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Macro Invertebrate Community from Sonamarg Streams of Kashmir Himalaya

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Abstract: This study analyses a macroinvertebrate community survey for River Sindh and its tributary including Baltal, Yashmarg, Sonamarg and Thajwas Grar considering the extreme hydrological conditions linked with the seasonal low-flow period typical for some streams in this area. This study attempts to provide an overview of the macro invertebrate assemblages and physico-chemical variables of the River Sindh and its important tributary. Four study sites were selected from the River Sindh and its tributary including Baltal, Yashmarg, Sonamarg and Thajwas Grar for studying the ecological distribution of Macroinvertebrate assemblages. Totally, 33 taxa of macroinvertebrates were recorded from the two streams belonging to Mollusca-3 (Gastropoda-2 and Bivalvia-1), Annelida-1 and Arthropoda-29 (Insecta-29). Among insects Ephemeroptera (7), Trichoptera (6) and Diptera (13) dominated. Except Yashmrag all sites were found devoid of annelids while as the mollusks were found absent at Sonamarg. Highest values of Shannon Weiner Index were found at Yashmarg (2.42) and lowest at Sonamarg (1.99) while as highest and lowest Sorensen's similarity coefficient were found between Baltal/Thajwas Grar (0.68) and Yashmarg/Thajwas Grar (0.39), respectively. A perusal of the data on physico-chemical characteristics showed that these streams were hard water type with high dissolved oxygen content. The ionic composition of the stream waters revealed the predominance of bicarbonate and calcium. Insecta dominated both qualitatively as well as quantitatively and the study revealed that the substrate compositions dominated by gravel, pebble and leaf litters are primary determinants of the invertebrate community structure recording maximum species diversity and abundance. Sample locations impacted by Amarnath yatris pilgrimage comparatively reflected slightly higher increase in nutrients than Thajwas Grar almost devoid of pilgrimage effect.

Key words: Macroinvertebrate, stream, sonamarg, ecological distribution, diversity

INTRODUCTION

Historically, stream ecologists have considered braided river channels to be relative biological deserts (Percival, 1932) with communities characterized by low species diversity and dominated by a few common, generalist species (Sagar, 1986; Scrimgeour and Winterbourn, 1989). However, a more holistic view of the river which includes the wider floodplain and underlying ground waters has revealed high spatio-temporal habitat heterogeneity in which spatially minor habitats contribute disproportionately to corridor biodiversity (Stanford, 1998; Ward *et al*., 1999).

The significance of stream discharge, substrate composition, temperature,water chemistry, Allochthonous and Autochthonous inputs for the structure of stream habitats and benthic communities has been widely confirmed (Cross *et al*., 2006; Gafner and Robinson, 2007; Clarke *et al*., 2008; Haidekker and Hering, 2008; Javanshir *et al*., 2008; Alvarez and Pardo, 2009) but the role of low discharges and drought is more difficult to decipher. Benthic invertebrates respond in different ways to in-stream changes of flow (Wood *et al*., 2001; Monk *et al*., 2008). In freshwater sediments, benthic invertebrates are diverse and abundant (Strayer, 2006) but they are often patchily distributed and relatively difficult to sample, especially when they live in deep subsurface sediments. Thus, the species richness and functional importance of freshwater benthic invertebrates generally go unnoticed until unexpected changes occur in

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ecosystems. Unanticipated changes in freshwater ecosystems are often due to alterations in the complex connections among Sediment dwelling species and associated food webs (Goedkoop and Johnson, 1996; Lodge *et al*., 1998; Stockley *et al*., 1998) or to disturbances, such as floods or drought (Covich, 1993; Power, 1995; Johnson *et al*., 1998) that alter the species composition of the benthos. These examples illustrate that benthic invertebrate species function in different ways that are important to maintaining ecosystem functions such as energy flow in food webs. Many benthic species convert live plant and dead organic material into prey items for larger consumers in complex food webs. In the process of maintaining energy flow, these benthic species simultaneously provide essential ecosystem services, such as nutrient cycling and aeration of sediments. Different species comprise distinct functional groups that provide ecological integrity. In some cases, these functional groups may be represented by only a few species, so that any loss of species diversity could be detrimental to continued ecosystem functioning. Thus, it is increasingly important to protect the biodiversity of benthic communities to lower the risk of unexpected and unwanted consequences.

Macroinvertebrate communities are integral components of freshwater ecosystems which influence sediment and bottom-water chemistry (Rhoads *et al*., 1977; Aller, 1980), alter sediment organic content (Pearson and Rosenberg, 1978) and structure (Rhoads and Young, 1970; Bokuniewicz *et al*., 1975; Rhoads *et al*., 1978; 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 (Lindegaard, 1994; Threlkeld, 1994; Blumenshine *et al*., 1997; Clarke *et al*., 1997) as well as to adjacent riparian zones of streams (Covich *et al*., 1996; Johnson and Covich, 1997; Naiman and Décamps, 1997; Wallace *et al*., 1997).

