

Assemblages of Benthic Macroinvertebrate Communities Downstream of a Dam on River Alaknanda in Garhwal Himalaya, Uttarakhand, India

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ABSTRACT

The assemblages of benthic macroinvertebrate communities along with the physicochemical variables in River Alaknanda (Garhwal Himalayan region of Uttarakhand) downstream of a dam of 330 MW power project, were recorded from three sampling sites during January 2019 to March 2019. The water temperature and pH remained low throughout the study, while the nutrient concentration, turbidity and conductivity were high at the downstream site. Among the benthic macroinvertebrates, a total of 37 genera, belonging to 22 families of 7 orders including molluscs were recorded. The maximum density of benthic fauna was recorded from the site nearest to the dam. Dipterans (Chironomidae) were the predominant order at all the three sampling sites, whereas Molluscs had the least density during the study. The canonical correspondence analysis (CCA) reveals that high nutrient, dissolved oxygen and moderate water velocity governs the occurrence of benthic fauna downstream of the dam. The present study reveals that the chironomidae being the most pollution tolerant taxa and occurring in high density suggest the organic pollution at sites downstream of the dam.

Key Words: Benthic Fauna, Physicochemical Variables, Canonical Correspondence Analysis, Organic Pollution

INTRODUCTION

Rivers are integral part of mountain landscape. To meet the basic necessities, the exploitation of aquatic resources has continued unabated. The flow manipulation and reservoir construction causing a massive dilapidation of river ecosystems, result in large changes in the flora and fauna of rivers, isolation of wildlife populations and fragmentation of their habitats (McIntosh et al. 2002, Benbow et al. 2005). River systems are affected by the disruption of their natural course and flow regime, altered water temperatures and disruption of river continuity (Ward and Stanford 1995,

Born et al. 1998, Bunn and Arthington 2002). As, the stream regulation has immense impact on various benthic communities (Spence and Hynes 1971, Lehmkuhl 1972, Trozky and Gregory 1974, Sugunan and Das 1983, Whitton 1984), benthic macroinvertebrates along with algae serve as the most important group of organisms used for assessing the water quality in rivers. The stream macroinvertebrates have been studied comprehensively for biomonitoring of numerous environmental stresses. They reveal stability in assemblage structure and are sensitive to watershed conditions thereby making them valuable for long-term monitoring of stream health. Macroinvertebrates have also been considered for evalu-

ating the restoration works owing to their rapid response to changing environmental conditions (Dickens and Graham 2002, Butcher et al. 2003, Sharma et al. 2004, Gusain and Gusain 2005, Gusain et al. 2009, Singh et al. 2010, Balodi and Koshal 2015, Kumar et al. 2016, Rana et al. 2017).

In Uttarakhand, several developmental activities such as road cutting, dam constructions etc. have been going on at a large scale. Dam construction has resulted in disturbance in the water bodies, thereby affecting the biotic communities of the river of that region. Hydroelectric projects cause alteration in the channel morphology of the river and thus influence biotic communities of the river. The present short-term study

records the benthic macroinvertebrate assemblages in River Alaknanda downstream of a dam in the Garhwal Himalayan region of Uttarakhand.

Study Area

River Alaknanda is a snow-fed river, which originates from Satopanth and Bhagirathi Kharak glaciers at an altitude of 3641 m above sea level, flows about 230 Km before joining the River Bhagirathi at Devprayag to form the River Ganga. A hydropower project has constructed a dam across the river near the township of Srikot. Benthic macroinvertebrates were sampled at three sites near the townships of Srinagar, Chauras and Srinagar (Table 1, Figure 1).

