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Hydrobiological Assessment Using Macroinvertebrates as Biomonitoring Tool in the Dagwan Stream, Kashmir Himalaya

Inam Sabha[1], Aadil Hamid[1], Sami Ullah Bhat[1*] and Javeed Ahmad Rather[2]

[1]Department of Environmental Science, School of Earth and Environmental Sciences, University of Kashmir, Jammu and Kashmir, India
[2]Department of Geography and Regional Development, School of Earth and Environmental Sciences, University of Kashmir, Jammu and Kashmir, India
***Corresponding Author Email**: samiullahbhat11@gmail.com.

ABSTRACT

The application of benthic macroinveretebrates as biomonitoring tool over physicochemical signatures is being practiced across the globe for pollution monitoring of aquatic systems. The study reports the macroinvertebrate community composition and hydrochemistry of Dagwan stream in Kashmir Valley. The study revealed the occurrence of 59 taxa of macroinvertebrate belonging to Mollusca (1), Annelida (3) and Arthropoda (56) and spread over 11 orders, 6 classes and 39 families. Phylum Arthropoda being dominant was represented by 56 taxa spread over three classes namely Crustacea, Arachinida and Insecta. EPT taxa richness and biotic indices indicated normal to good water conditions with little deviation downstream at Site 5. HKH biotic indices depicted upstream sites having ecological status I, Telbal as II, while as Duck pond falls in class III and critically polluted category. While calculating the correlation matrix (Pearson) some important relations were observed between insect taxa and water quality variables at alpha value 0.05. It was found that taxa, Individuals, Shannon, Simpson index, and Menhick index showed positive correlation with that of pH and DO and negative correlation with water temperature, conductivity, chloride, T.D.S, silicate and discharge. The study further revealed that temperature, discharge, pH and altitude have significant impact on macroinvertebrate diversity as the downstream sites were found to be less diversified then upstream sites showing direct relation with various water parameters. The corresponding analysis of similarity (ANOSIM) showed perfect separation between selected sites as site 1 and 2 were found to be significantly similar whereas site 5 was absolutely having distinctiveness in macroinvertebrate community composition whereas; similarity percentage analysis (SIMPER) indicated high β diversity along the gradient.

Keywords: *Biodiversity, Biotic indices, Aquatic Insects, Correlation*

INTRODUCTION

Stream ecosystems are subjected to various threats like agriculture (Liu *et al.*, 2021), waste management issues (Qian *et al.*, 2007), industrial pollution (Schmeller *et al.*, 2018), and urban sprawl (Zhu *et al.*, 2018) affecting their many critical eco-services (Sabha *et al.*, 2020) and are considered as some of the most endangered ecosystems across globe (Hallouin *et al.*, 2018). Surrounding landscape of streams and rivers has been extensively recognized as intrinsically linked to their ecological integrity (Allan, 2004; Llena *et al.*, 2020). Biomonitoring is used to evaluate response of aquatic communities to anthropogenic stressors like water quality (Yap *et al.*, 2006), energy source (Azrina *et al.*, 2006), flow regimes (Kennen *et al.*, 2010), habitat quality (Latha and Thanga, 2010), and biotic interactions (Nemati *et al.*, 2010). To estimate and characterize the ecological changes in streams biological indicators are commonly used (Bonada *et al.*, 2006). Among various biological indicators (such as algae, periphyton, macrophytes, benthic invertebrates and fish) benthic macro invertebrates are extensively used as biotic assemblage across the world (Rosenberg and Resh, 1993; Resh, 2008). Macroinvertebrate are known to respond openly and predictably to almost all types of anthropogenic activities, including eutrophication (Friberg *et al.*, 2010), acidification and chemical pollution (Masouras *et al.,* 2021), flow control (Norris and Hawkins, 2000), habitat change (Greig *et al*., 2022), fragmentation and human exploitation (Niemi and McDonald, 2004; Li *et al.,* 2010). They are commonly used indicators for bio-monitoring in lotic habitat worldwide (Bonada *et al*., 2006) and are vital for improving and preserving water quality as they play a significant role in recycling and mineralization of organic matter (Bilgrami and Dutta, 1985; Venkateswarlu, 1986). The sensitivity of macroinvertebrates to changes in environmental quality render them an integral part of any biomonitoring program (Hun, 2019). Macroinvertebrate not only facilitate in processing relatively large amounts of organic matter but also serves as a major basis of food for fishes. Because of elasticity of community structure of the organisms, the physical and chemical condition of riverine ecosystem becomes recognizable and can be expressed in terms of numeric composition (Wilhm and Dorris, 1968; Cairns and Dickson, 1971). Benthic aquatic macroinvertebrates are responsive indicators to environmental change in streams because they articulate long-term changes in water and habitat feature rather than immediate conditions (Johnson *et al*., 1993). Thus, benthic macroinvertebrates make ultimate focus for biological assessment of water quality (Hynes, 1970). The water flow, temperature and substrates are major factors determining the composition and abundance of benthic invertebrates (Ward and Stanford, 1979). Presence of numerous families of highly tolerant organisms is usually an indication of poor water quality. The presence/absence, morphology, number (% abundance), behavior or physiology of these indicator organisms can appreciably predict the physico-chemical conditions defining the status of given water body at a given location (Yap *et al*., 2006; Azrina *et al*., 2006; Kennen *et al*., 2010; Latha and Thanga, 2010; Nemati *et al*., 2010). Agricultural intensification leads to landscape change and loss of biodiversity which lead to losses of ecosystem function and reduction of the resilience of these systems to disturbance (Douglas, 2017). The valley of Kashmir is gifted with a network of streams ecosystems which is world famous for its beauty and ecosystem services they render. However, deteriorating water quality and changing land use patterns have send strong signals to policy makers for quick and continuous monitoring of these important stream ecosystems in the valley of Kashmir. A total of 144 taxa of macroinvertebrates fauna have been reported from various stream networks of Kashmir valley (Bhat and Sabha, 2016). The Jehlum River Basin (JRB) of the Kashmir Himalayas in more than 18 watersheds over 2 years was studied by Sabha *et al*. (2020). Dagwan Stream is an important water source flowing into the Dal Lake. Ecologically as well as economically it is significant, as it is the main catchment of Dal, it provides drinking water to a portion of Srinagar city and its water is used to irrigate rice fields. The evaluation of macroinvertebrates was used for the detection and assessment of health of Dagwan stream.

MATERIAL AND METHOD

Study area

Dachigam stream originates from the high altitude serene lake Marsar (12,500ft). The stream is connected by a number of perennial and non-perennial origin tributaries. Dachigam stream gets segmented into two segments one supplies water to agricultural fields and the floating gardens subject to vegetative cultivation while another stream segment is diverted to a reservoir known as Harwan reservoir with remaining part flowing as Dachigam stream. During its course, Dachigam stream in the national park flows through a variety of floral diversity comprising of pines, shrubs and scrubs or open scrubs and deciduous trees. After Dachigam national park, stream enters the Dal Lake on the northern side of Hazratbal basin.

The satellite imagery classification of our study area provided the spatial distribution of land use/land cover categories. The area has been classified into 16 land use/land cover classes namely coniferous forest, scrub lands, plantation, deciduous forest, sparse forest,agriculture fallow, aquatic vegetation, snow, water, grasslands, agriculture, horticulture water channel area, bare land, bare exposed rocks, built up and golf course. The deciduous forest dominated the land use/land cover area followed by the coniferous forest, plantation, and grasslands. The least representative of the classes was the golf course/the water channel area and the fallow land (Badar *et al*., 2013). Five study sites were selected for study among them first two sites were inside the Dachigam National Park whereas the other three sites were outside the national park. Kawpora (Site 1), Draphama (Site 2), Harvan (Site 3), Telbal (Site 4) and Near Duck pond (Site 5) were the sites selected for study from the mainstream channel of Dagwan stream. (Table 1, Fig. 1, 2).

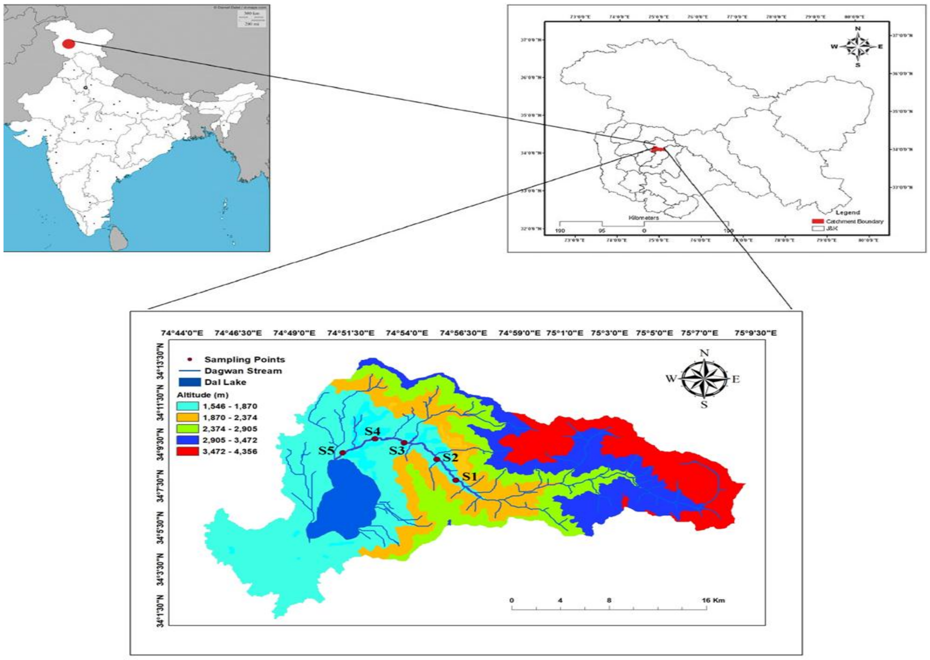

Fig. 1 Location of the study area with respect to Dal drainage catchment and sampling stations of the Dagwan Stream.