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, biological organisms are long-term integrators 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. Finally, macroinvertebrates are also good environmental indicators because they are common components of freshwater ecosystems, relatively sessile in their aquatic phase and can be inexpensively sampled (Furse *et al*., 2006; Arimoro *et al*., 2007a, b). The lakes of valley has been studied extensively while as there are only very few reports regarding the benthic fauna of streams in the vale of Kashmir (Engblom and Lingdell, 1999; Mahdi *et al*., 2005; Bhat and Pandit, 2006). Further in the recent years there has been a tremendous pressure in the catchement of these streams because of Amarnath Pilgrimmage likely to impact the water quality downstream. Taking above assumptions into consideration it was thought worthwhile to make an attempt of taxonomic survey of benthic fauna of streams in the Sonamarg area of Kashmir Valley.

MATERIALS AND METHODS

All sites were sampled on a single occasion during the July, September, October and December 2009. Benthic invertebrate samples were collected using a kick-net (mesh size 250 μm) and five samples taken over 2.5 m^2 were pooled into a single composite sample following the semi-quantitative procedure of Stark *et al.* (2001). Organisms were collected by stirring and disturbing the substrate by kicking for about 5 min to a depth of several inches to dislodge burrowing macro invertebrates ahead of the net per square meter (Hoffsten and Malmqvist, 2000; Ilmonen and Paasivirta, 2005). Samples were also obtained from the same locations by brushing organisms off the cobbles and rocks, following standard methods of Borror *et al.* (1976) and APHA (1998). The organisms were sorted out and preserved in 4% formalin and 70% alcohol depending upon the type of organisms to be preserved. The soft-bodied organisms were preserved in 70% alcohol while the shelled organisms like molluscs in 4% formalin (Borror *et al*., 1976). Identifications were made to the lowest taxonomic level possible, using keys by Edmondson (1959), Borror *et al.* (1976), Pennak (1978), McCafferty (1981), Ward (1992), Engblom and Lingdell (1999), Winterbourn *et al.* (2000), Yildiz and Balik (2005) and Rossetti *et al.* (2006). The parameters like water temperature, pH and conductivity (APHA, 1998) were measured with digital thermometer, pH metre and conductivity metre, respectively while dissolved oxygen (APHA, 1998; Wetzel and Likens, 1979) was estimated by Winkler's titration method. The parameters like chloride (Argentimeteric), alkalinity (Titrimetric) and hardness (EDTA titrimetrc method) were measured by tittrimetry methods while ammonical nitrogen (Phenate method), nitrate (Sodium salicylate), phosphorus (Ascorbic acid)-(APHA, 1998; Wetzel and Likens, 1979). Statistical analysis was carried out with the help of SPSS software.

Study area and sites: The high altitude valley of Kashmir is an ovoid basin with a nearly flat floor of around 4920 km^2 and is existing between the lesser and greater Himalayas. The vale of Kashmir with tectonic origin is 135 km long and 45 km broad at its middle, lying as an oval bowl between the Zanaskar range to the North and Pir Panjal range to the South. Most of the valley lies at an elevation of just over 1500 m, though its floor rises steadily from northwest to southwest (Wadia, 1966). The valley of Kashmir being surrounded by Himalayan ranges resembles the medditraean type being characterised by a rainfall occurring throughout the year except 2-3 dry periods in summer and autumn. The study area is only accessible for 5-6 months as the national highway which connects Srinagar with the Ladakh region is open for only few months which restrict the continuous sampling because of harsh climatic conditions.

Geology: Kashmir valley one of the many NW-SE oriented depressions of regional dimensions of Himalayan mountain systems is an intermontane valley bounded by four major ranges (Pir Panjal range, Saribal range, Great Himalayan range and Qazinag range).The valley itself occupies the core of a slightly basinal synclinorium where Triassic rocks are surrounded by Paleozoic series and are overlain by Pleistocene and recent sediments. The limestone is by no means pure and contains from 15-90% dolomite with the higher values being more spread. It is generally a very fine carbonate mosaic with small proportions of fossil fragments and mainly Ferruginous insoluble grains. The Pleistocene beds form the karewa series and alluvial plains comprising mainly fine lacustrine sandstones. In between the limestone ridges and karewa terraces are embedded a thick bed of alluvium mainly of coarse gravel and boulders. Due to diversified geological formations, lithological variations, tectonic complexity etc the valley is usually characterised by soft rocks (Karewas and alluvium) and hard rock (Panjal traps and Triassic limestones).

