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Full Length Research Paper

Benthic macroinvertebrate community of Yousmarg streams (Doodganga stream and Khanshah Manshah canal) in Kashmir Himalaya, India

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This study attempts to provide an overview of the benthic macroinvertebrate assemblages of Yousmarg streams. For studying the distribution of macroinvertebrate assemblages in the two streams, that is, Doodganga and Khanshah manshah canal, a total of 4 study sites were selected. During the period of investigation, 24 species of macrozoobenthos in Yousmarg streams were recorded. Arthropoda was found to be the most dominant group, comprising of 23 species followed by Annelida with 1 species. The phylum Arthropoda was represented by class Insecta (5 orders) and Crustacea (1 orders). The diversity of benthic invertebrates was high in Doodhganga stream (21 taxa) as compared to Khanshah-manshah canal (18 taxa). An inter-site comparison revealed maximum mean population density for Doodhganga stream as compared to Khanshah-manshah canal. Besides, it was observed that boulders and cobbles provided a stable habitat for macroinvertebrates dwelling. Also, greater diversity in the summers as against winters was recorded in both the streams. On the basis of the biotic indices, the Doodhganga stream is being adjudged pristine with no organic pollution, however slight organic pollution in Khanshah–manshah canal was recorded.

Key words: Kashmir Himalayas, benthic macroinvertebrates, Diversity**.**

INTRODUCTION

Unlike the earlier studies wherein the stream ecologists considered river channels to be relative biological deserts (Percival, 1932) with communities characterized by low species diversity and dominated by a few common, generalist species (Scrimgeour and Winterbourn, 1989), the contemporary research studies have shown not only the pivotal role played by the aquatic species in the energy-pathways but a host of more applied research have revealed the importance of aquatic insects in the spread of diseases, in the biological assessment of water quality, and in the reconstruction of past environments on earth (Willams and Feltmate, 1992). Usually, the stream communities are dominated by species of invertebrates (Morse et al., 1993). Macroinvertebrate communities being integral components of freshwater ecosystems influence sediment and bottom-water chemistry (Aller, 1980), alter sediment organic content (Pearson and Rosenberg, 1978) and structure (Rhoads and Boyer, 1982) and serve as major prey species for crustaceans and fish (Virnstein, 1977). Benthic organisms accelerate nutrient transfer to overlying open waters of lakes (Clarke and Scruton, 1997) as well as to adjacent riparian zones of streams (Covich et al., 1996; Wallace et al., 1997).

The benthic macroinvertebrates are the animals inhabiting the sediment or living on or in other available bottom substrate of fresh water, estuarine and marine ecosystem (A.P.H.A, 1998). The distribution of aquatic macroinvertebrate species and communities is controlled by a variety of environmental factors such as habitat characteristics (Peeters and Gardeniers, 1998), water quality (Hellawell, 1986), sediment quality (Chapman et al., 1976), sediment grain size (Tolkamp, 1980), contami-

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nants (Phipps et al., 1995), and by biological factors such as competition and predation (Macneil et al., 1999). In recent years, applied ecologists have recognized the utility of biological monitoring, with particular attention given to survey designed to sample benthic macroinvertebrates (Rosenberg and Resh, 1993). Unlike chemical data, which provides water quality information at a discrete point in time, the biological organisms are long-term indicators of environmental stressors. In addition, macroinvertebrates are more effective than chemical methods for detecting non-point source pollution. In part, this is because of the spectrum of taxa-specific responses among invertebrates to environmental stressors and their long-term response to these factors.

The present study was undertaken to document the distribution of macrozoobenthos in the concerned study sites, to evaluate seasonal dynamics of benthic faunal assemblage and to analyse the water quality of streams.

MATERIALS AND METHODS

Study site

Standing in the Pir panjal hills at an altitude of 2700 m, lies the meadow of Yousmarg (Figure 1). The valley is marked by lush green pastures, dense pine forests and impressive snow-capped mountain. It is approximately 47 km from the southwest of Srinagar and lies in the Budgam district of Jammu and Kashmir. It lies in the co-ordinates 33° 49'42" N, and 73° 39' 59" E and at an altitude of 2712 m a.s.l. The valley is surrounded on all sides by a chain of mountains which range from 4000 to 5000 m e.g. Tata kutti 4725 m and Sunset Peak 4746 m.