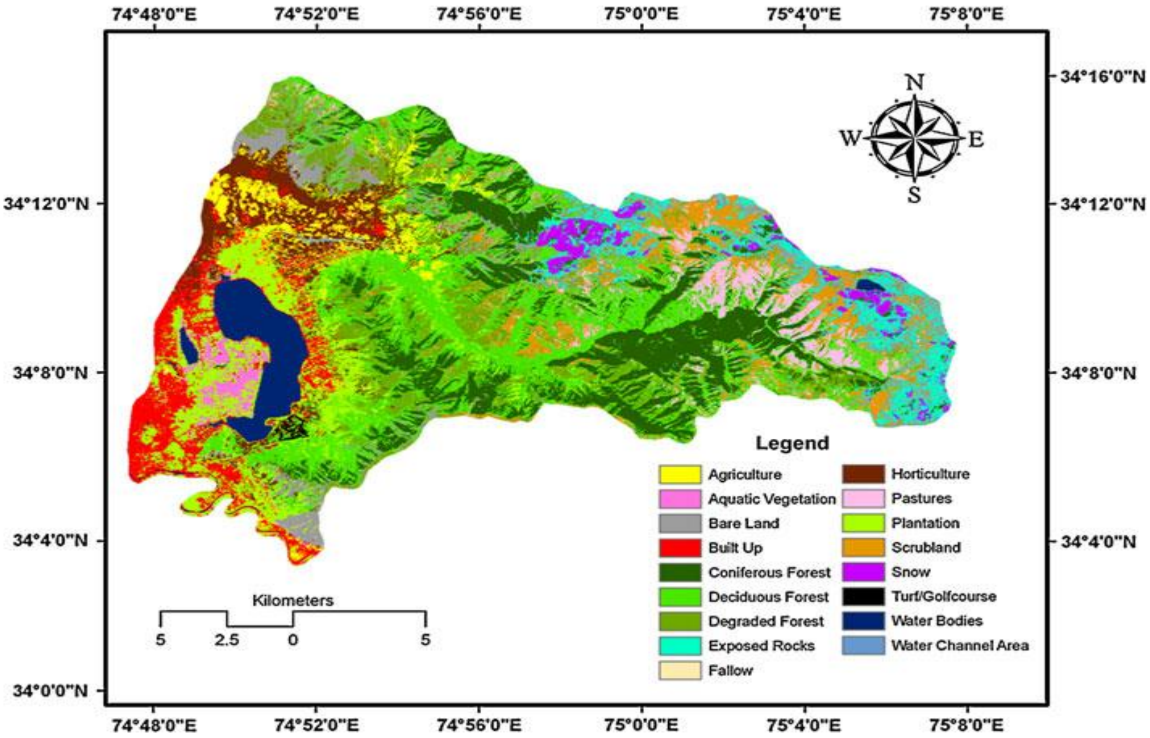

Fig. 2. Spatial distributions of land use/land cover for Dal lake catchment (Badar *et al.,* 2013)

Table 1. Study sites and their geographical coordinates

Sites No.	**Sites Name**	**Elevation**	**Latitude**	**Longitude**	**Substrate**	**Biofilm**	**Algal mass**	**Canopy cover**
1	Kawpora	1828 m	34°07′21.1′′ N	74°56′42.5′′ E	Boulders, Cobbles, Pebbles and Sand	+	-	dense
2	Draphama	1802 m	34°07′34.6′′ N	74°56′26.4′′ E	Boulders, Cobbles, Pebbles and Sand	+	-	dense
3	Harvan	1673 m	34°09′40.6′′ N	74°54′14.2′′ E	Boulders, Cobbles, Pebbles and sand	+	-	clear
4	Telbal	1610 m	34°09′41.1′′ N	74°51′56.8′′ E	Pebbles, Sand, Slit and Clay	-	-	clear
5	Near Duck park	1596 m	34°08′52.2′′ N	74°50′54.8′′ E	Sand, Slit and Clay	-	+	clear

METHODOLOGY

Monthly samplings, for analyzing the water parameters and macroinvertebrates, were taken from five sites between June 2014 to May 2015. Air and water temperatures were recorded with the help of a Celsius thermometer. Parameters like pH, electrical conductivity, dissolved oxygen, total alkalinity, free carbon dioxide, dissolved silica, sulphate, TDS, chloride, total hardness, calcium hardness, magnesium hardness, nitrite, nitrate, ammonia, ortho-phosphate, total phosphorus, velocity and flow were determined by standard work of APHA (2005), Wetzel and likens (2000). Macroinvertebrates for upstream sites were sampled with D-net (0.5 mm mesh net) and rock pick method covering 1m^2 of a quadrant. For downstream sites, they were sampled with Ekmans Dredge (6inch). The organisms collected were stored in vials or containers and were preserved by adding 70% ethanol for soft bodied organisms and 4% formalin for animals with calcareous exoskeleton (Borror *et al*., 1989). These macroinvertebrate fauna were identified to the lowest possible taxonomic using standard works of Prescott (1970), McCafferty and Provonsha (1998) and Wetzel and likens (2002). Various Biotic and diversity indices were calculated such as Shannon-Weiner diversity index, Simpson's Diversity Index (D), Menhinick's Diversity Index, EPT Index, Biological Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT), and HKHbios, Weighted average score per taxon (ASPTw),(Shannon-Weiner, 1949; Simpson, 1949; Menhinick, 1964; Friedrich *et al*., 1996; Hartmann *et al*., 2008).The data sets were administered to certain statistical analysis such as cluster analysis (CA), Canonical Correspondence Analysis (CCA), Similarity Percentages (SIMPER) analysis and Co-relation to reveal interaction between variables and various water parameters (Singh *et al*. 2004). Statistical calculation was done through Microsoft office EXCEL 2007, PRIMER e7and PAST (v.1.93) software applications.

RESULTS AND DISCUSSION

The analysis of hydrochemistry data shows that stream is neutral to alkaline and hardwater type with high dissolved oxygen content at upstream sites that change while going downstream. It was also observed that there was difference in concentration of different elements at different sites but an increasing trend from upstream to downstream was observed in most of the hydrochemistry attributes. The stream showed high velocity at upstream sites which decreased while moving downstream and also, an increased concentration of conductivity, alkalinity, chloride, hardness etc. was found while moving to downstream sites. However, midstream site showed varied nature because of the diversion of water to feed Sarband Lake for drinking water purpose. While comparing the results with WHO standards, the water quality was found well within permissible limits. The study of physico-chemical parameters indicates that quality of water moderately declines while moving downstream but is still within permissible limits for desired uses such as drinking, irrigation, washing, agriculture, fisheries, etc. Water temperature was found to be maximum at Site 5 (15.82±4.52) and minimum at site 1 (7.45±3.64). Dissolved oxygen showed relatively higher values at upstream sites and was found to be maximum at Site 1 (11.75±1.45) and minimum at Site 4 (7.47±1.78). The various hydrological attributes of the Dagwan stream are presented in Table 2.

Table 2. Water quality parameters and use of various biotic-indices for describing ecological conditions of the Dagwan stream at five different sites

Parameters	Site 1	Site 2	Site 3	Site 4	Site 5
Water Temperature (°C)	7.45±3.64	8.36±4.90	12.95±5.82	14.73±4.50	15.82±4.52
pH	8.87±0.19	8.84±0.12	8.29±0.21	8.09±0.27	8.35±0.23
Conductivity (µS/cm)	170±46	172±48	222±75	244±87	308±120
Dissolved oxygen (mg/L)	11.75±1.45	11.58±1.16	9.64±1.88	7.47±1.78	7.84±2.05
Free Carbon Dioxide (mg/L)	1.27±0.50	1.38±0.38	5.99±4.07	13.43±8.16	7.70±5.71
Chloride (mg/L)	8±2	7±2	10±4	11±2	11±3
Alkalinity (mg/L)	68±21	71±22	80±17	101±26	113±33
Total Hardness (mg/L)	99±50	106±56	110±50	135±74	161±65
Calcium (mg/L)	72±38	77±45	83±43	96±59	114±55
Magnesium (mg/L)	27±14	30±24	27±11	41±23	46±19
Nitrate- Nitrogen (µg/L)	392±226	383±221	1112±1185	1149±526	1154±445
Ammonical Nitrogen (µg/L)	37±19	34±13	43±20	56±43	54±29
Total Phosphorus (µg/L)	224±198	283±216	609±702	467±383	426±137
Sulphate (mg/L)	10±8	8±4	11±5	12±8	14±9
Sodium (mg/L)	16±13	13±6	36±21	31±13	35±11
Potassium (mg/L)	0.55±0.48	0.55±0.48	1.77±0.74	1.50±0.61	2.14±0.84
T.D.S (mg/L)	116±34	115±34	146±50	164±58	204±75
Silicate (mg/L)	8±4	8±4	9±3	12±4	12±4
Discharge (m^3/sec)	4±3	2±1	1±1	3±3	4±2
Velocity (m^2/sec)	0.66±0.30	0.62±0.25	0.36±0.23	0.21±0.10	0.15±0.10