River Sindh locally known as SENDH originates from the Panjtarni glacial fields at an altitude of 4,250 m (a.s.l) at the base of Saskut, a peak (4,693 m a.s.l) in the Ogput Range running parallel to the North-West to South-East. It has a catchment area of 1,556 km^2 which extends between the geographical co-ordinates of 34° 07' 40" to 34° 27' 46" N latitude and 74° 40' 37" to 75° 35' 15" E longitude. There is abundant Triassic limy shale and slaty limestones in the headwater region of the Sindh valley, while as in the middle granite and sandstone replace them as a dominant rock type (De Terra and Paterson, 1939).

After its origin from Panjtarni glacial fields at an altitude of 4,250 m (a.s.l) at the base of Saskut, a peak 4,693 m (a.s.l). River Sindh drops steeply north westward to reach the main strike valley. Gathering momentum, the river runs towards Sonamarg between steeply towering mountain areas, over a boulder stream bed, emerging into the pleasant upland serenity of the Sonamarg, as if to rest before it plunges roaring headlong torrent sharply to the Southwest through the Gagangir gorge, 4000 ft (1,230 m) deep. Four study (Fig. 1) sites were selected for studying

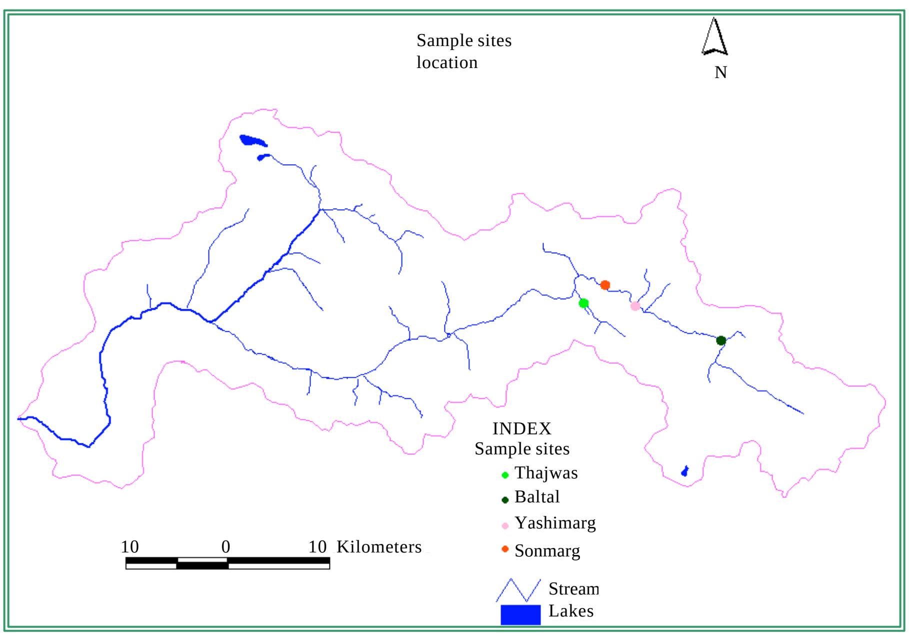

Fig. 1: Map of study area showing position of sampling sites

the ecological distribution of Macroinvertebrates in the mainstream channel of River Sindh and one site was selected from the tributary of Sindh namely, Baltal (site-I), Yashmarg (site II), Sonamarg (site III) and Thajwas Grar (site-IV).

Site-I: Baltal is located 14 km upstream from Sonamarg, lies between geographical co-ordinates of 34° 15' 23" N latitude and 75° 24' 29" E longitude and at an altitude 2,850 m (a.s.l). Being located at the Zoji La pass, it has a sacred cave in the upper reaches dedicated to Lord Shiva. This site is surrounded by rocky barren area. The bottom texture at this sampling site was mixture of cobble, gravel and pebbles (Table 1).

Site-II: Yashmarg is famous picnic spot located near Sonamarg, known for its pastures, ponies and firs. It lies between geographical co-ordinates 34° 17' N and 75° 19' E and at an altitude of 2,712 m (a.s.l). The bottom texture at this site was sandy with cobble (Table 1).

Site-III: Sonamarg is located 14km downstream of Baltal, at an altitude 2,705 m (a.s.l) within geographical co-ordinates of 34° 18' N and 75° 15' E. The bottom texture at this was muddy and sandy with pebbles (Table 1).

Site-IV: Thajwas Grar is located 3 km away from Sonamarg. It lies between geographical co-ordinates, 34° 17' N latitude and 75° 12' E longitude and at an altitude, of 2,617 m (a.s.l). Thajwas Grar is known for the glaciers, the miniature plateaus, snowfields, pines and islets. The bottom texture at the study site was dominated by gravel, pebbles, sand and leaf litter (Table 1).

