV (Psephenidae-Baetidae=Chironomidae=Elmidae-Dytiscidae - Hydropsychidae) and type V (Leptoceridae-Chironomidae). The abundant taxa (>10%) varied with respect to current velocity types in the river Ramganga. The abundance of Baetidae increased from extreme low velocity to moderate type velocity and decreased at high velocity. However, Hydropsychidae and Leptoceridae showed no definite pattern with respect to velocity. Chironomidae and Glossoscolecidae decreased from extreme slow to high velocity (Fig. 3).

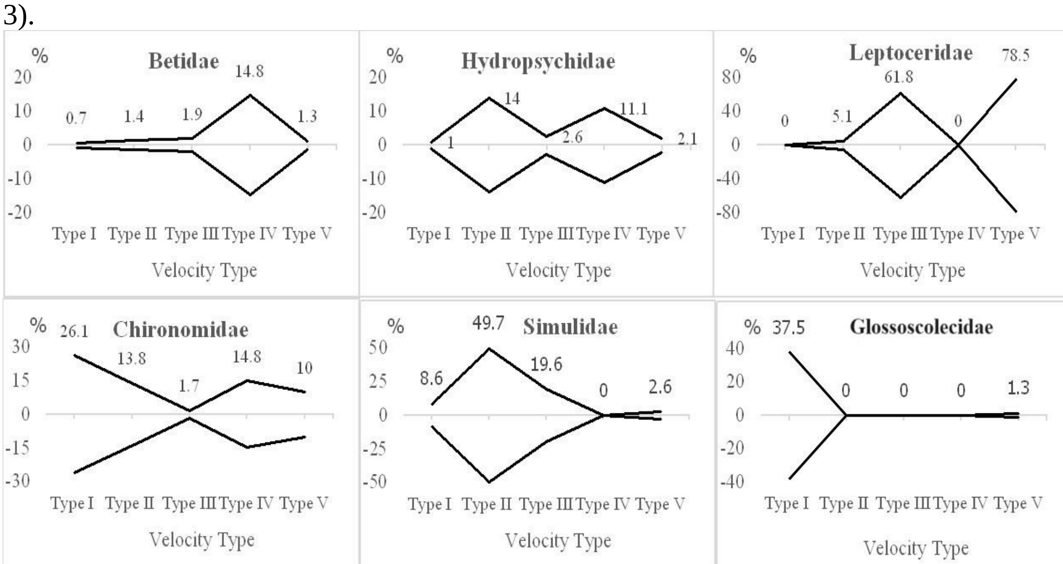

Fig 3: Variation of abundant taxa (>10%) with respect the various type of current velocity

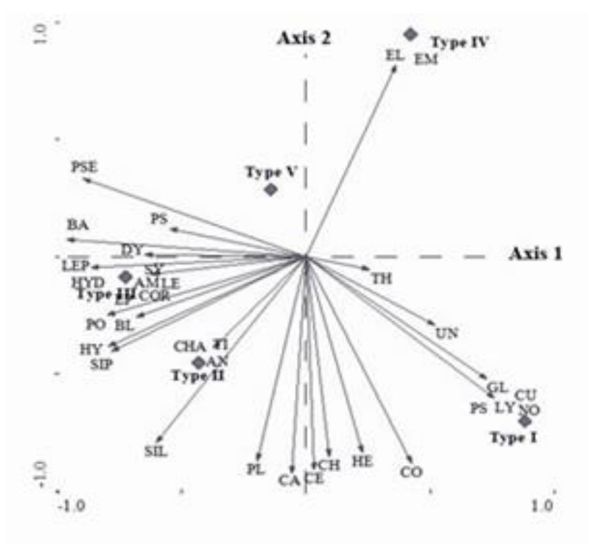

Figure 4. PCA ordination indicated the invertebrate characteristic taxa at various

Table 2 Taxonomic richness and composition of benthic macroinvertebrate fauna at various types of current velocity groups in the river Ramganga *viz* Type I (0-15 cms^{-1}), Type II (15-30 cms^{-1}), Type III (30-45 cms^{-1}), Type IV (45-50 cms^{-1}), Type V (> 60 cms^{-1}).