A total of 59 taxa were recorded from Dagwan stream, presented in Table 3. At Site 1, the total number of taxa found was 45, with Trichoptera being the most dominant orders and having an average of 37% relative density, followed by Diptera (24%) and Ephemeroptera (16%) and Plecoptera (11%). The average number of individuals were found to be 134 ind./m^2. The dominance of Ephemeroptera, Plecoptera and Trichoptera reflects the clean water conditions (Miserendino and Pizzolon, 2003). There was dominance of *Chironomus* sp. and *Erpobdella octocullata* at the Site 4 and 5. The appearance of *Erpobdella octoculata* at these sites may be attributed to low flow condition and their greater power of utilizing organic matter from beneath the surface of soft bottom sediments (Poddubnaja and Sorokin, 1961; Pandit, 1980). Appearance of *Chironomus* sp. at this Site 1ndicates degraded water quality described by low dissolved oxygen and high nutrient concentration (Langdon *et al.*, 2006). Free-swimming larvae of common midges (Chironomidae) can colonize larger and deeper bodies of water at great depths (Hovemeyer, 2000). Further downstream, at Site 5, there was again decrease in number of taxa that amounted to only 10. Diptera was the dominant order (72%) followed by

Pharyngobodellida (16%) and Amphipoda (7%). Among taxa the dominant were *Chironomus* sp*., Erpobdella octoculata* and *Gammarus pulex*.

Table 3. List of macroinvertebrate taxa collected during the present study from Dagwan Stream

Phylum	**Class**	**Order**	**Family**	**Taxa /Species**	**Authority**
Mollusca	Gastropoda		Lymneacidae	*Lymena ovata*	Lamarck,1799
Annelida	Oligochaeta	Opisthopora	Lumbriculidae	*Lumbricus* sp.	Linnaeus, 1758
	Hirudinea	Pharyngobdellida		*Placobdella* sp.	Say,1824
			Erpobdellidae	*Erpobdella octoculata*	Linnaeus, 1758
	Crustacea	Amphipoda	Gammaridae	*Gammarus pulex*	Linnaeus, 1758
	Arachinida	Araneae	Arachnoidae	*Eylaoidea* sp.	Leach, 1815
				Hygrobatoidae sp.	Koch, 1842
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Alainites* sp.	Linnaeus, 1758
				Baetidae sp.	Leach, 1815
				Baetiella sp.	Uéno, 1931
				Baetis rhodani	Pictet, 1843
				Baetis sp.	Leach, 1815
			Ephemerellidae	*Drunella Submontana*	Brodsky, 1930
			Caenidae	*Caenis Srinagri*	Traver,1939
			Heptagenidae	*Ecdyonurus* sp.	Eaton,1868
				Epeorus sp.	Eaton, 1881
		Odonata	Libellulidae	*Libellulidae* sp.	Rambur, 1842
		Plecoptera	Capniidae	*Allocapnia* sp.	Claassen, 1928
			Neumouridae	*Nemouridae* sp.	Latreille, 1796
			Perlidae	*Perlidae* sp.	Latreille, 1802
			Chloroperlidae	*Chloroperla* sp.	Newman, 1836
		Coleoptera	Elimidae	*Elimidae* sp.	Curtis,1830
				Optioservus sp.	Sanderson, 1954
				Stenelmis sp.	Dufour,1835
			Hydrophillidae	*Hydrophilidae* sp.	Latreille,1802
			Coccinilidae	*Coccinilidae* sp.	Latreille, 1807
			Helodidae	*Helodidae* sp.	Fleming ,1821
			Dytiscidae	*Dyticus* sp.	Linnaeus, 1758

	Trichoptera	Glossosomatidae	*Glossosoma* sp.	Wallengren, 1891
		Hydropsychidae	*Cheumatopsyche* sp.	Wallengren, 1891
			Hydropsyche sp.	Curtis, 1835
		Limniphilidae	*Limniphilus* sp.	Brewster, 1815
		Symphitopsychidae	*Symphitopsyche* sp.	
		Polycentropodidae	*Polycentropus* sp.	Ulmer, 1903
		Brachycentridae	*Brachycentrus* sp.	Ulmer, 1903
		Lepidostomatidae	*Lepidostoma* sp.	Rambur, 1842
		Hydroptilidae	*Hydroptilidae* sp.	Stephens, 1836
		Stenopsychidae	*Stenopsyche* sp.	Martynov, 1924
		Rhyacophilidae	*Rhyacophila Yamanakensis*	Iwata, 1927
			Rhyacophila Obscura	Martynov, 1927
			Rhyacophila sp.	Stephens, 1836
	Diptera	Athericidae	*Atherix* sp.	Meigen, 1803
		Tabanidae	*Chrysops* sp.	Linnaeus, 1758
			Tabanus sp.	Linnaeus, 1758
		Tipulidae	*Antocha* sp.	Osten Sacken, 1860
			Hexatoma sp.	Latreille, 1809
			Limoninae sp.	Meigen, 1803
			Tipula sp.	Linnaeus, 1758
		Culicidae	*Culex* sp.	Linnaeus, 1758
		Ceratopogonidae	*Bezzia* sp.	Newman, 1834
		Chironomidae	*Chironomous* sp.	Meigen, 1803
			Diamesinae sp.	Pagast, 1947
			Procladius sp.	Skuse, 1889
			Tanypodinae sp.	
		Empididae	*Emphididae* sp.	Linnaeus, 1758
		Psychodidae	*Pychodiadae* sp.	Newman, 1834
		Blephariceridae	*Blephaceridae* sp.	Loew, 1861
			Biliocephala sp.	Macquart, 1843
		Simulidae	*Simulium* sp.	Latreille, 1802

Certain invertebrate taxa were found only at particular stream sites. Although some taxa were low in occurrence and occurred only at one site throughout the study. Among them are *Rhyacophila obscura, Libellulidae* sp., *Emphididae* sp., *Blephaceridae* sp., *Limoninae* sp., *Chrysops* sp., *Lepidostoma* sp., *Polycentropus* sp., *Dyticus* sp., *Coccinilidae* sp., *Optioservus* sp. and *Lumbricus* sp. The unique taxa at upstream sites were *Libellulidae* sp., *Biliocephala* sp., *Pychodiadae* sp., *Antocha* sp., *Hexatoma* sp., *Tabanus* sp., *Chrysops* sp., *Atherix* sp., *Stenopsyche* sp., *Polycentropus* sp., *Symphitopsyche* sp., *Helodidae* sp., *Nemouridae* sp. and *Perlidae* sp.; all of which are sensitive taxa. The downstream sites, especially Site 5, had less sensitive taxa like *Chironomus* sp., *Lumbricus* sp. and *Erpobdella octoculata*.

At Site 1, highest density (299 ind./m^2) was recorded in the month of January, 2015, while lowest density (45ind./m^2) was recorded in the month of April 2015. Site 2 depicted highest density (340 ind./m^2) in January, 2015 and lowest density (30 ind./m^2) in November 2014. Site 3 recorded highest monthly density of (263 ind./m^2) in March 2015 and lowest density of (64 ind./m^2) was noticed in December 2014. Site 4 depicted highest density (98 ind./m^2) in July 2014 against lowest density (4 ind./m^2) recorded in December 2014. At Site 5, in contrast to upstream sites, maximum monthly density (73 ind./m^2) was registered in July 2014, while as minimum monthly density (3 ind./m^2) was recorded in February 2015 (Appendix).

All study sites were dominated by gatherer/collector community with relative densities ranging between 18% at Site 1, 21% at Site 2, 30% at Site 3, 41% at Site 4 and 56% at Site 5 (Fig. 3). The substantial presence of collector/gatherer, scraper and predator community at all study sites points to the fact that allochthonous and autochthonous origin of organic matter is readily available in water column (Plafkin *et al.*, 1989). Predator dominated at first three sites; Site 1, 2 and 3. Habitation of predator at these study sites is a direct consequence of increase in prey base, whereas collector/gatherer was dominant at Site 4 and 5 possibly due to availability of fine particulate organic matter made available by shredder community (Cudney and Wallace, 1980). The functional feeding group scrapper showed its presence at all study sites. The presence of shredder decreased moving downstream and Site 5 recorded no shredder at all, which is a direct consequence of abundant availability of coarse particulate organic matter either from upstream areas or the stream bed (Merritt and Cummins, 2006). An analysis of the results of functional feeding groups revealed that stream under study behaves somehow like the River Continuum concept but because of certain limitations and varying nature of stream, it couldn't be concluded as the upstream higher reaches close to the origin was not sampled because of inaccessibility. And even the intermittent behavior of midstream Site 3 made it incomparable.