Table 1: Mean density of various groups of benthic fauna at different sites in the Sindh River System from July-2009 to December 2009

Group/Taxa	Sites	July	September	October	December	Mean	SD (±)
Annelida							
Erpobdella octuculata	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	2	0	1	0	0.8	1.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	n.r	0	0	n.r	0.0	0.0
Total	*Annelida*	2	0	1	0	0.8	1.0
Mollusca							
Corbicula sp.	Baltal	n.r	4	0	n.r	2.0	2.8
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	2	1	2	n.r	1.7	0.6
Lymnae sp.	Baltal	n.r	2	1	n.r	1.5	0.7
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	2	0	0	n.r	0.7	1.2
Radix ovata	Baltal	n.r	5	6	n.r	5.5	0.7
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	1	2	0	n.r	1.0	1.0
Total	*Mollusca*	5	14	9	0	7.0	5.9
Arthropoda							
Atherix sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	3	0	0.8	1.5
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	0	0	0	n.r	0.0	0.0
Baetis rhodani	Baltal	n.r	42	9	n.r	25.5	23.3
	Yashmarg	11	6	7	1	6.3	4.1
	Sonamarg	5	12	3	0	5.0	5.1
	Thajwas grar	5	7	8	n.r	6.7	1.5
Baetiella sp.	Baltal	n.r	4	1	n.r	2.5	2.1
	Yashmarg	2	5	4	1	3.0	1.8
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	2	29	0	n.r	10.3	16.2
Bezzia sp.	Baltal	n.r	1	0	n.r	0.5	0.7
	Yashmarg	0	1	0	0	0.3	0.5
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	0	0	0	n.r	0.0	0.0
Chironomus sp.	Baltal	n.r	3	0	n.r	1.5	2.1
	Yashmarg	4	26	1	0	7.8	12.3
	Sonamarg	0	2	0	0	0.5	1.0
	Thajwas grar	0	1	0	n.r	0.3	0.6
Clinocera sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	0	3	0.8	1.5
	Sonamarg	0	0	4	0	1.0	2.0
	Thajwas grar	0	0	1	n.r	0.3	0.6

Table 1: Continued

Group/Taxa	Sites	July	September	October	December	Mean	SD (±)
Cricotopus sp.	Baltal	n.r	0	2	n.r	1.0	1.4
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	19	12	0	1	8.0	9.1
	Thajwas grar	0	1	0	n.r	0.3	0.6
Capnia vernalis	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	0	1	0.3	0.5
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	0	0	0	n.r	0.0	0.0
Culex sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	1	0	0.3	0.5
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	0	0	0	n.r	0.0	0.0
Diamesinae sp.	Baltal	n.r	8	1	n.r	4.5	4.9
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	1	1	1	0.8	0.5
	Thajwas grar	8	2	5	n.r	5.0	3.0
Dytiscus sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	1	3	0	1.0	1.4
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	0	0	0	n.r	0.0	0.0
Ecdyonurus sp.	Baltal	n.r	0	7	n.r	3.5	4.9
	Yashmarg	0	4	7	0	2.8	3.4
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	0	0	2	n.r	0.7	1.2
Epeorus sp.	Baltal	n.r	0	10	n.r	5.0	7.1
	Yashmarg	0	0	5	0	1.3	2.5
	Sonamarg	4	1	0	0	1.3	1.9
	Thajwas grar	0	0	2	n.r	0.7	1.2
Ephemerella sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	2	3	0	n.r	1.7	1.5
Hexatoma sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	2	3	1	n.r	2.0	1.0
Hydropsyche sp.	Baltal	n.r	3	2	n.r	2.5	0.7
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	2	1	3	n.r	2.0	1.0
Limoniinae sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	1	2	0	n.r	1.0	1.0
Limnephilus sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	4	0	0	1.0	2.0
	Thajwas grar	3	4	2	n.r	3.0	1.0
Nigrobaetis gracilis	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	2	3	0	4	2.3	1.7
	Sonamarg	0	6	0	0	1.5	3.0
	Thajwas grar	19	0	28	n.r	15.7	14.3
Perlodidae sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	0	0	2	n.r	0.7	1.2
Rhithrogena sp.	Baltal	n.r	0	2	n.r	1.0	1.4
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	0	0	0	n.r	0.0	0.0
R. lobifera	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	6	5	2.8	3.2
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	0	0	0	n.r	0.0	0.0

