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Diversity pattern of macrozoobenthos and their relation with qualitative characteristics of river Yamuna in Doon valley Uttarakhand

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ABSTRACT

Macrozoobenthos comprises of an important group of aquatic fauna by way of their contribution to ecosystem stability, besides acting as potential bioindicators of trophic status. Being efficient energy converters, they constitute an important link in the aquatic food web. In view of importance of such an aquatic bioresource on one hand and scarcity of information about them, on the other, the present study aimed at working out the species composition and diversity Macrozoobenthos of the River Yamuna in Uttarakhand and their relation to several physico-chemical parameters. The samples were collected from three sampling stations (Kalsi S1, Dakpathar S2 and Asan Lake S3) from August 2011 to March 2012. The data collected on various physico-chemical parameters and benthic fauna showed slight site-specific fluctuations. The present study showed that the temperature, water velocity, turbidity and dissolved oxygen and nature and size of the bottom substrates do play a major role in determining the macro-invertebrate diversity of river Yamuna. The benthic fauna was comprised of 27 genera belonging to 7 orders which mostly include *Ephemeroptera*, *Diptera*, *Coleoptera*, *Hemiptera, Plecoptera, Odonata and Trichoptera.* The total benthic diversity was found highest at S1 (307 ind/m^2) followed by S2 (286.5) and S3 (268.8) respectively. The ecological relevance of the measured physico-chemical parameters was investigated by comparing their degree of correlation with macrozoobenthic density and diversity and it was revealed that the macroinvertebrate showed a fairly good relation with physico-chemical attributes and the values of date obtained reflected the conditions existing in the River Yamuna in terms of the quality and quantity of the biota.

KEYWORDS

Bioindicators;
Correlation;
Macrozoobenthos;
River Yamuna.

INTRODUCTION

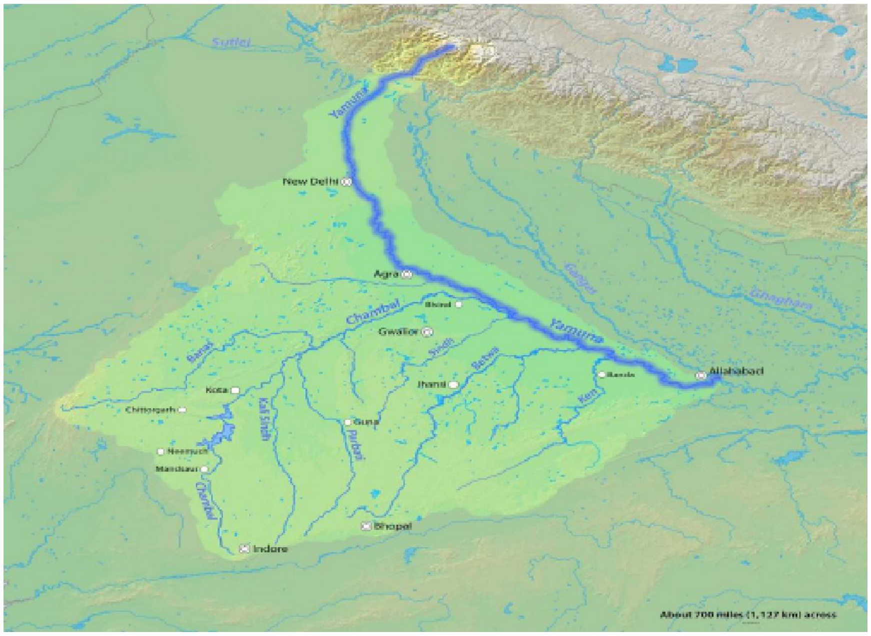
Freshwater is an invaluable as well as a finite natural resource to man's varied activities. Like other water bodies, rivers are specialized habitats of plants and animals; their ecosystems are particularly sensitive to change induced basically by man's activities in water balance, in water chemistry and in habitats. Benthic macro-invertebrates are invertebrates (or animals without a backbone) that live on the bottom of streams during all or part of their life cycle. Benthic macro-invertebrates often go unnoticed because of their size and habitat; they are an extremely important part of river ecosystems, and serve as a link in the food web between decomposing leaves and algae, and fish and other vertebrates[1]. They act as the secondary producers and form a part of food web of aquatic ecosystem. Aquatic macroinvertebrates are important food for fish and waterfowls. They also play an important role in transferring energy from the first trophic level to second trophic level in freshwater ecosystems. Benthic aquatic macro-invertebrates are sensitive indicators of environmental changes in streams because they express long-term changes in water and habitat quality rather than instantaneous conditions[2]. Water being used by every species on earth is over exploited in several ways. It is highly polluted due to the different activities of human beings. The impact of these activities is not only on the quality of water but also on the aquatic biodiversity present in it[3]. The loss of biodiversity in aquatic ecosystems has important implications, diminished resistance and resilience to disturbance, system simplification and loss of ecological integrity[4]. The maintenance of a healthy aquatic ecosystem is dependent on the physico-chemical properties of water and the biological diversity. A considerable work on the aquatic macro-invertebrate has been done by several aquatic biologists[5-14]. Some of the studies have also been made in the different parts of the Indian subcontinent[15-21]. However, no effort has been made so far to study the macro-invertebrates dwelling in the rivers of Doon Valley, India, inspite of the fact that the wide variety of micro-habitats (rock surfaces, plant surfaces, leaf debris, logs, back waters, sandy sediments, crevices in gravel and pebbles) are available in the rivers of Doon Valley to aquatic macro-invertebrates. In understanding the existing relation the present study was conducted to study the diversity pattern of Macrozoobenthos and their relation with qualitative characteristics of River Yamuna in Doon valley Uttarakhand.