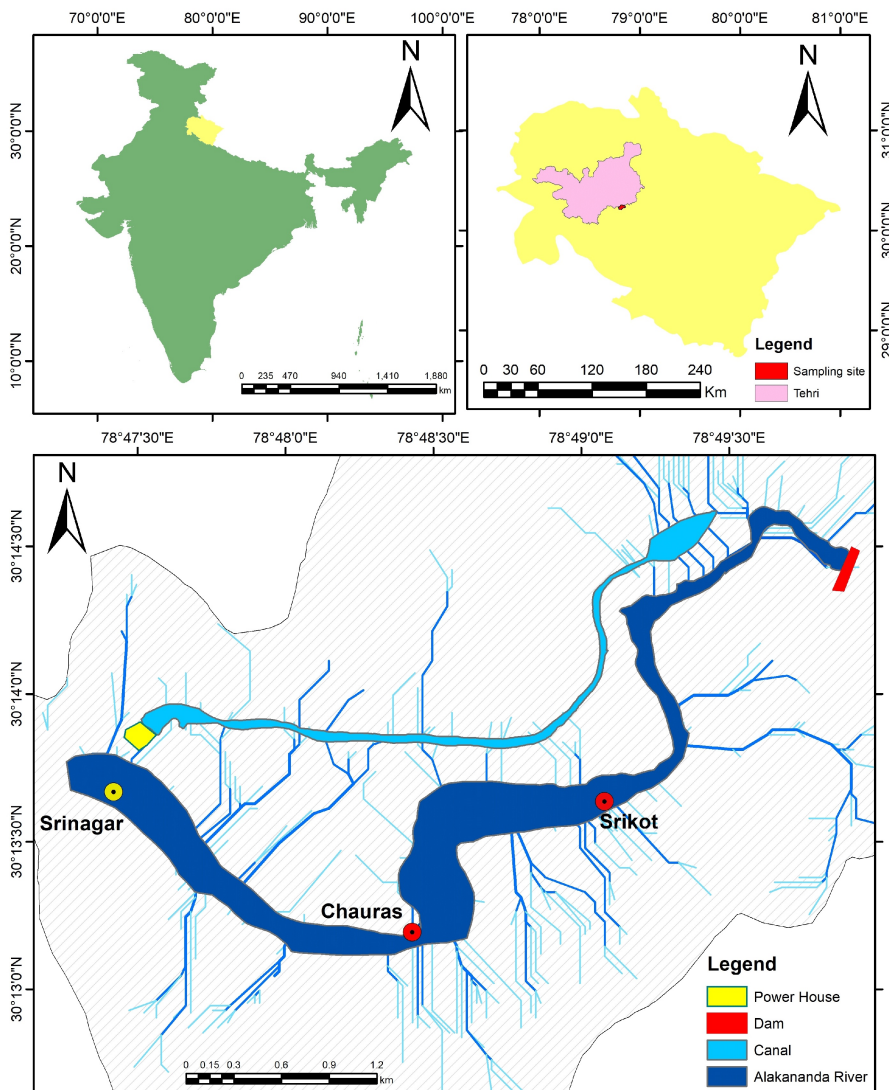


Figure 1. The designated sampling site at downstream to dam on River Alaknanda.

Table 1. Sampling sites at downstream to dam on River Alaknanda.

Site	Latitude (N)	Longitude (E)	Altitude (m)	Distance from dam (km)	Substrate composition
Srikot	30°13'39.97"	78°48'01.02"	540.41	3.1	Sand/Gravels/Pebbles/Cobbles
Chauras	30°13'10.63"	78°48'17.72"	533.70	5.2	Sand/Gravels
Srinagar	30°13'42.76"	78°47'22.12"	530.96	7.2	Gravels/Pebbles/Cobbles

METHODS

Selected physicochemical parameters such as air temperature, water temperature, mean channel width, mean flow velocity, mean water depth, conductivity, pH, dissolved oxygen, free carbon dioxide, phenolphthalein alkalinity, total alkalinity, nitrate, phosphate and total dissolved solids of water were measured and analyzed at all the sampling sites following standard methods (Trivedy and Goel 1984, APHA 2005).