Table 1: Continued

Group/Taxa	Sites	July	September	October	December	Mean	SD (±)
Rhyacophila obscura	Baltal	n.r	0	1	n.r	0.5	0.7
	Yashmarg	0	1	2	0	0.8	1.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	0	0	0	n.r	0.0	0.0
R. yamanakensis	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	0	4	0	1.0	2.0
	Thajwas grar	0	2	0	n.r	0.7	1.2
Simulium sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	2	2	0	1.0	1.2
	Sonamarg	1	3	1	0	1.3	1.3
	Thajwas grar	0	1	1	n.r	0.7	0.6
Stenopsychae sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	2	0	0.5	1.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	0	0	0	n.r	0.0	0.0
Tabanus sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	1	0	0	0.3	0.5
	Thajwas grar	0	0	0	n.r	0.0	0.0
Telmatoscopns sp.	Baltal	n.r	0	0	n.r	0.0	0.0
	Yashmarg	0	0	0	0	0.0	0.0
	Sonamarg	0	0	0	0	0.0	0.0
	Thajwas grar	1	0	29	n.r	10.0	16.5
Tipula sp.	Baltal	n.r	0	2	n.r	1.0	1.4
	Yashmarg	0	2	1	1	1.0	0.8
	Sonamarg	2	0	1	0	0.8	1.0
	Thajwas grar	0	0	0	n.r	0.0	0.0
Total	Arthropoda	95	210	179	18	125.5	86.6
Total	A +M+A	102	224	189	18	133.3	92.4

n.r = Not recorded

RESULTS

Four sites were selected that represented the extreme geographic and hydrologic conditions within the area (Fig. 1). Sites depicted from nearly pristine conditions to very moderate to high tourist influenced destination with variations in steep, substrate, flow, allochthonous matter. Gernal chrateristics of four study sites are shown in Table 2.

Table 2: General characteristics of four study sites

Site	Code	Altitude (a.m.s.l)	Latitude	Longitude	Substrate type
Baltal	I	2,850 m	34°15'N	75° 24' E	Cobble, Gravel, Pebbles
Yashmarg	II	2,712 m	34°17'N	75° 19' E	Cobble, Sand
Sonamarg	III	2,705 m	34°18'N	75° 15' E	Mud, Sand and Pebbles
ThajwasGrar	IV	2,617 m	34°17'N	75° 12' E	gravel, Pebbles, Sand and leaf litter

The benthic invertebrate fauna exhibited diversity in species composition and abundance across the study sites (Table 1). In all 33 taxa of Macroinvertebrates, insects as well as non-insects were recorded from four sampling sites belonging to Mollusca-3 (Gastropoda-2 and Bivalvia-1), Annelida-1 and Arthropoda-29 (Insecta-29). Thus, benthos was comprised of 29 insect and 4 non-insect forms. The non-insect community was comprised of only 3 species of Mollusca and 1 Annelida. Among the stream invertebrates, the three most common species found at all the four sites during the period of study included *Baetis rhodani, Epeorus* sp., *Chironomus* sp. against the fourteen rare ones (*Erpobdella octoculata, Atherix* sp., *Capnia Vernalis, Dytiscus* sp., *Ephemerella* sp., *Hexatoma* sp., *Limoniinae* sp., *Perlodidae* sp., *Rhithrogena* sp., *Rhithrogena lobifera, Rhyacophila obscuras, Stenopsychae* sp., *Tabanus* sp., and *Telmatoscopus* sp.) found only at one site especially at Yashmarg and Thajwas Grar (Table 1). Certain forms were recorded only from two and three sites out of four signaling towards habitat heterogeneity. Amongst the 33 taxa identified the greatest number of taxa was noted for Site IV (21 taxa), followed by Site-II (18 taxa), site I (17 taxa) and Site-III (12 taxa).

Annelida was represented by only three individuals of a lone species of *Eprobdella octoculata* only restricted to Yashmarg. Phylum Mollusca was represented by a total of three species, namely *Corbicula* sp., *Radix ovata*, *Lymnaea* sp. and was altogether absent at Yashmarg and Sonamarg. The densities of the group were quite low and the mean density of 12±7 ind. m^{-2} oscillating between minimum of 5 ind. m^{-2} in July to a maximum of 14 ind. m^{-2} in September. The maximum number of individuals were observed in the month of September (14 ind. m^{-2}) while as mollusks were altogether absent in the month of December.

