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A Study of Benthic Macroinvertebrate Fauna in a Tributary of Himalayan River Bhilangana, Uttarakhand, India

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Abstract: The present study is focused on structural and functional composition of benthic macroinvertebrate fauna in the river Nailchami, a tributary of Bhilangana River. The seasonal samples were collected during March 2018 to February 2019 at three different stations (S1, S2, and S3) by lifting of stones and sieving of soft substrate (0.5 mm mesh size) from marked area (1ft square). Standard procedures were adopted to identify and analysis for preserved samples. The physico-chemical parameters varied among the stations. The total mean density varied seasonally at each station and found significantly different. The highest density was found in winter season followed by summer and monsoon. Fifty-eight invertebrate families were recorded among all the stations. Simulidae was most abundant family at all stations during summer season (S1-17.5%, S2-6.8%, S3-11.3%). However, in the monsoon season, chironomidae was abundant at S1 (22.8%) and S3 (10.6%), while limnephilidae (16.2%) at S2. In winter season, stations S1, S2 and S3 were dominated by chironomidae (48%), limnephilidae (12.4%) and simulidae (16.7%), respectively. PCA ordination techniques identified characteristic benthic macroinvertebrate taxa at different stations. Gathering collectors were most abundant functional feeding groups at all stations as well as seasons. Thus, river indicated heterotrophic status along the river length.

Keywords: Bhilangana • Forest landuse • Heterotrophic status • Himalaya • PCA • Simulidae

Introduction

The structural organisation of benthic communities varies along longitudinal gradient from headwater to mouth zone in a river (Vannote et al. 1980; Bahuguna and Negi 2018). Further the ecotonal system is characterised by high structural heterogeneity and significant fluctuation in the chemical-physical parameters of water and sediments, even on small spatial and temporal scales (Basset et al., 2001). The benthic macroinvertebrate organisms in a river show a wide range of tolerance to varying degree of pollution and are useful in biomonitoring programmes in various parts of the world (Wright et al. 1993; Dickens and Graham 2002; Butcher et al. 2003) as well as in India especially Uttarakhand Himalaya (Ormerod et al. 1994; Dobriyal et al. 2011; Rana et al. 2017; Bahuguna and Dobriyal 2018; Semwal and Mishra 2019).

Various physico-chemical factors are responsible for structuring the benthic macroinvertebrate community (Dobriyal et al. 1991; Rempel et al. 2000). Variation in the composition of the regional species pool and local environmental conditions over space and time result in much variability in natural communities, but the composition of the particular communities nonetheless is governed by a small number of underlying principle (Begon et al. 2006).

There is substantia information on the structural and functional aspects of benthic macroinvertebrate fauna available in different ecological regions of India; including the Himalayan region (Singh and Nautiyal 1990; Singh et al. 1994; Gusain et al. 2009; Nautiyal et al. 2015; Balodi and Koshal 2015; Koshal et al., 2017: Semwal and Mishra 2019), central India (Khan and Kulshreshta1993; Mishra and Nautiyal 2011, 2013a, 2016; Nautiyal et al. 2017; Mishra and Pandey 2019; Pandey and Mishra 2021) and western Ghat (Nair et al. 1989; Subramaniam et al. 2005).

In Uttarakhand, many anthropogenic and developmental activities such as road cutting, dam constructions etc. have been ongoing at a large scale. Out of these, abstraction of water for agriculture and drinking purpose cause habitat and flow disturbances in the river ecosystem and thus impact on biotic communities of the river.

The river Nailchami, a spring fed left bank tributary of river Bhilangana in Tehri Garhwal, Uttarakhand, is lifeline for people settled in small hamlets along its banks. Water from the river is abstracted for irrigation and drinking. The villagers do fishing in the river for their own consumption and recreation. These disturbances affect the taxonomic composition the river and also affect the functional status of the river. Therefore, this study is designed to determine the benthic macroinvertebrate composition and functional status of the river Nailchami.