MATERIAL AND METHODS

Study area

River Yamuna, the largest tributary of Ganges (Ganga) in northern India originates from the Yamunotri Glacier at a height of 6,387 mtrs., on the south western slopes of Banderpooch peaks in the Mussoorie range of Lower Himalayas, in the Uttarkashi district of Uttarakhand, it travels a total length of 1,376 kilometers (855 mi) and has a drainage system of 366,223 km2, 40.2% of the entire Ganges Basin, before merging with the Ganges at Triveni Sangam, Allahabad, the site for the Kumbha Mela every twelve years. Three sampling sites were selected in the river. Site S1 was chosen from Kalsi, site S2 from the Dakpathar and site S3 from the Asan Lake.

Maps showing Doon valley in Uttarakhand



Map showing river Yamuna

Collection and analysis of samples

The sampling was carried out on monthly basis from August 2011-March 2012. Water samples were collected early in the morning in sterilized sampling bottles and were analysed for twenty important physical and chemical Parameters. Few physico-chemical parameters like Temperature (0C), Transparency (cm), Velocity (m/s), pH, Free CO2 (mg/l), and Dissolved Oxygen (mg/l) were performed on spot and other parameters like Turbidity (JTU), Electric conductivity (μmho/cm), Total Solids (mg/l), TDS (mg/l), TSS (mg/l), Total Alkalinity (mg/l), Total Hardness (mg/l), Calcium (mg/l), Magnesium (mg/l), Chloride (mg/l), BOD (mg/l), COD (mg/l), Phosphate (mg/l), Nitrate (mg/l), Water samples were analysed in accordance with APHA[22], Trivedi and Goel[23], and Khanna and Bhutiani[24]. For collection of macrozoobenthos the mud samples were collected by Ekman's dredge (size 15 cm2) soon after lifting the grab the samples were immediately transferred to an enamel basin and then passed through a series of sieves with addition of water on the spot. The animals were hand picked with the help of forceps and preserved in 70% alcohol for detailed analysis subsequently. The population density was expressed as individuals per square meter. Different taxa were identified with the help of keys given by Ward and Wipple[25-26], Edmondson[27] and Tonapi[28].