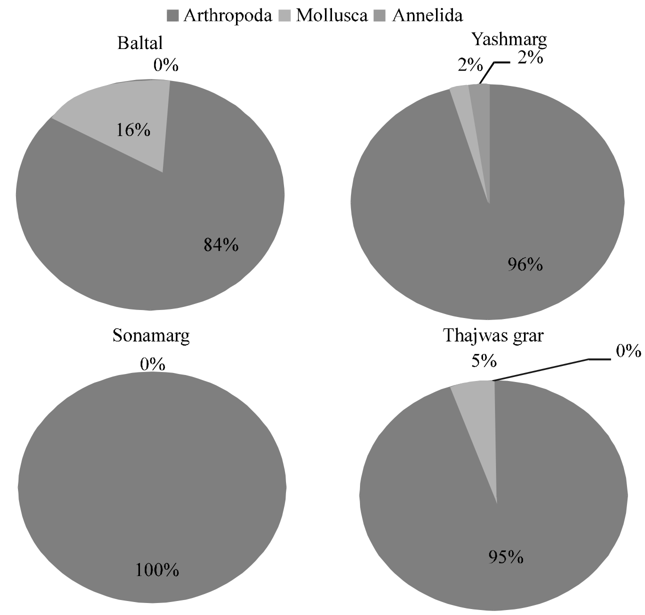

Fig. 2: Relative density (%) of various taxonomic groups of benthic fauna at different sites in the Sindh River System from July 2009 to December 2009

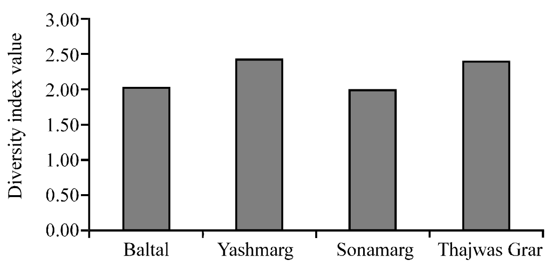

Fig. 3: Shannon weiner diversity indux of macro-invertebrates

The species rich class Insecta is itself an assemblage of different forms belonging to 5 different orders (Ephemeroptera-7, Diptera-13, Trichoptera-6, Plecoptera-2 and Coleoptera-1). The mean density of Insecta fluctuated from 88 ind. m^{-2} at Site-III to 185 ind. m^{-2} at Site-IV, with an overall mean density of 128 ind. m^{-2} from July-2009 to December-2009. *Baetis rhodani* and *Nigrobaetis gracilis* were the dominant insect taxa, recording the maximum density of 51 ind. m^{-2} at Baltal and 47 ind. m^{-2} at Thajwas Grar, respectively from July-2009 to December-2009. Insecta class was dominated by order Diptera followed by Ephemeroptera and Trichoptera at all four sites. While as two taxa belonging to Plecopterans were recorded from only two sites (Yashmarg and Thajwas Grar) and only one taxa of Coleoptera was recorded from Yashmarg. In general, the mean density of benthos was recorded as 136 ind. m^{-2}, with a range of 88 ind. m^{-2} at Site-III-195 ind. m^{-2} at Site-IV from July-2009 to December-2009.

Table 3: Similarity coefficient (Sorenson index) between different selected sites on the basis of Macroinvertebrates

Sites	Yashmarg	Sonamarg	Thajwas grar
Baltal	0.45	0.48	0.68
Yashmarg		0.46	0.41
Sonamarg			0.6

Among the sites, the highest mean density of all the benthic organisms was recorded for site-IV (195 ind. m^{-2}), followed by site-II (133 ind. m^{-2}), site I (127 ind. m^{-2}) and declining to 88 ind. m^{-2} at site-III from July-2009 to December-2009 (Table 1). Annelida was least abundant group with highest relative density of only 2.25% at Yashmarg while being absent at rest of the sites. Mollusca showed highest relative density of 15.51% at Baltal but was completely absent at Sonamarg. In general, Arthropoda (Insecta) depicted the highest relative density at almost all the study sites with 100% contribution at Sonamarg (Fig. 2).

The Shannon Diversity Index incorporates both the taxa richness as well as the evenness of the numbers of individuals in each taxa. Highest values of the Index (Fig. 3) were found at Yashmarg (2.42) followed by Thajwas Grar (2.39), Baltal (2.03) and declining to the lowest at Sonamarg (1.99). Sorensen's Similarity Index was employed to benthic fauna in order to determine the similarity between the different sites in terms of benthic fauna. The higher S orensen's similarity coefficient (Table 3) was found between Baltal/Thajwas Grar (0.68), Sonamarg/Thajwas Grar (0.60). The sites like Baltal/Sonamarg (0.48), Yashmarg/Sonamarg (0.46),

Table 4: Summary statistics of physico-chemical parameters of water at different study sites