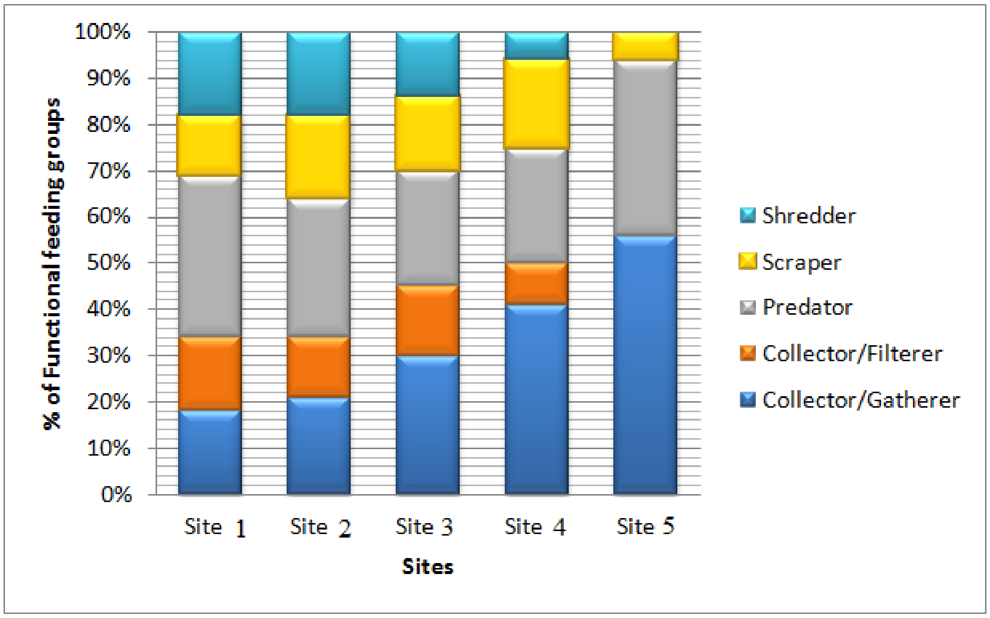

Fig. 3. Percentage of Functional feeding groups at different study sites from Dagwan stream

BMWP Score showed a value of more than 100 at all study sites except for Site 5 having a lowest of 28 and a highest of 171 at Site 3. The ASPT represents average tolerance score of all taxa within the community and is calculated by dividing BMWP Score by the number of families represented in the sample (Friedrich *et al*., 1996). Average Score Per Taxon recorded highest score of 6.3 at Site 1 which in gradual fashion, decreased to the lowest of 3.5 at Site 5 (Table 4). Mason (2002) and Chapman (1996) classified water quality as ‘good’ where BMWP and ASPT exceed 100 and 4.3 respectively. Considering this criterion, all study sites can be considered to have good water quality except for Site 5. Hindu Kush-Himalayan Biotic Score (HKHBios), in general, showed a decreasing trend with Site 1 recording a value of 7.09 which decreased to 4.5 at Site 5 thereby indicating very good water quality condition at upstream sites and moderate water quality downstream (Hartman *et al*., 2008). Similarly, the trend as reflected from values of Shannon-Weiner Diversity Index (H), Simpson Index etc. reflects the clear division of upstream and downstream conditions. If the classification of sampling sites is now summarized according to the HKH index WQC, it can be observed that Site 1, 2 and 3 fall in WQ class I, Site 4 in WQ class II, and Site 5 in WQ class III (Table 5).

Table 4. Use of biotic-indices for describing ecological conditions of the Dagwan stream at five different sites

Sites	Site 1	Site 2	Site 3	Site 4	Site 5
Total no of taxa	45	42	43	22	10
Number of individuals	1611	1279	1468	373	195
EPT Score	17	17	16	10	1
No. of Ephemeroptera	8	9	9	8	0
No. of Plecoptera	4	4	4	1	0
No. of Trichoptera	11	8	10	5	1
BMWP score	170	157	171	104	28
ASPT	6.3	6.28	6.11	6.12	3.5
(HKHbios) ASPT	7.09	7.5	6.82	6.35	4.56
(HKHbios) ASPTw	7.17	7.79	6.95	5.96	4.69
Shannon_H	3.21	3.12	2.97	2.56	1.04
Simpson_1-D	0.94	0.94	0.92	0.90	0.48
Menhinick	1.12	1.17	1.12	1.14	0.72

Table 5. HKH bios values to describe the water quality class of different sites of Dagwan stream

HKHbios values	Water quality classes	Ecological status classification	WQ characteristics degree of organic pollution	Site 1	Site 2	Site 3	Site 4	Site 5
6.00-10.00	I	High	None to very slight organic pollution	7.17	7.79	6.95	-	-
5.00-5.99	II	Good	Moderate pollution	-	-	-	5.96	-
4.00-4.99	III	Moderate	Critical pollution	-	-	-	-	4.69
2.50-3.99	IV	Poor	Heavy pollution	-	-	-	-	-
1.01-2.49	V	Bad	Extreme pollution	-	-	-	-	-

After assessing the correlations of macroinvertebrate metrics with physical and chemical parameters of water at $p<0.05$ significance level, it was found that taxa, individuals, Shannon, Simpson index, and Menhick index showed positive correlation with that of pH and DO and negative correlation with water temperature, conductivity, chloride, T.D.S, silicate and discharge. BMWP and ASPT scores also showed positive correlation with DO and pH, whereas, they showed negative correlation with water temperature, conductivity, chloride, T.D.S, silicate and discharge. Simpson index and ASPT was shown highly correlated with value 1 (Table 6). While calculating the correlation matrix (Pearson) some important relations were observed between insect taxa and water quality variables at alpha value 0.05 (the calculated p values for bold ones were less than alpha value); insect taxa shown in the table illustrate some notable correlation whereas the taxa not mentioned has not showed any major association. Water temperature, conductivity and chloride showed strong positive correlation with many taxa except for a few like *Chironomus* sp., *Coccinilidae* sp*.,* *Lumbricus* sp. and *Erpobdella octoculata.*Whereas parameters like Altitude, Velocity, DO, pH showed negative co relation with *Chironomus* sp., *Coccinilidae* sp*.,* *Lumbricus* sp. and *Erpobdella octoculata* depicting these organisms to be of tolerant nature (Table 7).

Table 6. Linear-correlation between different physico-chemical characteristics and some macroinvertebrate diversity indices of all study sites at Dagwan stream

Variables	Taxa	Ind	Sha	Simp	Menh	BMWP	ASPT	WT	pH	Cond	DO	Cl	T.D.S	Sili	Dis
Taxa	0														
Ind	**0.98**	0													
Sha	**0.93**	**0.84**	0												
Simp	**0.84**	0.72	**0.98**	0											
Menh	0.79	0.65	**0.95**	**0.99**	0										
BMWP	**0.98**	**0.93**	**0.97**	**0.92**	**0.88**	0									
ASPT	**0.83**	0.7	**0.97**	1	**0.99**	**0.91**	0								
WT	-0.83	-0.83	-0.77	-0.65	-0.6	-0.76	-0.64	0							
pH	0.62	0.66	0.46	0.3	0.25	0.49	0.29	-0.92	0						
Cond	-0.92	-0.86	-0.94	-0.87	-0.84	-0.91	-0.87	**0.94**	-0.73	0					
DO	**0.86**	**0.88**	0.72	0.58	0.52	0.77	0.56	-0.97	**0.93**	-0.89	0				
Cl	-0.77	-0.74	-0.73	-0.62	-0.59	-0.7	-0.61	0.98	-0.92	**0.92**	-0.95	0			
T.D.S	-0.86	-0.76	-0.9	-0.87	-0.87	-0.87	-0.86	0.79	-0.57	**0.92**	-0.77	**0.81**	0		
Sili	-0.94	-0.97	-0.79	-0.65	-0.58	-0.87	-0.63	0.91	-0.81	**0.88**	-0.97	**0.85**	0.77	0	
Dis	-0.59	-0.54	-0.5	-0.49	-0.5	-0.6	-0.46	0.18	-0.03	0.37	-0.32	0.17	0.63	0.46	0

Marked correlations are significant at $P < 0.05$

Where,Ind= individuals, Sha=Shanon index, Simp= Simpson index, Menh= Menhick index ,BMWP, Biomonitoring working plan, ASPT=Average score per taxa , WT= water temperature, Cond.= Conductivity, DO = Dissolved oxygen, Cl=Chlorine, T.D.S = Total dissolved solids, TH, Sili = Silica, Dis=Discharge

Table 7. Correlation matrix (Pearson) between macroinvertebrates and water quality variables (Values in bold are different from 0 with a significance level alpha=0.05)