Site I

Doodganga stream is a principal left bank tributary of the river Jehlum. Doodhganga (its name derived from its milk white foam) finds its origin on the eastern slope of pir-panjal mountain ranges of Himalayas below the Tata kutti peak. The source of water for this stream is snow-fields, springs, and a number of smaller lakes. It empties itself in the flood-spill channels. The stream passing through Yousmarg is of fourth order.

Site II

Khanshah manshah canal is a 30 km long canal feeding the Sadarmauj reservoir. This 34 years old reservoir supplies water for irrigation and domestic purpose to many villages namely Pakherpora, Darwan, Fudlipora, Zinpanchal, etc. The sources of water for this canal are the glaciers.

Methods

Semi quantitative sampling was done for 4 months (May, June, November and December) in 2010 via following the protocol for hard-bottomed streams (Stark et al., 2001). Two sampling stations each were selected on both streams. These sites were approx. 3 km apart; this was done to make the study more representative. Samples collected were preserved for later identification in the laboratory. The animals with calcareous/exoskeleton were preserved in 4% formalin and soft bodied organisms were preserved in 70% ethanol (Borror et al., 1976). In the present study, the identification of the preserved animals was done up to genus level with the help of standard works of McCafferty and Provonsha (1998), Wetzel and Likens (2000) and Ward (1992).

RESULTS

The general characteristics of sampling sites are exhibited in Table 1. Benthic invertebrate fauna exhibited diversity in species composition (Table 2). During the period of investigation, 23 taxa of macrozoobenthos in Doodganga streams were recorded, followed by Khanshah manshah with 18 taxa. Arthropoda was found to be the most dominant group, comprising of 23 species followed by Annelida with 1 species. The former was represented by class Insecta (5 orders) and Crustacea (1 order). The species rich class Insecta is itself an assemblage of different forms belonging to 5 different orders (Ephemeroptera-2, Diptera-12, Trichoptera-5, Plecoptera-2 and Coleoptera-1) (Table 2). Insecta class was dominated by order Diptera followed by Trichoptera, Ephemeroptera and Plecoptera at all four sites.

Diptera was the most dominant group, contributing 54.0% to the total benthic entomofauna (Figure 2). Its density ranged from 268 ind.m^{-2} (May) to 137 ind.m^{-2} (December) (Table 4). The major species contributing to the Diptera group were represented by *Bibiocephala* sp., *Diamessinae* sp. and *Clinocera* sp. recording mean densities 63.0, 59.0 and 31.5 ind.m^{-2}, respectively (Table 3). Tricoptera was the next most dominant group with the relative density of 34.0% (Figure 2). Its density ranged from 279 ind.m^{-2} (May) to 41 ind.m^{-2} (December) as shown in Table 4. Within the group, the mean density was recorded highest for *Limnephilus* sp. (83.0 ind.m^{-2}) followed by *Glossosoma* sp. (26.2 ind.m^{-2}) (Table 3).

The monthly changes in various diversity indices calculated from the data collected during the present study is represented in Table 5. The Shannon-Weiner Index (Shannon and Weiner,1976) value for Doodhganga stream fluctuated from 2.58 (May) to 1.82 (December) with a mean value of 2.18, but for Site II it ranged from 2.16 (May) to 0.98 (November). The evenness index or equitability index gave the distribution pattern of individuals in the benthic community. The maximum evenness or homogenous distribution was recorded in May (E = 0.93), while the minimum was recorded in December (E = 0.80) for Site I. As is evident from the values, the distribution of various taxa was more or less uniform during the sampling periods, the mean value being 0.85; on the other hand, Site II fluctuated from 1.19 (November) to 1.06 (June). Simpson index (Simpson, 1949) fluctuates from 0.14 in June to 0.19 in December for Site I, and for Site II it portrayed the mean value of 0.22, thereby clearly reflecting that no single specie dominated in any of the sampling sites.