Benthic macroinvertebrates were sampled at the three sampling sites at 15 days' interval from January 2019 to March 2019 using modified Surber's square foot sampler (Welch 1952). The collected macroinvertebrates were transferred to a plastic container and preserved in 4% formalin. Benthic macroinvertebrates were identified to the genus level, with the help of different keys (Needham and Needham 1962, Usinger 1971, Macan 1979, Elliott and Humpesch 1983, Epler 2001), using Olympus Stereozoom binocular microscope (SZ-series) and Magnus MIPS USB 2.0, Capture and Display software. The density of benthic macroinvertebrates was expressed as number of individuals m^{-2} .

Data Analysis

The data collected on benthic macroinvertebrates counts was further analyzed by calculating various ecological indices viz, Shannon-Wiener species diversity index (Shannon and Wiener 1963), Species richness index (Margalef 1957, Odum 1971) and Evenness, using PAST 1.73 (Hammer et al. 2001). Analysis of variance (ANOVA) was carried out to test the significance of variation of physicochemical variables and benthic taxa at various sampling sites using SPSS 20. Relationship between physicochemical variables and occurrence of benthic macroinvertebrates was analysed by canonical correspondence analysis (CCA) by using PAST 1.73 (Hammer et al. 2001).

RESULTS

Physicochemical Characteristics

During the present study air temperature varied up to 26°C (4.0 ±0.0°C to 30.0 ±0.0°C), while water temperature varied up to 10°C as it ranged between 3.0 °C and to 13.0 °C. The mean width, mean depth, mean velocity and pH vary significantly ($p < 0.05$) between the sampling sites downstream to dam. The mean velocity was recorded minimum (0.029 ±0.002 $m s^{-1}$) at Chauras, while it was maximum (0.48 ±0.00 $m s^{-1}$) at Srinagar during the study period (Table 2).

Dissolved oxygen in water remains high and ranged between 9.83 ±0.43 $mg L^{-1}$ (Chauras) to 12.05 ±0.05 $mg L^{-1}$ (Srikot). Free CO₂ varied from being absent to 16.50 ±7.78 $mg L^{-1}$ (Srikot). Similarly, the nutrient concentration viz phosphate and nitrate along with turbidity, conductivity and total dissolved solids remains higher at Srikot, the closest site at downstream to dam (Table 2).

Benthic Macroinvertebrates Communities

A total of 35 genera of benthic macroinvertebrates belonging to 21 families of 7 orders in class Insecta were recorded. The dominant insects order was Diptera (14 genera) followed by Ephemeroptera (8 genera), Trichoptera (7 genera), Odonata and Coleoptera (2 genera each), whereas Plecoptera and Hemiptera were represented by single genus. Besides, one genus of each Mollusca and unidentified taxa were also recorded during the present study period. The highest number of benthic macroinvertebrate taxa was recorded from below the reservoir at Srikot with 33 genera followed by Chauras and Srinagar with 22 and 21 genera respectively, during the present study period (Table 3).

The density of benthic macroinvertebrates was recorded between 489.09 ±11.40 (Chauras) and 693.74 ±6.86 (Srikot) during the study period (Table 4).

Table 2. Range and analysis of variance (ANOVA) of physicochemical parameters recorded at three sampling sites on River Alaknanda during the present study (Mean \pm SD).