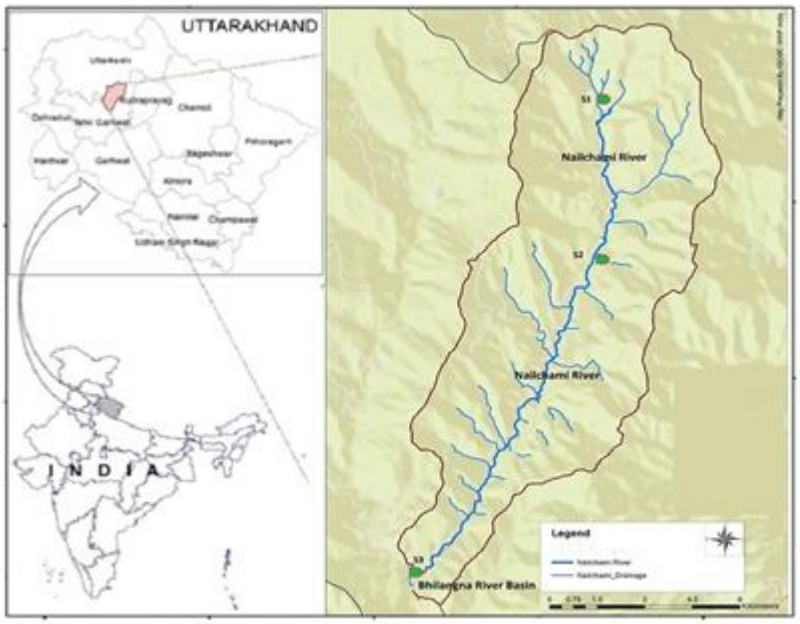

Fig 1: Geographical location of the Uttarakhand as well as Nailchami river. The sampling stations (S1, S2 and S3) are indicated in the Nailchami river as green colour filled circular rings

Materials and Methods

Study Area

The Garhwal Himalaya situated between the latitude $29^0$26' to 31^0 28' ^{O}N and longitude 77^0 49' to $86^0$06" ^{O}E blessed with large number of river system like Bhagirathi, Bhilangana, Yamuna, Alaknanda, Mandakini, Pindar etc. Nailchami a 29.5 km long tributary of River Bhilangana, originate near Chirbatiya at an elevation of 2170 m asl. in the Garhwal Himalaya (Agarwal and Singh 2021). The landuse pattern is mainly forest (pine, oak, deodar and mixed forest) throughout the river length. During the summer and winter season, river has very less water discharge because of abstraction of water for irrigation to the agriculture fields. The river is usually shallow with intermittently large deep pools.

Sampling of abiotic parameters and benthic macroinvertebrate fauna

The abiotic components and benthic macroinvertebrate fauna were sampled seasonally, at three different locations (S1-Tharti, S2-Dangi, S3-Chawashera) during March 2018 to February 2019. The parameters like water temperature (digital thermometer, Mextech multi meter), turbidity (Nephelometer), depth (pole with tape measure) water current velocity (ENCON current meter), pH (model HI 96107),

conductivity (LABTRONICS model-LT23), free CO_2 titration method (APHA 1998) and dissolved oxygen Winkler's methods (APHA1998) were measured at each station. The substrate pattern was categorised following Wentworth classification of substrate particle size (http://fwcb.cfans.umn.edu/courses/fw8459/Private/ substrate and Hyporheos 08-2.pdf). The benthic macroinvertebrates fauna was collected by lifting the stones and sieving the soft substrate (0.5 mm mesh size) from marked area (1ft square) further washed in a bucket full of water by dipping it a number of times to dislodge the attached fauna. The samples were preserved in 5% formalin for further analysis. Various benthic invertebrate taxa were identified to family level with the help of different keys (Macan 1979; Edington and Hildrew 1995). Family level counts were performed to obtain abundance (as %). Significant difference in density among the stations and seasons using the Kruskal–Wallis (H) test (PAST software http://nhm2.uio.no/norlex/past). The functional feeding group (FFG) was calculated by Cotta Ramusino et al. (1995) and Mishra and Nautiyal (2013b). Principal Component Analysis (PCA) was used to determine the characteristic taxa at each station (CANOCO ver 4.5; ter Braak and Smilauer 2002).