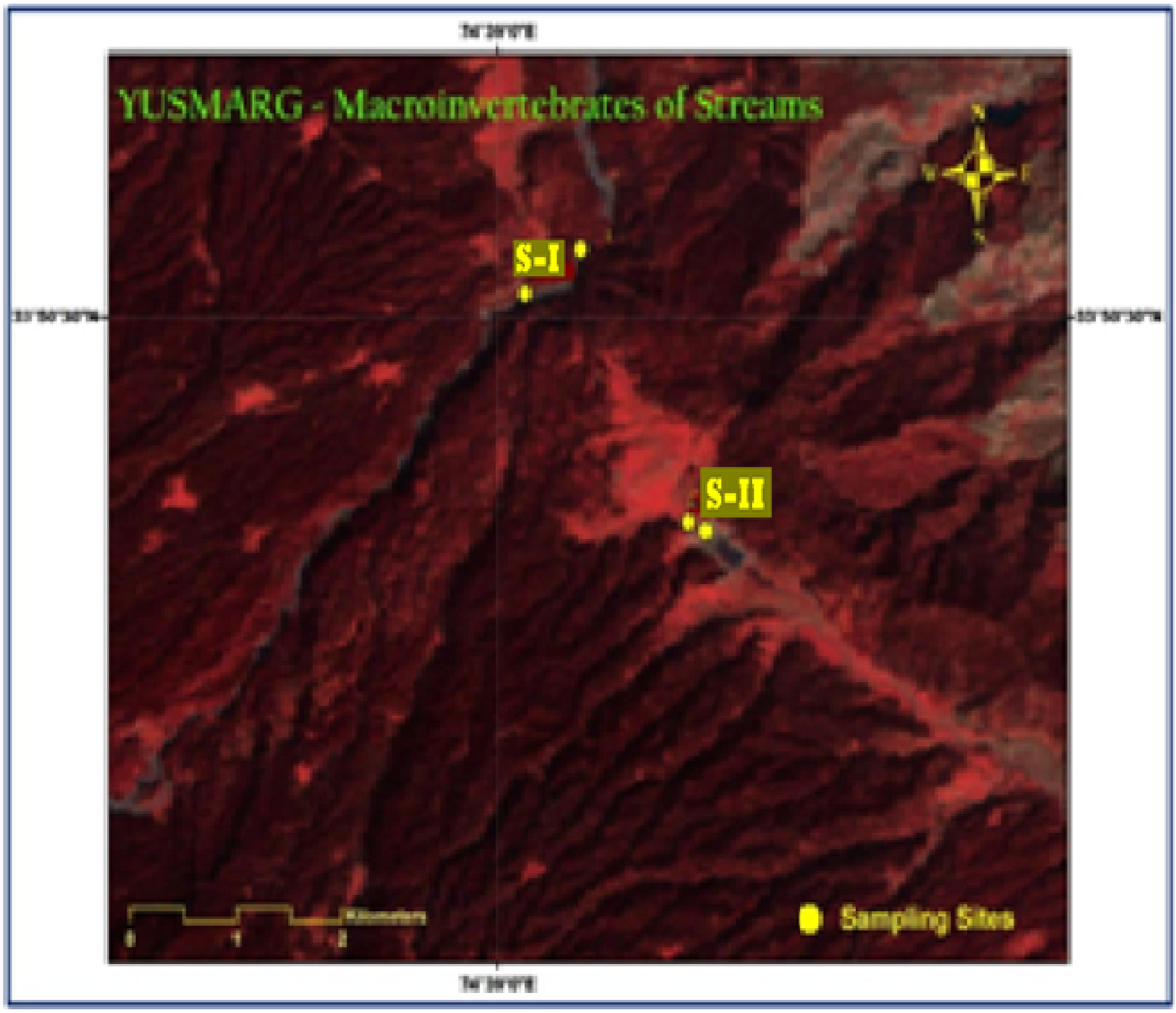


Figure 1. Satellite image of Yousmarg study area and the sampling stations on both the streams.

In both streams, the density during summers was high as compared to winters as shown in Figure 3. On a ho-listic scale of pollution tolerance index, excellent water quality is indicated for both streams. But on the basis of a more accurate and explicit scale of Hilsenhoff Biotic Index, it is indicated that there is a possibility of slight organic pollution in Khanshah–manshah canal, while for site I, apparently no organic pollution is reported (Table 6).

DISCUSSION

The present study indicates that the environmental characteristics of stream such as water depth, current velocity, temperature, altitude and physical stability of substrate all to a varying degree influenced density and richness of macroinvertebrates. This is in accordance with the study of Negi and Singh (1990) wherein stream flow, nature of substratum and organic pollution regulated the species composition and dominance of different taxa in various stretches of rivers.