Physicochemical parameters	Srikot		Chauras		Srinagar		p value
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	
Air temperature (°C)	4.00 \pm 0.00	21.50 \pm 2.12	5.50 \pm 0.71	23.00 \pm 1.41	18.75 \pm 3.18	30.00 \pm 0.00	0.099
Water temperature (°C)	3.00 \pm 0.00	11.25 \pm 0.35	4.25 \pm 0.35	13.25 \pm 1.06	9.00 \pm 0.00	13.00 \pm 0.00	0.507
Mean width (m)	81.00 \pm 2.83	92.50 \pm 13.44	76.20 \pm 1.41	78.60 \pm 0.85	28.00 \pm 0.00	56.00 \pm 36.77	0.000
Mean depth (m)	0.11 \pm 0.01	0.22 \pm 0.03	0.13 \pm 0.03	0.26 \pm 0.03	0.24 \pm 0.01	0.31 \pm 0.01	0.030
Mean velocity (m s ⁻¹)	0.09 \pm 0.13	0.17 \pm 0.24	0.029 \pm 0.002	0.045 \pm 0.007	0.22 \pm 0.32	0.48 \pm 0.00	0.006
Turbidity (NTU)	1.50 \pm 0.71	6.00 \pm 1.41	1.00 \pm 0.00	4.00 \pm 2.83	1.50 \pm 0.71	2.00 \pm 0.00	0.258
Conductivity (μ S cm ⁻¹)	139.25 \pm 0.35	364.00 \pm 125.87	159.50 \pm 7.78	273.00 \pm 2.83	158.50 \pm 12.02	174.00 \pm 0.00	0.504
pH	8.30 \pm 0.28	8.85 \pm 0.07	8.10 \pm 0.71	8.80 \pm 0.42	8.90 \pm 0.14	9.00 \pm 0.21	0.049
Dissolved oxygen (mg L ⁻¹)	10.74 \pm 0.86	12.05 \pm 0.05	9.83 \pm 0.43	11.56 \pm 0.00	10.24 \pm 3.01	11.96 \pm 0.00	0.074
Free CO ₂ (mg L ⁻¹)	—	16.50 \pm 7.78	—	14.08 \pm 0.62	—	4.40 \pm 6.22	0.838
Phenolphthalein alkalinity (mg L ⁻¹)	—	27.50 \pm 3.54	—	16.25 \pm 5.30	2.00 \pm 0.00	2.50 \pm 3.54	0.125
Total alkalinity (mg L ⁻¹)	12.25 \pm 3.89	127.50 \pm 3.54	7.00 \pm 2.83	73.75 \pm 5.30	7.50 \pm 0.00	8.90 \pm 1.56	0.087
Phosphate (mg L ⁻¹)	0.01 \pm 0.01	0.05 \pm 0.01	0.01 \pm 0.00	0.03 \pm 0.02	0.03 \pm 0.00	0.04 \pm 0.05	0.094
Nitrate (mg L ⁻¹)	0.89 \pm 0.69	1.70 \pm 1.23	0.28 \pm 0.17	1.07 \pm 0.63	1.26 \pm 0.65	1.59 \pm 0.00	0.167
Total dissolved solids (mg L ⁻¹)	99.50 \pm 9.19	230.50 \pm 79.90	105.50 \pm 3.54	140.50 \pm 2.12	106.25 \pm 5.30	118.00 \pm 0.00	0.234

Dipterans were the predominant order having maximum density at all the three designated sampling sites, whereas phylum Molluscs represents the least density during the study (Table 5). In the present study chironomidae was the most dominant family, represented by 7 genera at downstream to dam. Among the genera, *Tanytarsus* was most dominant taxa followed by *Chironomus*, while *Physsa* was the least dominant genera during the present study period (Table 4).

Analysis of variance (ANOVA) for the recorded taxa reveals that density of *Ephemerella*, *Baetis*, *Hydropsyche*, *Glossosoma*, *Agapetus*, F-Chironomidae vary significantly ($p < 0.05$) between all the designated sampling sites (Table 4). The Shannon-Weiner diversity index (H) was recorded between 1.61 (Chauras) and 2.55 (Srikot). Similarly, the evenness index (E) varied between 0.23 and 0.39 at Chauras and Srikot respectively. Also, the Margalef's richness index (D') was ranged between 3.04 and 4.61 respectively at Chauras and Srikot during the study (Table 6).

Relationships Between Physicochemical Parameters and Macroinvertebrate Communities

The pattern of the benthic macroinvertebrate commu-

nities distributed along the environmental variables over the sampling sites during the present study was revealed by canonical correspondence analysis (CCA). In the CCA the first two significant canonical axis explained together 100% ($\lambda_1=0.09$ and $\lambda_2=0.07$) of the total inertia of macroinvertebrate assemblages at three designated sampling sites. Among the 15 physico-chemical parameters, dissolved oxygen, turbidity, phenolphthalein alkalinity (PA), total alkalinity (TA), free CO₂, conductivity, mean width and total dissolved solids (TDS) were the significant variables in the upper left quadrant whereas air temperature, water temperature, pH, mean velocity and mean depth were significant in the lower right quadrant. Nitrate and phosphate were plotted in the upper right quadrant (Figure 2).