Results and Discussion

The abiotic parameters varied between the sampling stations in the river Nailchami. The sampling depth of the varied at each station from 0.15-0.38 m. The velocity decreased downstream of the river from S1 (0.30-0.70 ms^{-1}) to S3 (0.17- 0.45 ms^{-1}). The range value of turbidity increased from S1 (1.0-to 4.5) to S2 (1.0-to 5.5) and decline at S3 (Table 1). Water temperature and pH value increased from 22.5^{O}C to 27.5 ^{O}C and 7.5 to 8.5, respectively at S1 and S3. S1()to S3 (, 8.5), similarly free CO_2 also indicated increasing trend from S1 to S3 (1.2-1.72 mgl^{-1}). Although, benthic macroinvertebrate sensitivities to pH vary (Yuan 2004), value below 5.0 and greater than 9.0 are considered harmful. Low pH values are associated with lower density of benthic macroinvertebrates (Thomsen and Friberg 2002). However, slight decrease in dissolved oxygen was observed from S1 (10.5 mgl^{-1}) to S3 (10.2 mgl^{-1}; Table 1). The conductivity of river water increased from S1 to S2 and decreased to S3. Nautiyal (2001) observed that water temperature, pH and conductivity increases downstream in the rivers of Garhwal Himalaya.

The benthic macroinvertebrate community consisted belonging to phylum annelida, arthropoda and mollusca. The arthropods contributed >90% of the total community. Total mean density varied at each station as well as season. The highest density was found in winter season followed by summer and monsoon (Figure 2). Among the seasons, Kruskal-Wallis test indicated significant difference in density at all stations (S1- p value=0.001271; S2- p value=0.008281; S3- p value =0.01906). The highest density in winter season was also reported in most of the studies on Himalayan rivers (Nautiyal et al. 2015; Semwal and Mishra 2019; Negi and Singh 2021) as stable ecosystems and healthy water quality occur just after flood (monsoon season).

Total 58 invertebrate families were recorded in the Nailchami river. Among these, insect families were predominant. The faunal composition of invertebrate fauna at family level varied temporally at all the stations (S1, S2 and S3). In the summer season, simulidae was most abundant taxa at all stations (S1-17.5%, S2-6.8%, S3-11.3%). However, in the monsoon season, chironomidae was abundant at S1 (22.8%) and S3 (10.6%), while limnephilidae (16.2%) at S2. In winter season, stations S1, S2 and S3 were dominated by chironomidae (48%), limnephilidae (12.4%) and simulidae (16.7%), respectively. Semwal and Mishra (2019) observed abundance of

simulidae at headwater stations in spring fed river of Garhwal Himalaya. The abundance of chironomidae in the monsoon season was attributed to dominance of silt and sand substratum (Death 2003; Aagaard et al. 2004; Mishra and Nautiyal 2011).

Table 1 Geographical co-ordinate of different sampling stations in Nailchami River along with different forest types, substratum and physico-chemical characteristics. Acronyms: ORF-Oak-Rhododendron Forest, Agri-Agriculture, PF-Pine Forest LB-Large Boulders, SB-Small Boulder, C-Cobbles, P-Pebbles, St-silt

Stations	Tharti (S1)	Dangi (S2)	Chawashera (S3)
Latitude	30°25'39"	30°25'39"	30°25'39"
Longitude	78°39'56"	78°39'56"	78°39'56"
Altitude masl	1840	1200	894
Stream order	II order	III order	III order
Forest	ORF- Agri	PF-Agri	PF-Agri
Substratum	LB-SB-C-P-St	LB-C-P	LB-C-P
Sampling Depth (m)	0.15 –0.38	0.15 –0.38	0.15 –0.38
Velocity (ms^{-1})	0.30–0.70	0.17–0.63	0.17–0.45
Turbidity (NTU)	1.0–4.5	1.0–5.5	1.0–4.5
Water temperature (°C)	3.5 - 22.5	4.5 - 25.7	3.5 - 27.5
pH	6.8 –7.5	7.5 –8.5	7.0 –8.5
Dissolved oxygen ($mg\ l^{-1}$)	7.5 –10.5	7.1 –10.2	7.5 – 10.2
Free CO_2 ($mg\ l^{-1}$)	0.36 –1.2	0.55 –1.27	0.32 –1.72
Conductivity (Scm^{-1})	74.5 –199.2	69.5 –204.4	94.5 –120.5