Sites	Statistics	Air Temp.	Water temp.	pH	Conductivity	DO*	CO_2*	Alkalinity*	Cl*	Harduess*	Ca*	NH_3**	NO_2**	NO_3**	P**
Baltal	Mean	14	7.25	7.45	243	8.8	13	69.5	5.25	169	28.5	28	9	42	35
	SD	4.24	2.47	0.21	32.53	0.57	4.24	6.36	0.35	43.84	7.07	2.83	1.41	5.66	7.07
	Mini.	11	5.5	7.3	220	8.4	10	65	5	138	23.5	26	8	38	30
	Max	17	9	7.6	266	9.2	16	74	5.5	200	33.5	30	10	46	40
Yashmarg	Mean	12.75	7.00	7.35	312.50	8.48	7.05	75.00	5.88	177.00	39.25	31.00	10.00	43.50	31.75
	SD	7.35	3.34	0.25	128.42	2.62	1.75	33.21	1.11	28.91	14.04	4.69	3.27	9.98	14.22
	Mini.	4	2.5	7.1	210	7	5.2	40	5	140	28.5	26	6	35	18
	Max	20	10	7.7	500	12.4	9	120	7.5	200	59	37	14	57	51
Sonamarg	Mean	12.25	6.50	7.48	315.00	8.60	6.50	75.00	6.75	193.00	35.83	27.75	16.50	70.50	31.50
	SD	7.71	3.70	0.45	123.42	2.10	2.38	36.75	1.19	37.26	6.04	6.85	16.03	7.37	14.18
	Mini.	4	2	7.1	250	7.1	4	30	5.5	150	28.6	20	4	62	22
	Max	20	10	8	500	11.6	9	120	8	228	42.5	36	40	80	52
Thajwas	Mean	14.67	7.83	7.27	193.33	8.33	7.33	50.00	5.83	109.33	19.50	26.33	11.67	26.00	28.33
Grar	SD	6.33	2.02	0.31	86.22	1.30	2.31	26.46	1.01	38.85	4.00	4.04	6.51	10.54	4.73
	Mini.	7.5	5.5	7	100	7	6	20	5.2	76	15.5	22	5	16	23
	Max	19.5	9	7.6	270	9.6	10	70	7	152	23.5	30	18	37	32

* = mg L^{-1}; ** = µg L^{-1}

Baltal/Yashmarg (0.45), Yashmarg/Thajwas Grar (0.39) were fairly similar.

A perusal of the data on physico-chemical characteristics showed that these streams were hard water type with high dissolved oxygen content (Table 4). The ionic composition of the stream waters revealed the predominance of bicarbonate and calcium.

DISCUSSION

This study has shown that physical characteristics of stone microhabitats such as water depth, current velocity, horizontal position, embeddedness and size (surface area) all to a varying degree influenced spatial distribution of invertebrate density and richness in the studied streams. The composition of the fauna of a given stream is at least partially, determined by the streams environmental characteristics such as temperature, altitude and physical stability. The density of aquatic macroinvertebrate species and communities is controlled by a variety of environmental factors such as habitat characteristics (Hynes, 1970; Peeters and Gardeniers, 1998), sediment quality (Chapman and Lewis, 1976), sediment grain size (Tolkamp, 1980) and by biological factors such as competition and predation (Kohler, 1992; MacKay, 1992; Macneil *et al.*, 1999). Negi and Singh (1990) considered stream flow, nature of substratum and organic pollution to generally regulate the species composition and dominance of different taxa in various stretches of rivers.

The presence and absence of certain species, due to the differences in microenvirons, accounts for the differences in total number of species. Sediment type and sediment organic content are known to have pronounced effect on the spatial distribution of benthic organisms (Wu and Richards, 1981; Cyrus and Martin, 1988) with more benthic animals occurring in sandy sediment than in mud (Boltt, 1969; Boltt and Allanson, 1975; Cyrus and Martin, 1988). In the present investigation, the results indicated that substrate composition at Thajwas Grar dominated by gravel, pebble and leaf litter proved primary determinant of the invertebrate community structure recording maximum species diversity and abundance. In fact, the capacity of Macroinvertebrates to exploit areas with optimum food supply might be explained by their abundance (Grimas, 1965). Further high discharge has been shown to increase the invertebrate number of taxa elsewhere (Cantonati *et al.*, 2006) which does not stands true in the present study as the site recording maximum diversity is a small tributary to the River Sindh with comparatively low discharge.

Collier *et al.* (1998) suggested that the higher diversity in a stream ecosystem is directly proportional to the variability in its substrate. Both biotic and biotic factors play a role in shaping the organization of communities and in the distribution and abundance of species .The Main River Sindh (Fig. 1) and its tributary (Sites IV, II, I, III) were dominated by individuals from Arthropoda (Emere and Nasiru, 2007; Arimoro *et al.*, 2007). Group Arthropoda mostly dominated at sites where bottom texture was dominated with hard stones (i.e. Sites I, II and IV). The contribution of other groups was very low. Macroinvertebrates recorded highest diversity at Site-IV, right bank tributary and at Site II. Site I was represented by 17 taxa which are likely to be the result of low temperature regime, low organic input and generally severe habitat conditions at such altitudes. Site-II was represented by 18 taxa, may be because of the composition of substrate, being mainly dominated by cobbles which provide a stable environment for macroinvertebrates. Site-III was represented by only 12 taxa throughout the study period. Such a comparatively low diversity may be because of the