Among the recorded genera, the occurrence of *Hexatoma* was associated with the increased water temperature while that of F-Chironomidae was found to be related to mean velocity in the lower right quadrant at Srinagar. In the upper right quadrant, *Pentaneura*, *Cinygma* and *Antocha* were associated with the nitrate. In the upper left quadrant, the occurrence of *Ablabesmyia* was closely associated with the total alkalinity (TA) whereas *Procladius* and *Chironomus* were closely associated with the raised total dissolved

Table 3. Checklist and Occurrence of benthic macroinvertebrates at designated sampling sites in River Alaknanda during the present study.

Class/ Order	Family	Genera	Srikot	Chauras	Srinagar
Class Insecta					
Ephemeroptera	Heptageniidae	<i>Heptagenia</i>	+	+	+
		<i>Cinygma</i>	+	-	+
	Baetidae	<i>Baetis</i>	+	+	+
		<i>Platybaetis</i>	+	-	-
	Leptophlebiidae	<i>Leptophlebia</i>	+	+	-
		<i>Thraulodes</i>	+	-	-
	Ephemerellidae	<i>Ephemerella</i>	+	-	+
Caenidae	<i>Caenis</i>	+	-	-	
Odonata	Gomphidae	<i>Ophiogomphus</i>	+	+	-
		<i>Progomphus</i>	-	+	-
Plecoptera	Perlidae	<i>Perla</i>	-	-	+
Hemiptera	Pleidae	<i>Plea</i>	-	-	+
Coleoptera	Elmidae	<i>Narpus</i>	-	+	-
	Dytiscidae	<i>Agabus</i>	+	+	-
Trichoptera	Hydropsychidae	<i>Hydropsyche</i>	+	-	+
	Philopotamidae	<i>Philopotamus</i>	+	+	+
	Rhyacophilidae	<i>Rhyacophila</i>	+	-	-
	Glossosomatidae	<i>Glossosoma</i>	+	-	-
		<i>Agapetus</i>	+	-	+
	Limnephilidae	<i>Limnephilus</i>	+	+	-
	Hydroptilidae	<i>Hydroptila</i>	+	+	+
Diptera	Blephariceridae	F-Blephariceridae	+	-	-
		Chironomidae	F-Chironomidae	+	+
		<i>Chironomus</i>	+	+	+
		<i>Pentaneura</i>	+	-	+
		<i>Ablabesmyia</i>	+	+	+
		<i>Procladius</i>	+	+	-
		<i>Tanypus</i>	+	+	+
		<i>Tanytarsus</i>	+	+	+
	Psychodidae	<i>Psychoda</i>	+	+	+
	Ceratopogonidae	<i>Bezzia</i>	+	+	+
		<i>Culicoides</i>	+	+	-
		Tipulidae	<i>Tipula</i>	+	-
		<i>Hexatoma</i>	+	+	+
		<i>Antocha</i>	+	+	+
	Phylum Mollusca	Physidae	<i>Physa</i>	+	+
Unidentified			+	-	-

solids (TDS). The occurrence of *Ophiogomphus* was associated with the mean width and conductivity while that of *Baetis* was associated with the dissolved oxygen in the upper left quadrant at Srikot. However, *Culicoides*, *Limnephilus*, *Narpus*, *Agabus*, *Progomphus*, *Psychoda*, *Bezzia*, *Tanypus* and *Tanytarsus* do not show any pattern associated with physicochemical variables (Figure 2).

The ordination plot of CCA reveals that the conductivity along with high dissolved oxygen, raised nitrate concentration and moderate water velocity was the significant variables explaining the distribution of the benthic macroinvertebrates downstream to dam on River Alaknanda.