Fig 2: Total mean density of benthic macroinvertebrate fauna in summer (S), monsoon (M) and winter (W) seasons at different stations in Nailchami river

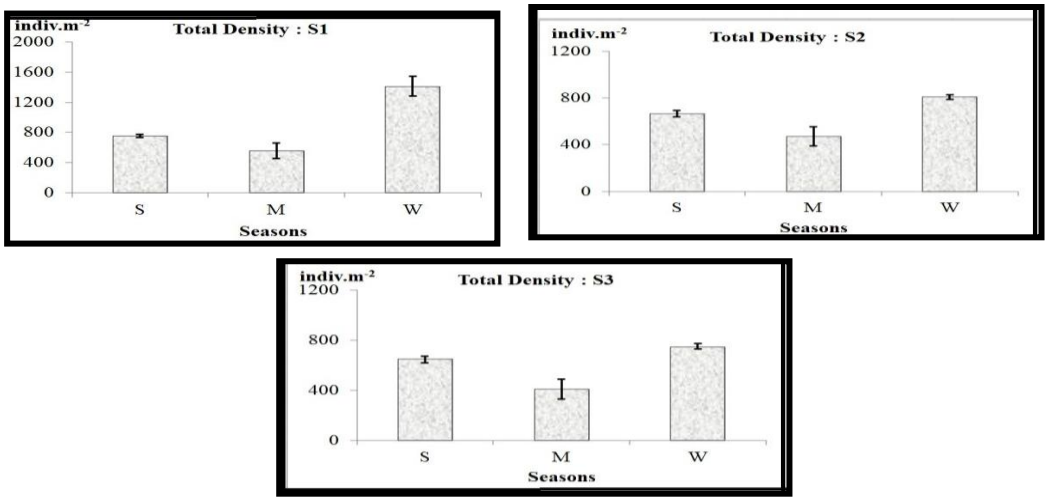

Table 2. Seasonal variation in the percentage composition of functional feeding groups at different stations in the river Nailchami.

Stations	Season	Shredders	Gathering collectors	Filtering collectors	Scrapers	Predator
S1	S	14.6	44.1	9.1	9.0	23.3
	M	15.9	48.2	8.9	7.4	19.5
	W	10.2	65.2	6.5	5.5	12.6
S2	S	15.6	31.4	10.5	12.9	29.7
	M	23.7	34.9	9.0	13.0	19.4
	W	20.5	37.6	9.5	9.0	23.3
S3	S	17.8	34.1	10.6	10.5	27.0
	M	15.2	36.8	10.4	13.3	24.4
	W	17.3	32.9	10.3	14.5	25.0

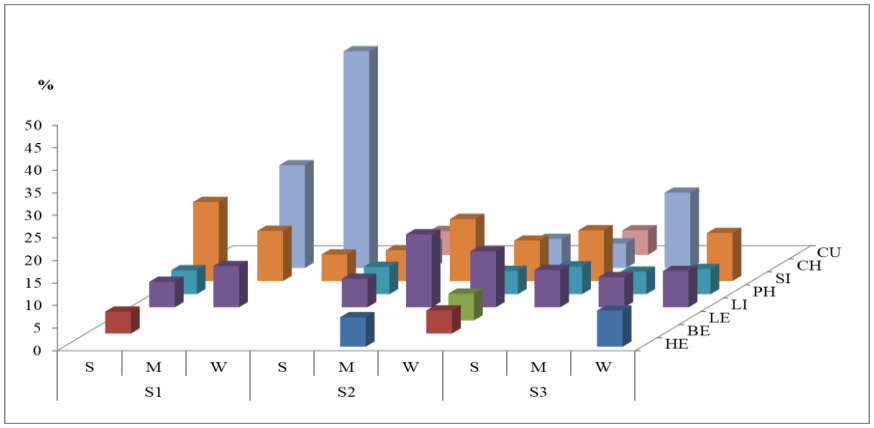

Fig 3: The taxonomic composition of benthic macroinvertebrate taxa (>5%) at various stations and in different seasons. Acronyms: HE- Heptageniidae, BE –Baetidae, LE –Leptophlebiidae, Li-Limnephilidae, PH-Philopotamidae, SI-Simulidae, CH-Chironomidae, CU-Culicidae