Variables	Insect1	Insect5	Insect7	Insect10	Insect12	Insect13	Insect17	Insect19	Insect21	Insect25	Insect28	Insect31
WT	**-0.902**	**-0.921**	**-0.924**	**0.883**	**-0.961**	-0.779	-0.817	-0.602	**-0.98**	**-0.884**	**-0.892**	**-0.919**
pH	0.792	0.858	**0.897**	-0.638	**0.954**	0.605	0.845	0.498	**0.943**	0.737	0.866	**0.885**
Cond	-0.86	-0.813	-0.785	**0.989**	-0.827	-0.816	-0.735	-0.679	**-0.9**	**-0.911**	-0.749	-0.867
DO	**0.934**	**0.89**	0.863	-0.849	**0.908**	0.838	0.801	0.724	**0.972**	**0.934**	0.826	**0.92**
Cl	-0.817	-0.854	**-0.889**	0.852	**-0.965**	-0.674	**-0.9**	-0.587	**-0.992**	-0.829	-0.85	**-0.96**
Alk	**-0.943**	-0.842	-0.775	**0.968**	-0.799	**-0.923**	-0.683	-0.778	**-0.898**	**-0.982**	-0.739	-0.851
Ca	-0.85	-0.783	-0.722	**0.984**	-0.721	-0.851	-0.563	-0.63	-0.786	**-0.885**	-0.697	-0.734
Mg	**-0.895**	-0.737	-0.659	**0.953**	-0.714	**-0.91**	-0.696	**-0.882**	-0.869	**-0.991**	-0.612	-0.858
NN	-0.785	-0.866	**-0.92**	0.765	**-0.988**	-0.606	**-0.895**	-0.492	**-0.978**	-0.76	**-0.886**	**-0.933**

NiN	-0.821	-0.707	-0.642	**0.996**	-0.675	-0.846	-0.61	-0.735	-0.792	**-0.91**	-0.605	-0.773
AN	**-0.889**	-0.794	-0.762	0.858	-0.841	-0.824	-0.835	-0.827	**-0.961**	**-0.95**	-0.712	**-0.946**
TP	-0.464	-0.715	-0.85	0.386	**-0.888**	-0.193	-0.722	0.007	-0.734	-0.334	-0.843	-0.663
OP	**-0.919**	-0.823	-0.775	**0.951**	-0.83	**-0.88**	-0.773	-0.808	**-0.941**	**-0.978**	-0.731	**-0.914**
Dis	-0.306	0.047	0.178	0.479	0.069	-0.51	-0.245	**-0.881**	-0.248	-0.575	0.237	-0.363
Vel	**0.917**	**0.91**	**0.901**	**-0.899**	**0.942**	0.809	0.814	0.654	**0.981**	**0.913**	0.867	**0.926**
Alt	**0.911**	**0.925**	**0.925**	-0.865	**0.962**	0.785	0.817	0.614	**0.983**	**0.888**	**0.893**	**0.92**

Variables	Insect33	Insect34	Insect36	Insect39	Insect42	Insect43	Insect45	Insect49	Insect50	Insect54	Insect56	Insect58
WT	-0.562	**-0.984**	**-0.946**	**-0.963**	-0.839	-0.731	**-0.896**	-0.613	0.587	-0.872	0.587	0.801
pH	0.476	**0.924**	**0.913**	**0.888**	0.701	0.407	0.801	0.5	-0.222	0.684	-0.222	**-0.923**
Cond	-0.64	**-0.917**	-0.818	**-0.879**	-0.87	**-0.922**	**-0.905**	-0.689	0.83	-0.87	0.83	0.619
DO	0.682	**0.997**	**0.879**	**0.958**	**0.91**	0.667	**0.93**	0.735	-0.506	0.766	-0.506	**-0.899**
Cl	-0.57	**-0.966**	**-0.926**	**-0.904**	-0.783	-0.696	**-0.907**	-0.586	0.553	-0.815	0.553	0.801
Alk	-0.724	**-0.948**	-0.793	**-0.922**	**-0.959**	-0.87	**-0.926**	-0.796	0.757	-0.819	0.757	0.722
Ca	-0.573	-0.831	-0.743	-0.836	-0.845	**-0.966**	-0.812	-0.651	**0.905**	**-0.884**	**0.905**	0.474
Mg	-0.841	**-0.92**	-0.685	-0.849	**-0.984**	-0.856	**-0.956**	**-0.894**	0.747	-0.698	0.747	0.736
NN	-0.475	**-0.942**	**-0.951**	**-0.896**	-0.71	-0.585	-0.847	-0.491	0.429	-0.796	0.429	0.82
NiN	-0.692	-0.832	-0.673	-0.791	**-0.882**	**-0.978**	-0.867	-0.749	**0.917**	-0.799	**0.917**	0.504
AN	-0.8	**-0.981**	-0.789	**-0.895**	**-0.939**	-0.684	**-0.975**	-0.831	0.529	-0.669	0.529	**0.907**
TP	0.008	-0.65	-0.87	-0.659	-0.26	-0.211	-0.464	0.014	0.076	-0.663	0.076	0.581
OP	-0.768	**-0.973**	-0.802	**-0.914**	**-0.958**	-0.828	**-0.967**	-0.818	0.701	-0.775	0.701	0.79
Dis	**-0.89**	-0.311	0.142	-0.139	-0.641	-0.493	-0.567	-0.875	0.482	0.083	0.482	0.309
Vel	0.614	**0.992**	**0.923**	**0.963**	0.873	0.748	**0.919**	0.665	-0.604	0.853	-0.604	-0.816
Alt	0.573	**0.99**	**0.944**	**0.968**	0.846	0.7	**0.898**	0.624	-0.549	0.852	-0.549	-0.832

The nMDS plot based on faunistic data produced an ordination using dissimilarity matrix, revealed a clear separation of selected sites on the basis of assemblage composition with a value below 0.05 which is considered to be good fit. The corresponding analysis of similarity (ANOSIM) showed perfect separation between the selected sites (Global R, 0.45; P, 0.001). However, test showed that species assemblages of all selected sites didn’t differ significantly (R, 0.75; P, 0.001). Finer levels of classification were able to interpret more distinctive community assemblages as site 1 and 2 were found to be significantly similar whereas site 5 was absolutely having distinctiveness in macroinvertebrate community composition (Fig. 4).

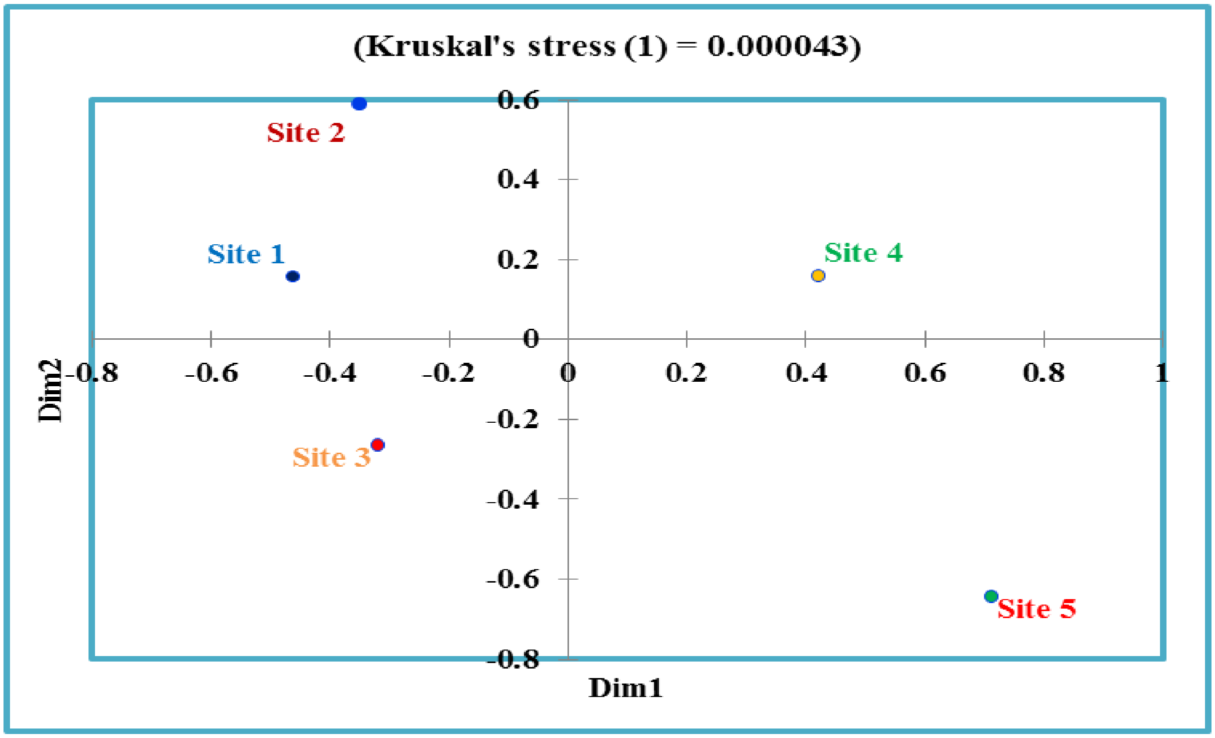

Fig. 4. nMDS of the selected stream sites based on the faunistic data. Dissimilarity index: Pearson.

In SIMPER (Similarity Percentage) analysis group 1 (Site 1 and Site 2) had an average dissimilarity of 21.22%, group second (Site 1 and Sites 3) of 31.29%, group third (Site 2 and Site 3) of 30.67%, group fifth (Site 1 and Site 4) of 63.7%, group sixth (Site 2 and Site 4) of 60.22%, group seventh (Site 3 and Site 4) 52.40%, group eighth (Site 1 and Site 5) 91.40%, group ninth (Site 2 and Site 5) of 95.03%, group tenth (Site 3 and Site 5) of 82.70% and group eleventh (Site 4 and Site 5) of 62.76%, indicating a high β diversity along the altitudinal gradient.