Table 4. Density (Ind. m⁻²) and analysis of variance (ANOVA) of various taxa of benthic macroinvertebrates at designated sampling sites in River Alaknanda during the present study (Density ± SE)

Genera	Total density (Ind. m ⁻²)			p value
	Srikot	Chauras	Srinagar	
<i>Heptagenia</i>	20.85±4.46	0.49±0.17	8.97±2.50	0.139
<i>Cinygma</i>	6.05±1.44	–	7.17±1.00	0.105
<i>Baetis</i>	14.80±1.55	2.93±0.63	3.59±1.00	0.031
<i>Platybaetis</i>	1.35±0.50	–	–	0.405
<i>Leptophlebia</i>	6.73±2.50	0.49±0.17	–	0.442
<i>Thraulodes</i>	2.02±0.48	–	–	0.141
<i>Ephemerella</i>	2.69±0.41	–	1.79±0.50	0.048
<i>Caenis</i>	3.36±0.75	–	–	0.115
<i>Ophiogomphus</i>	4.04±1.50	2.45±0.31	–	0.660
<i>Progomphus</i>	–	1.96±0.49	–	0.472
<i>Perla</i>	–	–	1.79±0.50	0.065
<i>Plea</i>	–	–	276.17±77.00	0.065
<i>Narpus</i>	–	0.98±0.33	–	0.651
<i>Agabus</i>	0.67±0.25	6.36±1.08	–	0.209
<i>Hydropsyche</i>	18.83±2.94	–	7.17±2.00	0.039
<i>Philopotamus</i>	11.43±3.92	0.98±0.33	3.59±1.00	0.439
<i>Rhyacophila</i>	1.35±0.50	–	–	0.405
<i>Glossosoma</i>	16.81±1.55	–	–	0.001
<i>Agapetus</i>	10.09±1.11	–	3.59±1.00	0.007
<i>Limnephilus</i>	6.73±2.50	16.63±5.67	–	0.788
<i>Hydroptila</i>	23.54±5.88	0.98±0.33	5.38±0.50	0.214
F–Blephariceridae	0.67±0.25	–	–	0.405
F–Chironomidae	18.16±6.75	0.98±0.33	78.91±6.00	0.004
<i>Chironomus</i>	202.42±35.41	58.69±6.29	5.38±1.50	0.117
<i>Pentaneura</i>	68.60±21.09	–	130.91±23.50	0.133
<i>Ablabesmyia</i>	20.18±3.66	11.25±1.60	3.59±0.00	0.385
<i>Procladius</i>	8.74±3.25	3.42±0.65	–	0.595
<i>Tanytus</i>	79.36±20.79	151.13±14.94	1.79±0.50	0.199
<i>Tanytarsus</i>	90.12±14.56	209.82±22.29	10.76±2.00	0.129
<i>Psychoda</i>	1.35±0.50	3.42±0.48	3.59±1.00	0.527
<i>Bezzia</i>	3.36±0.63	5.87±0.82	3.59±1.00	0.629
<i>Culicoides</i>	4.04±0.87	5.87±0.86	–	0.513
<i>Tipula</i>	1.35±0.29	–	–	0.100
<i>Hexatoma</i>	3.36±0.95	2.45±0.48	8.97±0.50	0.121
<i>Antocha</i>	31.61±5.86	1.47±0.50	39.45±11.00	0.139
<i>Physa</i>	7.40±1.55	0.49±0.17	1.79±0.50	0.157
Unidentified	1.35±0.50	–	–	0.405
Total density	693.35±6.86	489.09±11.4	607.94±14.15	

Table 5. Density of various orders of benthic macroinvertebrates at designated sampling sites in River Alaknanda during the present study (Density±SE).

Order	Total density (Ind. m ⁻²)		
	Srikot	Chauras	Srinagar
Ephemeroptera	57.84±2.47	3.91±0.82	21.52±1.64
Odonata	4.04±1.50	4.40±0.24	–
Plecoptera	–	–	1.79±0.50
Hemiptera	–	–	276.17±77.00
Coleoptera	0.67±0.25	7.34±2.69	–
Trichoptera	88.77±2.87	18.59±5.22	19.73±0.86
Diptera	533.29±15.13	454.37±21.69	286.93±13.73
Phylum Mollusca	7.40±1.55	0.49±0.17	1.79±0.50
Unidentified	1.35±0.50	–	–

Table 6. Shannon-Wiener diversity index (H), Evenness index (E) and Margalef's richness index (D') at the three sampling sites in River Alaknanda during the present study.