The distribution, abundance and diversity of the macrozoobenthos is affected by inter and intra specific competition, as well as tolerance capacity of organisms to changing physico-chemical features of water. The present investigation revealed that the Arthropoda was the most dominant phylum in all the study sites. It is the most prominent freshwater taxa because of the fact that these occupy every heterotrophic niche in benthic as well as the pelagic habitats of most permanent and temporary aquatic systems (Thorp and Covich, 1991; Williams and Feltmate, 1992). Mostly, the group Arthropoda are known to dominate at sites where bottom texture is dominated with hard stones (Emere and Nasiru, 2007; Arimoro et al., 2007) which is true for all the sites under investigation where the boulders and cobbles provide a stable

Table 1. General characteristics of the study sites.

Location	Sampling station number	Altitude (a.m.s.l)	Latitude (n)	Longitude (e)	Depth (m)	Temperature (^{0}c)	Oxygen Content (mg/l)	Water flow Rate (m^3 / s)	Substrate type
Doodhganga stream	I	2,304 m	33° 50′ 34.4″	74° 39′ 12.4″	1.23	8.75	6.2	2.06	Hard-bottomed stream+ leaf litter from adjoining forest.
Khansha mansha canal upstream	II	2,414 m	33°49'38.9"	74°39'41.7"	0.52	10	6.33	0.515	Hard-bottomed stream+ leaf litter from adjoining forest and grassland+ deposition of muddy sediments due to lowering velocity of water flow at the inlet of reservoir.

environment for macroinvertebrates.

However, within the phylum Arthropoda, the greatest diversity in form and habit was exhibited by the class Insecta. The apparent reason being the superior competitive abilities of insects, as this class represents all the functional feeding groups, ranging from predators, shredders, grazers (orscrapers) to filter feeders and gatherers. This class is known to occupy every kind of freshwater habitat imaginable, including temporary streams and ponds, the shallowest and deepest areas of lakes, the most pristine and polluted rivers, roadside ditches, within and on macrophytes and all ranges of water chemistry, from acidified to alkaline bodies of water (Mackie, 1998). The phylum Annelida is represented by a single specie (*Erpobdella octoculata*). The leeches form an important component of benthos of freshwater (Sawyer, 1986). But in the present study, their contribution to the total density was merger, as the oligochaete communities have been observed to thrive well in soft depositing substrates rather than stony beds. The presence of these taxa might probably be due to their greater power of utilizing the organic matter below the surface of bottom sediments (Poddubnaja and Sorokin, 1961) which makes them less dependent on the immediate inflow of food, a conjecture also held by Kajak and Dusoge (1975).

During the course of study, a more or less consistent trend line of Diptera and Tricoptera dominating over the other orders is observed. The reason might be the optimal environmental conditions which favored the growth and development of these organisms, as no appreciable variation in the physico-chemical parameters was found for all the four sampling period, which lead to development of a uniform trend line. The species belonging to these groups have a better tolerance capacity not only with respect to pollution (Hilsenhoff, 1998) but also with reference to the adjustment to the fluctuation in the water flow rate. They are efficient inter- and intra-specific competitors; this is clearly reflected by their diverse feeding habits ranging from collectors/ gatherers, scrappers, shredders to predators (Mackie, 2001). However, in the present study, negligible diversity of Amphipoda (*Gammarus pulex)* was reported. Although, it is found dominant in the streams of Kashmir valley, its dominance has also been reported elsewhere (Shaw and Minshall, 1980; Duran, 2006). The proportion of insect / non-insecta taxa is largely determined by water quality, with the present study sites being soft water streams while the amphipods are known to dominate inhard water areas (Glazier and Gooch, 1987).

Quantitatively the highest contribution was made by Diptera as these aquatic legless larvae outnumbered, in both individuals and genus, with respect to all the other aquatic insects taken together. The greater diversity of dipteral is due to the fact that these are one of the insect communities known to survive and adapt to extreme environmental conditions (William and Feltmate, 1992). Hutchinson (1993) concluded that Diptera are, by far, the most diverse order of insects in freshwaters. They are, in fact, the most diversified of any major taxon of freshwater organisms. Tricoptera closely followed Diptera as the next most dominant group. Although caddisfly larvae are found in a wide range of aquatic habitats, the greatest diversity occurs in cool

Table 2. Macrozoobenthos species composition in both the streams.