Table 5: Pearsons correlation between different parameters

Parameters	AirTemp	WaterTemp	pH	Cond	DO	CO_2	Alkalinity	Cl	Hardness	Ca	NH_3	NO_2	NO_3	P
Water Temp.	0.974**													
pH	-0.822**	-0.778**												
Cond.	-0.787**	-0.829**	0.574*											
DO	-0.834**	-0.890**	0.538	0.861**										
CO_2	0.237	0.225	-0.136	-0.270	-0.133									
Alkalinity	-0.845**	-0.857**	0.660*	0.909**	0.848**	-0.232								
Cl	0.667*	0.622*	-0.606*	-0.431	-0.625*	-0.056	-0.639*							
Hardness	-0.304	-0.270	0.394	0.291	0.041	0.157	0.139	0.196						
Ca	-0.716**	-0.735**	0.437	0.860**	0.654*	-0.252	0.802**	-0.295	0.510					
NH_3	0.835**	0.828**	-0.757**	-0.531	-0.742**	0.184	-0.702**	0.706**	0.114	-0.304				
NO_2	0.563*	0.488	-0.548	-0.205	-0.338	0.061	-0.544	0.706**	0.108	-0.240	0.610*			
NO_3	0.142	0.074	0.033	0.149	-0.160	-0.191	-0.028	0.615*	0.578*	0.221	0.301	0.477		
P	-0.486	-0.585*	0.266	0.766**	0.830**	-0.132	0.767**	-0.479	-0.233	0.483	-0.490	-0.219	-0.051	
Macro Invert.	0.313	0.422	-0.237	-0.547	-0.314	0.407	-0.375	-0.226	-0.537	-0.663*	0.011	-0.135	-0.682*	-0.236

** = Correlation is significant at the 0.01 level (2-tailed), * = Correlation is significant at the 0.05 level (2-tailed), n = 13

composition of bottom substrate, being mainly dominated by sand and mud. Highest macroinvertebrate diversity was recorded at site-IV (21 taxa), right bank tributary which can be the result of availability of food resources and open canopy cover. Plecopterans were found at sites (S-II and S-IV), may be attributed to the low temperature regime at such altitudes. Only one individual from Coleopterans was recorded from Site-II. Molluscs and Annelida, had their highest representation at sites (S-II and S-IV), characterized by high organic matter in the form cattle faeces and plant litter. Macroinvertebrates recorded highest diversity for Ephemeroptera, Diptera and Trichoptera at almost all sites. At all sites the class Insecta contributed more than 90% of the benthic population and was dominated by Ephemeroptera, Diptera and Trichoptera (Table 1). However, in the present study *Gammarus* sp. was not observed which otherwise is found dominant in the stream of Kashmir valley and its dominance in macro invertebrates has also been reported elsewhere (Shaw and Minshall, 1980; Duran, 2006).

The presence of *Erpobdella octoculata* may be probably due to the 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). In general, oligochaete communities have been observed to thrive well in soft depositing substrates rather than stony beds. 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. The dominance pattern, in terms of density of insects, more precisely by chironomid larvae is related to bottom stream and mud water interface which plays important role in dipteran larval populations as sand and gravel substrate (Jankovic, 1969) supports small chironomid populations because these provide little food and substrate while as large particle size substrate is unsuitable for case construction. Williams (1996) considered Ephemeroptera, Trichoptera, Coleoptera and several families of Diptera (Simuliidae, Tipulidae and Chironomidae) to be particularly well dapted to temporary freshwaters which does not hold true for the present study, thereby indicating that these species seem to be ubiquitous.

Glazier and Gooch (1987) have suggested that proportion of insect taxa/non-insecta taxa be largely determined by water quality, with amphipods dominating hard water. In the present study, however, amphipods were lacking either due to insufficient sampling or extreme cold conditions. Excepting Thajwas Grar which is almost free from effect of Amarnath pilgrimage, rest of the sites relatively display higher concentration of ions and specific conductance. Lacs of yatris are visiting every year to Amarnath cave in this fragile ecosystem thereby putting lot of pressures as there is no sufficient arrangement of toilets for yatris. Additionally waters were found to hold good amount of dissolved oxygen because of cold conditions. Ionic concentration is further indicative of catchment rich in calcium and magnesium. Both calcium (r = -0.663) and nitrate (r= -0.682) were found to have dominant influence on Macroinvertebrate density as is visible from the Pearson's negative correlation coefficient (Table 5).

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