The canonical corresponding analysis concludes that the sites/taxa data are linearly related to the sites/variable data with 5% significance level, p-value obtained is just above the chosen threshold alpha we chose (0.05 against 0.017). Eigenvector analysis within Canonical corresponding analysis, reveals most of the inertia is carried by first axis (75%). With second axis, 99 % of the inertia is explained. It means that two dimensional canonical corresponding analysis plot, is enough to analyze the relationships between sites, taxa and variables. On all axis, permutation test was significant (pseudo-F, 2.77; p, 0.05). Furthermore, on canonical corresponding analysis plot for the Insect48 and 28, the frequency is associated with TP, Insect58 and 59; the frequency is associated with WT and OP, Insect27 with NN, Insect52 with discharge, Insect50 and 56 with NiN. It was observed that annelids were strongly associated with the nitrates and phosphates. Results suggested that decline in altitude reflected deterioration in water quality, increment of organic material and nutrients as well as decline of heterogeneity of macroinvertebrates with longitudinal gradient towards downstream (Fig. 5).

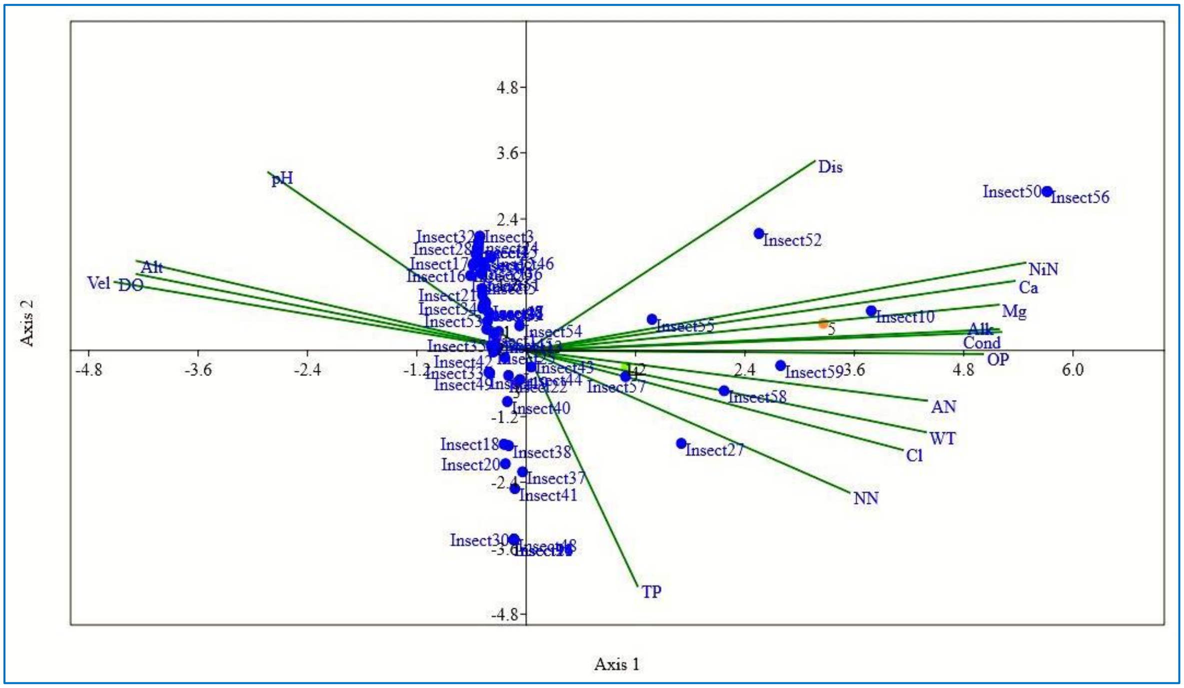

Fig. 5. Canonical Corresponding Analysis (based on eigenvalues, cumulative percentage of variance explained on the first two canonical axes) between sites, taxa and variables.

CONCLUSION

Our findings depicted that stream size revealed that sensitive species seemed to prefer high flow and good water quality conditions. It was also found that a high diversity and density of Ephemeroptera, Plecoptera and Trichoptera was present in higher stream currents and stony substratum. Therefore, these conditions are potentially favourite habitat for sensitive taxa which are good indicators of the health of stream ecosystems. Moreover, high abundance and diversity of benthic macroinvertebrate in forest and mixed land use was observed as compared to residential and downstream sites. At the same time, predominant functional feeding group observed in upstream was Predator and in downstream was Collector/ Gatherer. This study demonstrates the applicability of benthic macroinveretebrtaes as a promising biomoonitoring tool for stream ecosystem monitoring and management.

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APPENDIX

Table A1 Temporal dynamics of macroinvertebrate density (ind. /m^2) at Site 1 from June 2014-May-2015

		SUMMER			**AUTUMN**			**WINTER**			**SPRING**			
Order	**Taxa /Species**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**MAY**	**TOTAL**
Pharyngobdellida	*Erpobdella octoculata*	-	-	4	-	-	3	-	-	-	2	-	-	9
Amphipoda	*Gammarus pulex*	-	-	1	1	1	3	10	4	3	-	-	-	23
Araneae	*Eylaoidea* sp.	-	10	4	-	-	-	-	-	-	2	-	-	16
	Hygrobatoidae sp.	-	5	1	8	-	10	15	5	5	2	-	-	51
Ephemeroptera	*Alainites* sp.	9	-	-	-	-	-	5	3	-	-	9	2	28
	Baetidae sp.	-	4	4	-	2	-	-	-	-	3	2	-	15
	Baetiella sp.	-	-	-	-	-	7	17	22	-	-	-	-	46
	Baetis rhodani	-	-	-	-	1	-	5	16	-	-	-	-	22
	Baetis sp.	-	-	-	-	-	-	-	-	-	1	-	1	2
	Caenis Srinagri	3	5	-	-	6	-	7	-	-	-	3	2	26
	Drunella Submontana	8	5	5	-	3	-	5	2	-	-	7	3	38
	Ecdyonurus sp.	15	5	4	6	2	4	-	24	3	2	8	4	77
Odonata	*Libellulidae* sp.	-	-	-	-	-	-	-	-	-	1	-	-	1
Plecoptera	*Allocapnia* sp.	-	-	-	-	-	-	-	5	2	-	-	-	7
	Chloroperla sp.	2	4	2	-	-	4	7	33	2	3	-	1	58
	Nemouridae sp.	-	-	1	-	-	4	26	45	7	1	-	-	84
	Perlidae sp.	-	-	1	7	-	-	6	6	-	-	1	-	21
Coleoptera	*Elimidae* sp.	4	3	3	10	1	6	7	-	-	1	-	1	36
	Helodidae sp.	-	-	-	-	-	4	9	13	14	4	-	-	44
	Hydrophilidae sp.	-	-	-	1	2	-	-	-	1	-	-	-	4
	Stenelmis sp.	-	-	-	-	-	3	7	1	2	-	-	-	13
Trichoptera	*Glossosoma* sp.	-	-	3	-	1	3	8	-	1	2	-	3	21
	Brachycentrus sp.	20	10	10	14	14	30	21	23	36	7	10	19	214
	Cheumatopsyche sp.	-	-	-	-	-	-	-	-	-	1	-	-	1
	Hydropsyche sp.	-	3	-	8	2	-	12	-	10	-	-	2	37
	Hydroptilidae sp.	-	-	-	-	-	-	-	-	-	1	-	-	1
	Limniphilus sp.	28	60	50	6	5	3	-	-	-	39	-	32	223
	Polycentropus sp.	-	-	-	-	-	-	-	-	-	1	-	-	1
	Rhyacophila sp.	1	-	2	2	1	-	3	-	10	2	-	2	23
	Rhyacophila Yamanakensis	-	-	-	-	-	-	4	-	-	-	-	-	4
	Stenopsyche sp.	1	1	-	-	-	2	1	32	3	4	-	-	44
	Symphitopsyche sp.	-	-	-	-	-	1	3	12	10	3	-	-	29
Diptera	*Atherix* sp.	-	1	-	17	8	6	7	9	9	7	-	1	65
	Antocha sp.	-	-	3	-	-	3	6	8	28	6	1	1	56
	Biliocephala sp.	-	-	-	14	2	-	-	-	-	-	-	-	16
	Chironomous sp.	-	-	-	-	-	-	-	-	-	2	-	-	2

	Chrysops sp.	-	-	2	-	-	5	-	-	1	-	-	-	8
	Culex sp.	-	-	-	-	-	-	-	3	-	-	-	-	3
	Diamesinae sp.	2	10	2	-	3	7	21	11	49	9	3	3	120
	Hexatoma sp.	2	-	-	-	-	-	-	-	4	-	-	-	6
	Procladius sp.	-	1	5	-	-	3	-	1	-	-	-	-	10
	Pychodiadae sp.	-	-	-	-	-	-	5	9	3	-	1	-	18
	Simulium sp.	-	-	-	11	3	5	6	5	10	3	-	-	43
	Tabanus sp.	2	-	-	4	2	-	-	-	-	-	-	1	9
	Tipula sp.	4	1	2	-	1	5	6	7	3	6	-	1	36
	TOTAL	101	128	109	109	60	121	229	299	216	115	45	79	1611