Indices	Srikot	Chauras	Srinagar
H	2.55	1.61	1.77
E	0.39	0.23	0.28
D'	4.61	3.04	3.43

DISCUSSION

In the present study, the low temperature in the downstream of the dam was due to the release of cold water from dam. The prolonged exposure to air temperature and solar radiation leads to an increase in the water temperature with distance from the dam. However, the size of the stream below the dam and the depth of water also influences the temperature below the dam (Ward and Stanford 1979, Brooker 1981, Wotton 1995, Jakob et al. 2003).

The artificial flow manipulation leads to the decrease in the channel depth and water velocity at downstream to dam (Dewson et al. 2007). The pH of water is relatively low in the downstream of the dam due

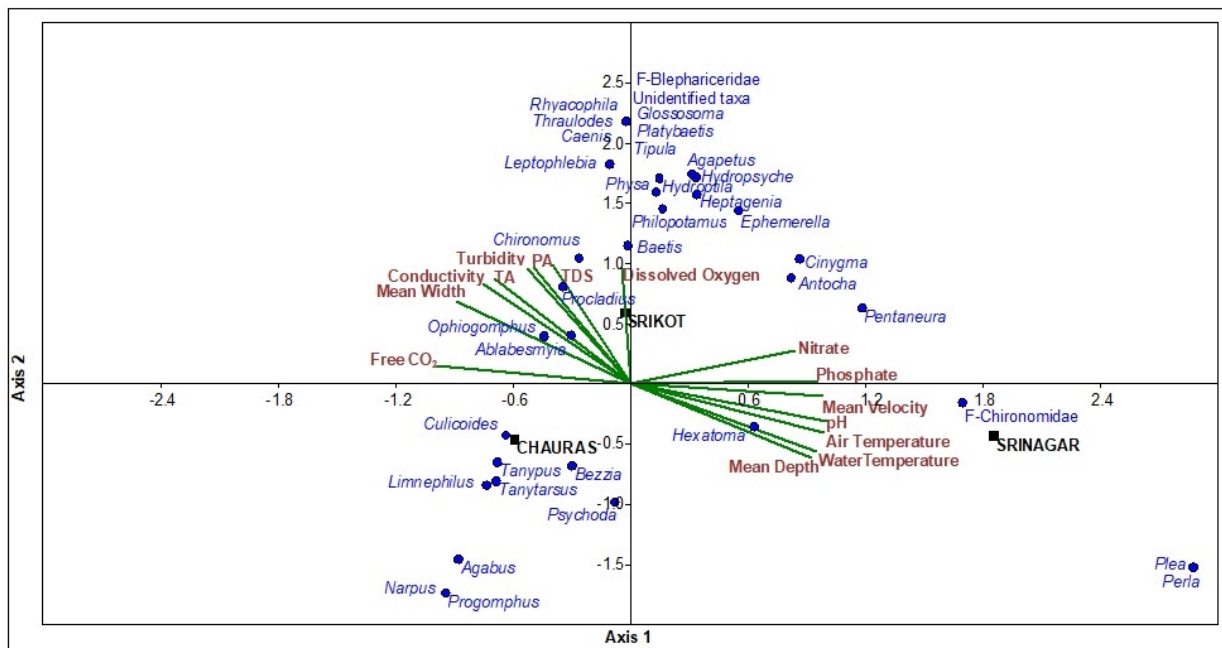


Figure 2. CCA ordination diagram with sampling sites (■), macroinvertebrate taxa (●) and physicochemical parameters (arrow), first axis horizontally and second axis vertically. PA= Phenolphthalein alkalinity, TA= Total alkalinity and TDS= Total dissolved solids.

to the influx of reservoir water with low pH, however the increases in pH with distance from the dam attributed to the degassing of carbon dioxide in the surface water (Wang et al. 2015). Furthermore, increase in the nitrate concentration also leads to decrease in the pH downstream of the dam (Chen et al. 2002, Han and Liu 2004).