Phylum	Class	Order	Family	Taxa/species
Arthropoda	Insecta	Diptera	Athericidae	*Atherix* sp.
			Blephariceridae	*Bibiocephala* sp.
			Chironomidae	*Diamessinae* sp. *Glyptotendipes* sp.
			Empididae	*Clinocera* sp. *Rhamphomyia* sp
			Tabanidae	*Tabanus* sp. *Chrysops* sp.
			Tipulidae	*Hexatoma* sp. *Tipula* sp.
			Simuliidae	*Simulium* sp.
			Dolichopodidae	*Rhaphium* sp.
		Trichoptera	Glossosomatidae	*Glossosoma* sp.
			Hydropsychidae	*Hydropsyche* sp
			Limnephilidae	*Limnephilus* sp.
			Rhyacophilidae	*Rhyacophila* sp.
			Brachycentridae	*Brachycentrus* sp.
		Plecoptera	Capniidae	*Allocapnia* sp
			Chloroperlidae	*Xanthoperla sp.*
		Ephemeroptera	Baetidae	*Alainites* sp.
			Heptageniidae	*Epeorus* sp.
		Coleoptera	Chrysomelidae	-
	Crustacea	Amphipoda	Gammaridae	*Gammarus pulex*
Annelida	Hirudinae		Erpobdellidae	*Erpobdella octoculata*

running waters as supported by the studies of Williams and Feltmate (1994). These larvae are known to occupy every conceivable trophic level or functional feeding group e.g. many Limnephiloidea are shredders or grazers, and Hydropsychidae are characteristically filter feeders, using silken nets to collect seston (Mackie, 2001).

The diversity during summer was found to be highest compared to winter; this is in conformity with the study of Lamp and Haube (2004). The seasonal difference in the relative abundance of major taxa in high altitude streams are largely governed by temperature (Gupta and Michael, 1983). As the optimal temperature not only favor conducive conditions, but the rate of decomposition of organic matter by microbial actions also increases, this process is further enhanced by the mechanical fragmentation of litter by invertebrates. When sufficient dissolved oxygen and appropriate substrata are available, many species of benthic organisms, especially insects and crustaceans, are known to accelerate microbial processing of dead organic material (Cummins et al., 1995). The larval stages of many of the invertebrate species were observed during the summer month investigation, these might have served food source for predator benthic macroinvertebrates, therefore contributing to greater food availability. The higher densities in the temperate streams probably reflect differences in the topographic relief and discharge rates,

Table 3. Mean population densities (number of individuals per m^2) of various groups of benthic fauna.

Group/taxa	Site	May	June	November	December	Mean	SD (±)
Arthopoda							
Atherix sp.	I	8	6	22	19	13.7	7.9
Atherix sp.	II	0	0	0	0	0	0
Bibiocephala sp.	I	138	114	0	0	63.0	73.4
Bibiocephala sp.	II	0	0	0	0	0	0
Diamessinae sp.	I	38	21	114	64	59.2	35.1
Diamessinae sp.	II	59	24	0	0	20.75	24.1
Clinocera sp	I	48	27	22	29	31.5	9.8
Clinocera sp	II	40	27	0	0	16.75	17.3
Tabanus sp.	I	0	0	8	4	3.0	3.3
Tabanus sp.	II	0	0	7	5	3	3.5
Hexatoma sp.	I	0	1	2	0	0.7	0.8
Hexatoma sp.	II	0	0	7	5	3	3.5
Tipula sp.	I	1	5	7	0	3.2	2.8
Tipula sp.	II	0	0	7	5	3	3.5
Simulium sp.	I	35	26	38	21	30	6.8
Simulium sp.	II	46	26	0	0	18	19.3
Glyptotendipes sp.	I	0	0	0	7	1.7	3.0
Glyptotendipes sp.	II	0	0	0	0	0	0
Chrysops sp.	I	0	0	5	0	1.2	2.1
Chrysops sp.	II	0	0	0	0	0	0
Rhaphium sp.	I	0	0	0	0	0	0
Rhaphium sp.	II	0	0	2	0	**0.5**	0.8
Alainites sp.	I	9	17	4	0	7.5	6.3
Alainites sp.	II	11	7	0	3	5.2	4.7
Epeorus sp.	I	10	6	0	0	2.7	2.9
Epeorus sp.	II	5	2	0	0	1.75	2.0
Glossosoma sp.	I	20	27	28	30	26.2	3.7
Glossosoma sp.	II	5	2	0	0	1.75	2.0
Hydropsyche sp.	I	24	35	17	3	19.7	11.6
Hydropsyche sp.	II	5	2	0	0	1.75	2.0
Limnephilus sp.	I	192	89	43	8	**83.0**	69.1
Limnephilus sp.	II	58	50	0	0	**27**	27.1
Rhyacophila sp.	I	15	19	8	0	10.5	7.2
Rhyacophila sp.	II	0	0	0	0	0	0
Brachycentrus sp.	I	28	39	0	0	16.7	17.1

Table 3. Contd.