-= not found

Table A2. Temporal dynamics of macroinvertebrate density (ind. /m^2) at Site 2 from June 2014-May 2015

		SUMMER			**AUTUMN**			**WINTER**			**SPRING**			
Order	**Taxa /Species**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**TOTAL**
Pharyngobdellida	*Placobdella* sp.	-	-	5	-	-	-	-	-	-	-	-	-	5
Amphipoda	*Gammarus pulex*	-	-	-	1	1	-	-	-	-	-	-	-	2
Araneae	*Eylaoidea* sp.	-	-	-	-	-	-	4	-	-	-	-	-	4
	Hygrobatoidae sp.	-	10	2	2	2	1	5	2	5	-	-	-	29
Ephemeroptera	*Alainites* sp.	-	3	-	1	2	4	2	18	-	-	-	-	30
	Baetidae sp.	-	-	3	-	2	-	-	-	-	-	-	-	5
	Baetiella sp.	-	-	-	-	3	-	9	20	-	-	-	-	32
	Baetis rhodani	5	2	3	4	-	-	-	-	-	-	-	2	16
	Baetis sp.	-	12	-	-	-	-	-	-	-	-	-	1	13
	Caenis Srinagri	-	3	4	-	5	-	3	3	1	4	-	2	25
	Drunella Submontana	9	7	15	-	4	-	-	-	-	2	-	4	41
	Ecdyonurus sp.	-	5	18	4	5	3	12	40	9	5	15	2	118
	Epeorus sp.	3	7	10	5	2	-	-	-	-	3	8	3	41
Plecoptera	*Allocapnia* sp.	2	3	-	-	2	2	-	12	3	-	-	1	25
	Chloroperla sp.	-	-	-	4	1	-	3	29	-	-	-	-	37
	Nemouridae sp.	-	-	-	-	2	-	8	30	45	-	-	-	85
	Perlidae sp.	-	-	1	1	1	-	-	1	-	-	-	-	4
Coleoptera	*Elimidae* sp.	-	3	2	4	-	-	-	-	-	-	-	-	9
	Dyticus sp.	2	-	-	-	-	-	-	-	-	-	-	1	3
	Helodidae sp.	2	-	-	-	-	-	4	5	2	-	-	-	13
	Hydrophilidae sp.	-	-	4	-	-	-	-	-	-	-	-	-	4
	Stenelmis sp.	-	-	-	4	-	-	-	-	-	-	-	-	4
Trichoptera	*Glossosoma* sp.	9	16	14	-	2	-	-	-	3	-	-	4	48
	Brachycentrus sp.	-	3	2	1	2	-	22	100	40	20	10	-	200
	Hydropsyche sp.	1	-	-	-	3	1	7	18	10	1	1	1	43
	Limniphilus sp.	27	70	-	-	12	-	-	-	-	-	-	23	132

	Rhyacophila sp.	2	-	5	-	1	2	-	3	18	2	1	2	36
	Rhyacophila Yamanakensis	-	-	-	-	-	-	9	-	-	-	-	2	11
	Stenopsyche sp.	-	-	-	-	-	-	-	18	-	-	1	-	19
	Symphitopsyche sp.	-	-	-	-	-	1	-	-	5	2	-	-	8
Diptera	*Atherix* sp.	2	-	3	1	1	10	4	4	6	3	-	2	36
	Antocha sp.	-	2	2	-	-	-	4	6	10	2	-	-	26
	Biliocephala sp.	-	-	16	16	4	-	-	-	-	-	-	-	36
	Blephaceridae sp.	-	1	-	-	-	-	-	-	-	-	-	-	1
	Diamesinae sp.	7	4	-	1	4	3	27	13	10	4	5	3	81
	Hexatoma sp.	-	-	-	-	-	-	-	1	-	-	-	-	1
	Limoninae sp.	1	-	-	-	-	-	-	-	-	-	-	-	1
	Procladius sp.	-	-	-	-	-	-	-	8	-	-	-	-	8
	Pychodiadae sp.	-	-	-	-	-	-	-	2	1	-	-	-	3
	Simulium sp.	-	1	2	6	5	-	-	2	4	-	2	1	23
	Tabanus sp.	1	-	-	-	-	-	-	-	-	-	-	-	1
	Tipula sp.	2	1	3	-	2	3	2	5	1	-	-	1	20
	TOTAL	75	153	114	55	68	30	125	340	173	48	43	55	1279

-= not found

Table A3. Temporal dynamics of macroinvertebrate density (ind. /m^2) at Site 3 from June 2014-May 2015

		SUMMER			**AUTUMN**			**WINTER**			**SPRING**			
Order	**Taxa /Species**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**April**	**May**	**TOTAL**
Lymnaeidae	*Lymena ovata*	-	-	1	-	-	-	-	-	-	-	-	-	1
Pharyngobdellida	*Placobdella* sp.	-	-	1	-	-	-	-	-	-	-	-	-	1
	Erpobdella octoculata	5	3	2	-	-	6	2	-	-	3	-	4	25
Amphipoda	*Gammarus pulex*	1	-	4	-	-	-	3	-	-	-	3	2	13
Araneae	*Eylaoidea* sp.	-	-	5	-	-	-	-	-	-	-	2	-	7
	Hygrobatoidae sp.	-	3	4	4	1	2	3	-	-	-	-	-	17
Ephemeroptera	*Alainites* sp.	3	2	12	12	4	7	2	-	-	-	-	-	42
	Baetidae sp.	-	-	-	-	-	-	-	-	-	54	-	2	56
	Baetiella sp.	9	13	5	-	4	-	-	2	2	2	-	2	39
	Baetis rhodani	9	3	8	7	3	3	7	5	5	2	10	1	63
	Baetis sp.	-	3	3	7	6	9	13	5	50	22	1	-	119
	Caenis Srinagri	-	4	-	-	-	-	-	11	-	50	-	2	67
	Drunella Submontana	-	-	-	-	-	-	-	-	-	17	-	-	17
	Ecdyonurus sp.	-	-	-	14	6	-	-	-	-	-	5	1	26

	Epeorus sp.	-	-	3	-	2	1	4	-	2	-	5	3	20
Plecoptera	*Allocapnia* sp.	5	-	3	-	2	-	3	2	5	1	-	-	21
	Chloroperla sp.	-	-	-	-	-	-	-	-	-	2	-	-	2
	Nemouridae sp.	-	-	-	-	-	-	-	3	32	1	2	-	38
	Perlidae sp.	-	-	-	-	-	-	3	10	-	-	-	-	13
Coleoptera	*Stenelmis* sp.	2	-	-	-	-	-	-	-	1	3	-	-	6
	Helodidae sp.	-	-	2	2	-	-	-	-	-	-	-	-	4
	Hydrophilidae sp.	-	-	1	-	-	-	-	-	-	-	-	-	1
	Optioservus sp.	-	-	4	-	-	-	-	-	-	-	-	-	4
Trichoptera	*Glossosoma* sp.	-	5	27	-	4	-	4	4	1	-	-	2	47
	Brachycentrus sp.	30	-	13	6	5	17	11	15	-	8	52	23	180
	Cheumatopsyche sp.	2	-	1	-	1	-	-	4	-	2	1	1	12
	Hydropsyche sp.	2	-	1	-	-	-	-	-	-	1	-	1	5
	Hydroptilidae sp.	-	-	-	-	-	-	-	-	5	4	-	-	9
	Lepidostoma sp.	-	-	-	-	-	-	-	3	-	-	-	-	3
	Limniphilus sp.	2	-	2	1	2	-	-	-	1	-	1	2	11
	Rhyacophila Obscura	-	-	-	-	-	-	-	-	-	-	12	-	12
	Rhyacophila sp.	-	-	1	-	-	-	-	-	-	-	-	-	1
	Symphitopsyche sp.	22	130	-	-	9	4	-	-	1	4	49	24	243
Diptera	*Atherix* sp.	-	-	-	12	3	2	-	10	-	8	1	1	37
	Antocha sp.	-	-	4	-	-	-	2	5	2	-	-	-	13
	Bezzia sp.	-	-	-	-	-	-	-	-	-	-	1	-	1
	Chironomous sp.	1	-	2	2	3	1	-	-	-	20	1	4	34
	Culex sp.	-	1	-	-	-	-	-	-	-	-	-	-	1
	Diamesinae sp.	3	13	11	-	12	7	-	7	7	51	3	5	119
	Emphididae sp.	-	1	-	-	-	-	-	-	-	-	-	-	1
	Simulium sp.	-	5	64	21	16	12	7	2	-	8	-	-	135
	Tanypodinae sp.	-	1	-	-	-	-	-	-	-	-	-	-	1
	Tipula sp.	-	-	-	-	-	-	-	1	-	-	-	-	1
	TOTAL	96	187	184	88	83	71	64	89	114	263	149	80	1468