In the lotic ecosystem, diffusion through the exposed water surface would be the main sources of dissolved oxygen (Welch 1952). The higher dissolved oxygen downstream of the dam reflects the oxygen saturation at low water temperatures (El-Sherif et al. 2010). An increased nutrient concentration downstream to dam could be attributed to the decomposition of dead leaves which is main cause of the nutrient loading and organic debris (Hart and Finelli 1999, Samuel et al. 2012). The higher discharge, slower transport velocities below the dam and increase in sediments and debris from the released water and riparian land uses are responsible for the increase in conductivity, turbidity and total dissolved solids downstream to dam (Jakob et al. 2003). One of key outcome of the dam is the increase in the downstream density of the benthic macroinvertebrates communities (Munn and Brusven 1991, Petts et al. 1993, Vinson 2001). The raised in the density of benthic fauna along with dominance of dipterans was attributed to the release of cold water from the dam (Trotzky and Gregory

1974, Ward 1974, Armitage 1978, Munn and Brusven 1991, Vinson 2001).

The Trichoptera was the second most dominant order at Srikot, the closest site of downstream to dam, reflecting the better bed stability at that site (Salant et al. 2006). The Plecoptera and Hemiptera were recorded only from Srinagar, the distant site from dam attributed to diversification of habitat and flow conditions in stream (Southwood 1977). The increase in nutrient concentration and organic food matter at downstream to dam leads to an increase in density of collectors/ gatherers/ filterers below the dam (Doi et al. 2008, Katano et al. 2009). Also, the small body size and production of desiccation resistant instars by some Chironomidae favours their dispersion at downstream to reservoir (Statzner et al. 2001, Furey et al. 2006).

The community composition with predominant *Chironomus* and *Tanytarsus* were also reported from other studies, attributed to stagnant and macrophyte habitats with average particulate organic matter at downstream to dam (Fillion 1967, Wiens and Rosenberg 1984, Dukowska et al. 2007). As the chironomidae are the most tolerant taxa of ecological pollutants, their high density suggests the organic pollution at downstream to dam and thus they might be used as the biological indicator for water quality and pollutants (Williams and Feltmate 1992, Wright et al. 1993).

The increase in the occurrence of scrapers (*Glossosoma* and *Agapetus*) and collectors/gatherers (*Ephemerella*, *Baetis* and F- Chironomidae) were attributed to the raise in primary productivity due to nutrient loadings at downstream to dam (Rehn 2008). The *Hydropsyche* can tolerate the less oxygen and confined to flowing water to feeds on drifting planktons downstream of the impoundment (Trotzky and Gregory 1974).

The habitat structure is an important factor which governs the distribution of benthic community. It was evident in present study that diversity at Srikot was maximum having sand, gravel, pebbles and cobbles as substratum, while it was minimum at Chauras with sand and gravels as main substrate composition. The heterogeneous habitat of a stream supports more diversity of benthic species (Sharma et al. 2008). Furthermore, the increased richness at downstream to dam could be due to the high organic particulate matters and nutrient loadings below the reservoir (Samuel et al. 2012).

CONCLUSIONS

The present study suggested that fluctuations in physical and chemical nature of water, habitat structure, nutrient loadings and organic particles downstream of a dam can alter the benthic macroinvertebrate communities. The daily irregularity in flow of released water from reservoir has the major influence on the assemblage of the benthic fauna. Some tolerant taxa (Chironomidae) may be favoured, while others (Plecoptera and Mollusca) became reduced downstream to dam due to the modified flow pattern of the river, and such taxa would be used as the biological indicator of water quality in regulated rivers. The biological integrity of river should be maintained through the management of the water release from reservoir similar to natural hydrological conditions at downstream to dam.

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