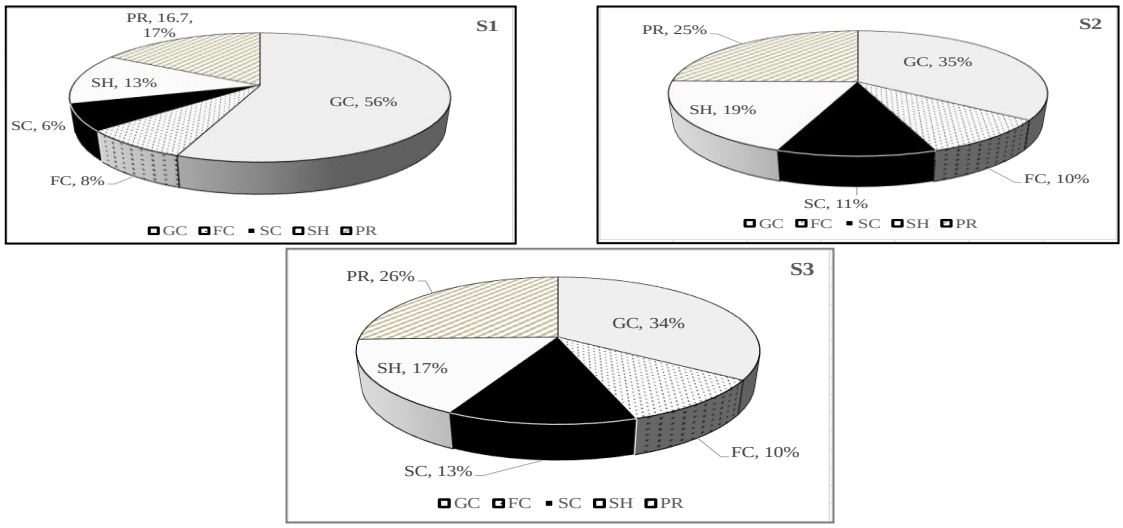

Fig 4: Functional feeding groups composition of benthic macroinvertebrate fauna at various stations. Acronyms: GC- gathering Collectors, FC-Filtering Collectors, SC-Scarpers, SH-Shredder, PR- Predators