-= *not found*

Table A4. Temporal dynamics of macroinvertebrate density (ind. /m^2) at Site 4 from June 2014-May 2015

		SUMMER			AUTUMN			WINTER			SPRING			
Order	**Taxa /Species**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**April**	**May**	**TOTAL**
Pharyngobdellida	*Placobdella* sp.	-	-	4	-	-	-	-	-	2	1	-	-	7
	Erpobdella octoculata	13	6	4	2	4	2	1	-	6	12	-	12	62
Amphipoda	*Gammarus pulex*	-	1	3	-	-	-	-	-	-	-	-	2	6
Araneae	*Hygrobatoidae sp.*	-	20	-	-	-	-	-	-	-	-	-	-	20
Ephemeroptera	*Alainites* sp.	4	-	-	-	-	-	-	-	-	-	3	-	7
	Baetidae sp.	-	-	-	-	-	-	-	-	-	-	5	2	7
	Baetis rhodani	4	-	-	-	-	-	-	-	1	-	-	-	5
	Baetis sp.	2	-	-	-	-	-	-	-	-	-	-	2	4
	Caenis Srinagri	5	4	-	-	1	-	-	-	-	4	2	1	17
	Drunella Submontana	-	-	-	-	-	-	-	-	-	-	2	1	3
	Ecdyonurus sp.	3	2	-	-	-	-	-	-	-	-	6	2	13
	Epeorus sp.	-	-	-	1	1	-	-	10	-	-	-	1	13
Plecoptera	*Chloroperla* sp.	-	3	-	-	-	-	-	-	-	-	-	-	3
Coleoptera	*Elimidae* sp.	-	3	-	-	-	-	-	-	-	-	-	-	3
Trichoptera	*Brachycentrus* sp.	12	-	-	-	-	-	-	-	2	-	4	10	28
	Hydropsyche sp.	1	-	-	-	1	-	-	-	-	-	-	-	2
	Hydroptilidae sp.	8	20	1	-	-	-	-	-	-	2	1	-	32
	Limniphilus sp.	24	15	-	1	1	-	-	-	-	-	-	12	53
	Rhyacophila sp.	1	-	-	-	-	-	-	-	-	-	-	1	2
Diptera	*Chironomous* sp.	6	20	10	2	4	3	3	4	4	-	-	10	66
	Diamesinae sp.	-	4	10	-	2	-	-	-	-	-	-	2	18
	Simulium sp.	-	-	-	2	-	-	-	-	-	-	-	-	2
	TOTAL	83	98	32	8	14	5	4	14	15	19	23	58	373

-= *not found*

Table A5. Temporal dynamics of macroinvertebrate density (ind. /m^2) at Site 5 from June 2014-May 2015

		SUMMER			AUTUMN			WINTER			SPRING			
Order	**Taxa /Species**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**March**	**April**	**May**	**TOTAL**
Lymnaeidae	*Lymena ovata*	-	-	-	1	-	-	-	-	-	-	-	-	1
Pharyngobdellida	*Placobdella* sp.	-	-	1	-	-	-	-	-	-	-	-	-	1
	Erpobdella	5	3	6	1	3	2	-	2	1	2	2	5	32

	octoculata													
Opisthopora	*Lumbricus* sp.	1	-	1	-	-	-	-	-	-	-	-	-	2
Amphipoda	*Gammarus pulex*	-	-	12	-	-	-	-	-	-	-	-	2	14
Trichoptera	*Hydroptilidae* sp.	-	-	1	-	-	-	-	-	-	-	1	-	2
Coleoptera	*Coccinilidae* sp.	-	-	-	-	-	-	-	-	-	1	-	-	1
	Dyticus sp.	2	-	-	-	-	-	-	-	-	-	1	-	3
Diptera	*Chironomous* sp.	12	70	10	2	5	4	6	10	2	2	2	11	136
	Diamesinae sp.	-	-	2	-	-	-	-	-	-	-	-	1	3
	TOTAL	20	73	33	4	8	6	6	12	3	5	6	19	195

-= *not found*

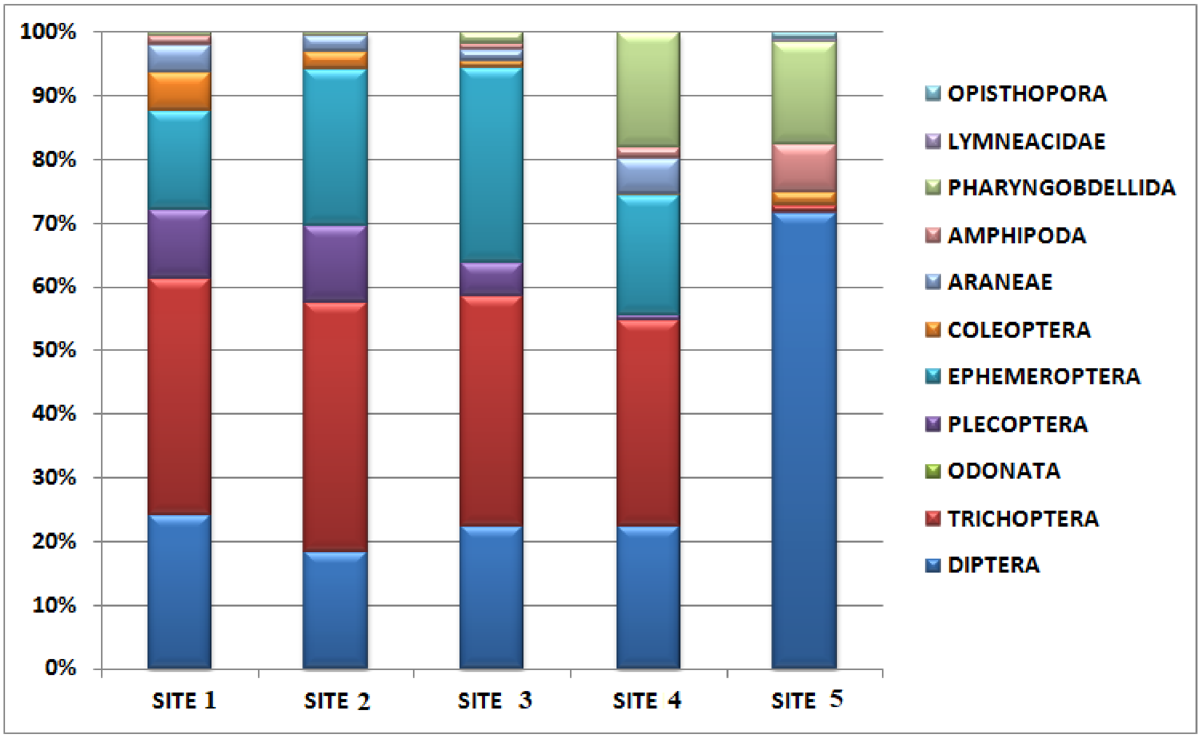

Fig. A1. Relative densities of different orders at five sites

Table A6. Coding of taxa used for some stastical analysis

Atherix sp.	Insect1	Polycentropus sp.	Insect24	*Stenelmis sp.*	Insect47
Tabanus sp.	Insect2	*Brachycentrus sp.*	Insect25	*Optioservus sp.*	Insect48
Chrysops sp.	Insect3	*Lepidostoma* sp.	Insect26	*Hydrophilidae* sp.	Insect49
Hexatoma sp.	Insect4	Hydroptilidae sp.	Insect27	*Coccinilidae* sp.	Insect50
Antocha sp.	Insect5	*Stenopsyche sp.*	Insect28	Helodidae sp.	Insect51
Limoninae sp.	Insect6	*Rhycophila Yamanakensis*	Insect29	*Dyticus* sp.	Insect52
Tipula sp.	Insect7	*Rhycophila Obscura*	Insect30	Eylaoidea sp.	Insect53
Culex sp.	Insect8	*Rhycophila* sp.	Insect31	Hygrobatoidae *sp.*	Insect54
Bezzia sp.	Insect9	Libellulidae sp.	Insect32	*Gammarus pulex*	Insect55
Chironomous sp.	Insect10	*Allocapnia* sp.	Insect33	*Lumbricus* sp.	Insect56
Tanypodinae sp.	Insect11	Nemouridae sp.	Insect34	*Placobdella* sp.	Insect57
Procladius sp.	Insect12	Perlidae sp.	Insect35	*Erpobdella octoculata*	Insect58
Diamesinae sp.	Insect13	Chloroperla sp.	Insect36	*Lymena ovata*	Insect59
Emphididae sp.	Insect14	Baetidae sp.	Insect37		
Pychodiadae sp.	Insect15	*Alainites* sp.	Insect38		
Blephaceridae sp.	Insect16	*Baetiella sp.*	Insect39		
Biliocephala sp.	Insect17	*Baetis rhodani*	Insect40		
Simulium sp.	Insect18	*Baetis sp.*	Insect41		
Glossosoma sp.	Insect19	*Drunella Submontana*	Insect42		
Cheumatopsyche sp.	Insect20	*Caenis Srinagri*	Insect43		
Hydropsyche sp.	Insect21	*Epeorus* sp.	Insect44		
Limniphilus sp.	Insect22	*Ecdyonurus* sp.	Insect45		
Symphitopsyche sp.	Insect23	*Elimidae sp.*	Insect46		