Taxa	**Extreme Low** (Type 1)	**Low** (Type II)	**Mild** (Type III)	**Moderate** (Type IV)	**High** **(Type V)**
Taxonomic richness	**16**	**19**	**22**	**8**	**12**
Baetidae	0.7	1.4	1.9	**14.8**	1.3
Caenidae	2.7	0.6	0.7		0.5
Leptophlebiidae			0.3		
Siphlonuridae		0.6	0.3		
Heptageniidae	5.5	0.4	0.7		
Ephemerellidae			0.4		
Polycentropodidae		0.4	1.6		
Hydropsychidae	1.0	**14.0**	2.6	**11.1**	2.1
Psychomyiidae		1.8	0.1	7.4	0.5
Hydrophilidae			0.1		
Leptoceridae		5.1	**61.8**		**78.5**
Blephariceridae		1.4	0.1		0.7
Chironomidae	**26.1**	**13.8**	1.7	**14.8**	10.0
Chaoboridae		1.0			
Simulidae	8.6	**49.7**	**19.6**		2.6
Empididae				7.4	
Tipulidae		2.6			
Anthericidae		0.4			
Psychodidae	1.4				
Ceratopogonidae	2.7	2.0	0.3		
Culicidae	0.7				
Syrphidae			1.6		
Psephenidae		1.2	4.2	**18.5**	1.3
Elmidae				**14.8**	
Dytiscidae		2.2	0.9	**11.1**	
Corixidae			0.4		
Notonectidae	2.7				
Glossoscolecidae	**37.5**				1.3
Lymneadae	1.7				
Planorbidae	0.3	0.2	0.1		
Thiaridae	0.3				0.8
Corbiculidae	7.6	1.0	0.1		
Amblemidae			0.1		
Unionidae	0.3				0.3

Principal component analysis (PCA) indicated that PCA axis 1 (eigen value, λ_1=0.450) and axis 2 (eigen value, λ_2=0.288) caused 45% and 28.8 % variation in benthic macroinvertebrate fauna. The PCA revealed that Glossoscolecidae, Culicidae, Psychomyiidae, Lymneadae, Notonectidae were characteristics taxa to type I velocity. Other taxa like Simulidae, Chaoboridae, Tipulidae, Anthericidae were characteristics to type II velocity, while Leptoceridae, Baetidae, Psephenidae, Hydrophilidae, Polycentropodidae, Siphlonuridae, Syrphidae, Amblemidae, Leptophlebiidae, Ephemerellidae, Corixidae, Blephariceridae were characteristic to type III and V velocities. The type IV velocity was responsible for abundance of only two taxa

Elmidae and Empidae (Fig 4). types of current velocity in the rive Ramganga. Acronyms: BA-Baetidae, HE-Heptageniidae, HY-Hydropsychidae, PS-Psychomyiidae, LP- Leptoceridae, CH-Chironomidae, SIL-Simulidae, EM-Empididae, PSE-Psephenidae, EL-Elmidae, DY- Dytiscidae, GL-Glossoscolecidae, CO-Corbiculidae, CA-Caenidae, LE-Leptophlebiidae, EP-Ephemerellidae, HYD-Hydrophilidae, LI-Limnephilidae, BR-Brachycentridae, BL- Blephariceridae, CHA - Chaoboridae, SY-Syrphidae, PY-Psychodidae, TI-Tipulidae, AN-Anthericidae, COR -Corixidae, NO-Notonectidae, LY- Lymneadae, AM - Amblemidae, PL-Planorbidae, PO-Polycentropodidae, TH-Thiaridae, UN-Unionidae, CE- Ceratopogonidae. Schoen et al (2013) reported higher richness and abundance of benthic macroinvertebrate fauna in the velocity >0.35 cms^{-1}. The fast current velocity often provides high heterogeneity in velocity (Wellnitz et al 2001) resulting niche expansion (Hart and Finelli 1999). The PCA ordination also characterized the indicator taxa in the different current velocity types. Glossosomatidae, Hydropsychidae, Brachycentridae and Baetidae were characteristics taxa to current velocity (Mishra and Nautiyal 2011).

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