	II	0	0	0	0	0	0
Allocapnia sp.	I	19	9	5	0	7.0	7.8
	II	0	0	0	0	0	0
Xanthoperla sp.	I	8	7	3	0	3.7	3.7
	II	10	3	0	0	3.25	4.0
Chrysomelidae	I	1	0	0	0	**0.2**	0.4
	II	0	0	0	0	0	0
Gammarus pulex	I	1	0	1	2	0.7	0.8
	II	0	0	0	0	0	0
Annelida							
Erpobdella octoculata	I	37	24	18	5	21.0	11.5
	II	17	12	10	0	9.7	6.1

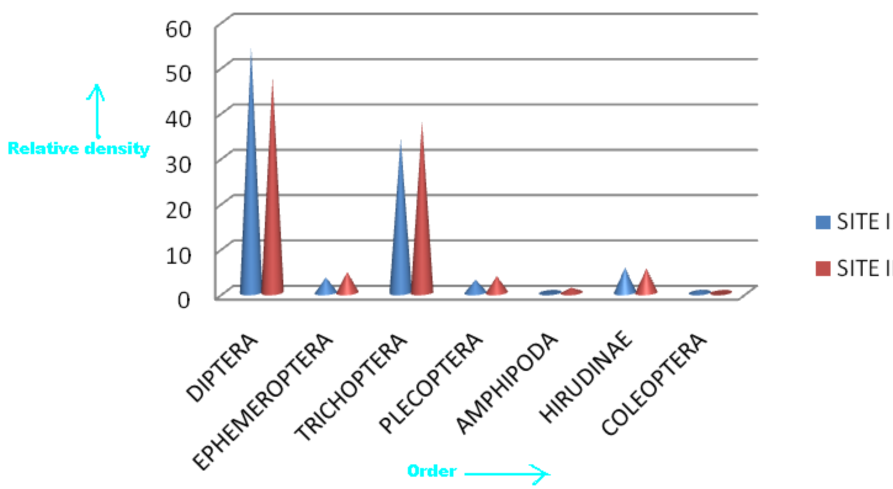


Figure 2. Relative density (%) of various orders.

substrate composition and/or water quality among streams of different orders (Bruce et al., 2003). Since both streams have snow-fed origin, the water supply during summer was as a result of melting of ice. This water had low nutrient concentration which favored the growth of not only pollution tolerant species but also pollution sensitive species. Further the lack of human population along the catchment probably aids in the abundance of these species. Maximum light penetration, that is, longer growth periods in summers also might be attributable to favors the growth of algae, periphytons and diatoms, which are primary food sources for many benthic species. As the streams are characterized by not only allochthonous (outside) where inputs of energy are in the form of terrestrially-derived leaf and woody debris, but also by the growth of autochthonous (inside) whereinput of energy is in the form of aquatic algae (Allan, 1995). Cowell et al. (1997) stated that the larger densities of benthos in higher order temperate streams are due to greater algal and/or macrophyte productivity, especially when the streams are wide enough to minimize the influence of canopy shading. Lastly, low densities during the winters might be due to the fact that generally the larval population (observed in summers) is high as compared to the actual number of organisms that survive and finally emerge as adults (Stark and Armitage,

Table 4. Population densities (number of individuals per m^2).

Family	Site	May	June	Nov.	Dec.
Diptera	I	268	200	218	137
	II	146	78	9	26
Ephemeroptera	I	19	23	4	0
	II	16	9	0	0
Trichoptera	I	279	209	96	41
	II	113	93	0	0
Plecoptera	I	27	16	0	0
	II	16	4	0	0
Coleoptera	I	1	0	0	0
	II	0	0	0	0
Amphipoda	I	1	0	1	2
	II	4	1	0	1
Hirudinea	I	37	24	18	5
	II	17	12	0	0
Total	I	632	472	329	185
	II	312	197	19	27