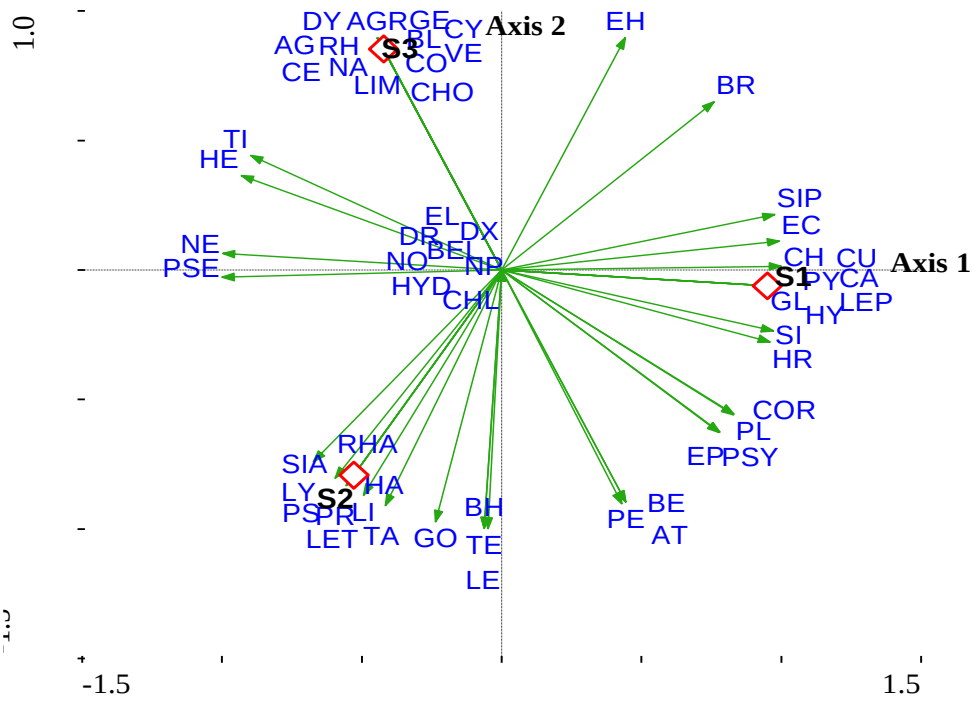

Figure 5: Principal component analysis (PCA): the ordination indicates the characteristic taxa (in circle) through graphical presentation between the taxon (arrows) and station (filled square) in the Nailchami river. The taxa close to the station are characteristic of that station and encircled. Acronyms: EP – Ephemerellidae, LE –Leptophlebiidae, CA - Caenidae, SIP - Siphlonuridae, EC - Ecdyonuridae, HY -Hydropsychidae, GL - Glossosomatidae, LEP - Leptoceridae, BR - Brachycentridae, RH - Rhyacophilidae, BL - Blepharoceridae, PSY –Psychodidae, LET – Leptidae, TI – Tipulidae, DX – Dixidae, AT – Athericidae, TA –Tabanidae, LM – Limoniinae, RA – Rhagionidae, PE – Perlodidae, PR –Perlidae, CHL Chloroperlidae, NE –Nemouridae, DR – Dryopidae, HYD – Hydrophilidae, EL – Elmidae, HA – Haliplidae, PSE – Psephenidae, DY – Dytiscidae, SIA –Sialidae, CY –Corydalidae, CO –Corixidae, NA –Naucoridae, GE –Gerridae, VE – Veliidae, NP –Nepidae, NO –Notonectidae, BEL – Belostomatidae, AG –Agrionidae, GO – Gomphidae, CE – Coenagrionidae, CHO –Chlorocyphidae, AG –Agridae, COR –Corydalidae, PY – Pyralidae, LY –Lymnaeidae, HR –Hirudinaria. Rest of acronyms in caption of figure 3.

Characteristics taxa at different stations

The PCA eigen values for axis 1 (λ1 =0.891) and 2 (λ2 =0.109) indicated 89.1% and 10.9.1% cumulative variance in taxonomic composition, respectively, in Nailchami river. The characteristic benthic macroinvertebrate taxa differed among the sampling stations. The family chironomidae, culicidae, pyralidae, caenidae, glossosomatidae, leptoceridae and hydropsychidae were characteristics taxa at S1. However, rhagionidae, sialidae, haliplidae, lymnaeidae, psychodidae, perlidae, limnephilidae, leptidae, tabanidae were characteristic taxa at S2. Similarly, dytiscidae, agridae, gerridae, corydalidae, blepharoceridae, agrionidae, rhyacophilidae, coenagridae, naucoridae, limoniidae, corixidae, vellidae and chlorocyphidae were recorded as characteristics taxa at S3 (Figure 4).

Functional feeding groups

Functionally gathering collectors was dominant at all the stations followed by predators, shredders, scrapers and filtering collectors (Figure 5). The percentage

composition of gathering collectors decreased seasonally from S1 (56%) to S3 (34%), while the remaining groups (predators, filtering collectors, scrapers and shredders) increased from S1 to S3 (Table 2). The ecological status of the river prevailed heterotrophic at all stations along the river length. However, level of heterotrophy decreased from S1 to S3, attributed to widening of river towards downstream, provided more area of habitat for sun rays penetration which cause photosynthesis and develop autotrophy. Thus, in present study, increase impact of agriculture and habitation changes the functional status of the river Nailchami from heterotrophy to autotrophy. Similar, observations were also reported in the other Himalayan rivers (Nautiyal et al. 2015; Semwal and Mishra 2019) and central Indian rivers (Mishra and Nautiyal 2013b; Mishra and Pandey 2019).

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