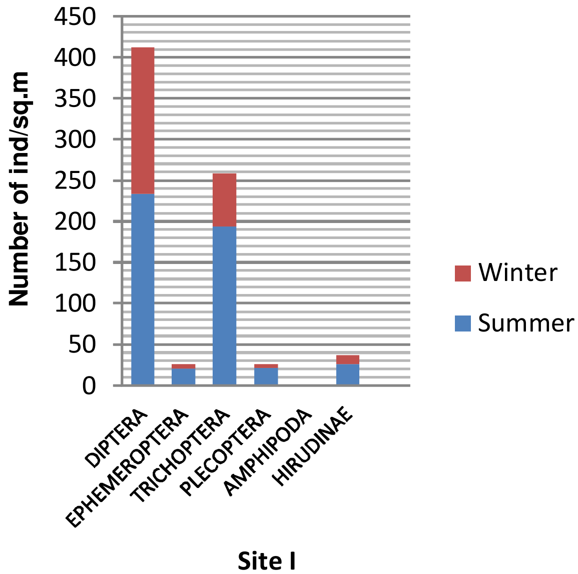
Table 5. Diversity Index for benthic macroinvertebrate community.

Index	Site	May	June	November	December	Mean
Shannon-Weiner index	I	2.59	2.24	2.09	1.82	2.18
	II	2.16	2.06	0.98	1.41	1.65
Simpson index	I	0.18	0.14	0.16	0.19	0.16
	II	0.12	0.14	0.38	0.25	0.22
Equitability index	I	0.93	0.86	0.83	0.80	0.85
	II	1.10	1.06	1.19	1.10	1.11

2000, 2004).

High diversity value in Doodhganga upstream is as a result of positive co-relation between the physico-chemical parameters and the corresponding diversity e.g. low temperature regime, low organic input and generally severe habitat conditions at such altitudes. On the other hand, Khanshah-manshah downstream had comparatively low diversity because of the composition of bottom substrate having approx. 25% of sand and mud.

Hilsenhoff Biotic Index is a better and explicit parameter to assess the water quality (Hilsenhoff, 1977, 1982, 1987). Only arthropods that require dissolved oxygen for respiration are used in the calculation of the HBI. The index indicated that there was 'no apparent organic pollution' in Doodhganga stream as there is no source of pollution in its vicinity. This observation was well supported by Pollution Tolerance Index. However, in Khanshah manshah canal slight organic pollution is reported due inflow of organics from pasture and construction activity being carried out nearby.



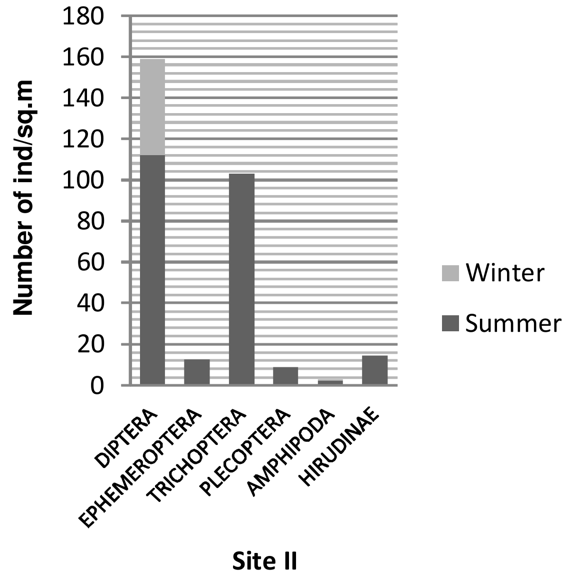


Figure 3. Seasonal variations in the study sites.

Table 6. Indices indicating the water quality.

Site	Hilsenhoff biotic index (H.B.I)	Pollution tolerance index (PTI)
I	3.5	28
II	3.80	24

Conclusions

The study was initiated with an objective to assess the benthic macroinvertebrate community of Doodhganga stream and Khanshah manshah canal. On the basis of the present study, the key findings are presented as follows: substrate type had a pronounced effect on the spatial distribution of benthic organisms. The boulders and cobbles provided a stable environment for macroinvertebrates dwelling, in such a way that it minimized the negative effect of increased water velocity in upstream areas. Greater diversity in the summers as against winters was recorded. The primary reason being the exposure to sunlight in these areas played an important role in determining the appropriate conditions for the colonization and establishment of different immature larval populations. On the basis of the biotic indices, the Doodhganga stream can be adjudged pristine with no organic pollution but in Khanshah manshah canal slight organic pollution is reported.

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