Statistical measurement

Statistical analysis like Standard deviation, Karl Pearson's correlation coefficient (r value) and ANOVA was used to find the relation between the between different parameters.

RESULTS AND DISCUSSION

Physico-chemical characteristics of water

Average (Avg±S.D) data of the physico-chemical characteristics of water recorded at the three sampling sites of the river are presented in TABLE 1. The most common physical assessment of water quality is measurement of temperature. Infact no other single factor has so intense influence and direct as well as indirect effect on biota of an ecosystem. During the present study maximum water temperature was recorded at S3 (18.25±1.90 0C) and minimum temperature was found at S1 (17.12±1.88 0C). There was no significant difference between the mean values recorded from three stations. Velocity was fairly good at S1 and S2 throughout the year with the highest value at S2 whereas the lowest velocity was recorded at S3 (0.41±0.09 m/s). Velocity was also found negatively correlated with temperature (r = -0.79, p < 0.05). Transparency was recorded greater at S3 due to more depth in the lake whereas it fluctuates at S1 and S2 due to less depth of river. Transparency showed a positive significant relation with temperature (r =0.96, p > 0.05) Turbidity was found to be maximum at S2 which may be due to high Total solids. However the turbidity was found to be negatively correlated with transparency (r= -0.48, p > 0.01) but positively correlated with velocity (r= 0.99, p> 0.05). Mostly the water is clear and the bottom could be seen through naked eyes throughout the year except in rainy season. Conductivity was recorded highest at S1 (0.183±0.007 μ mho/cm-1) and lowest at S3 (0.134±0.005 μ mho/cm-1). It was also found positively correlated with turbidity (r = 0.90, p > 0.05). The pH of the water was mostly alkaline throughout the course of the study. The pH range is comparatively narrow but falls within the recommended range (6.5 – 9) as suitable for aquatic life[29]. A pH of (8.18±0.12) was recorded at S3 followed by S2 and S1. The higher pH range reflects the alkaline nature of water. pH was also found to be positively correlated with temperature (r =0.94, p> 0.05). The average values of total alkalinity ranges from (182.75±21.21 mg/l) to (145.37±7.61 mg/l). The higher alkalinity values reflect the presence of salts in the catchment area. Total hardness was recorded highest at S1 (94.37±16.29 mg/l) followed by S3 and S2 and this may be attributed to presence of high calcium and magnesium levels. Presence of high calcium and magnesium indicates the marl character of river. Total hardness showed positive relationship with total alkalinity (r= 0.94, p> 0.05) but an inverse correlation with conductivity of the water. Chloride content was found highest throughout the study and was found maximum at S2 (36.16±3.50 mg/l) and minimum at S1 (29.43±4.58 mg/l). D.O values ranged from (11.32±0.83 mg/l) to (10.80±0.59 mg/l) from S1 to S3. The value was highest throughout the year but a slight decrease was recorded in summer due to high temperature though faster rate of organic matter decomposition also contributes to consumption of DO under warmer conditions[30]. Also DO was negatively correlated with temperature (r =-0.64, p < 0.05). Decomposition of organic matter substrate especially in summer contributes not only to higher value of free CO2 but also to depletion in O2 content subsequently leads to built up of free CO2 by the process of an aerobic digestion of organic wastes. Free CO2 was found to be highest at S2 (1.66±0.21 mg/l) followed by S3 and S1. Free CO2 showed positive relation with temperature (r = 0.01, p < 0.01). The concentration of BOD fluctuated from (2.80±0.33 mg/l) to (2.55±0.20 mg/l) from S1 to S3. BOD values increase with increase of temperature in the study. COD, Phosphates and Nitrates also showed slight fluctuations with changing seasons and months. The study of abiotic features indicates that the magnitude of various parameters is partially or wholly associated with the level of river discharge and season in the present study. Water temperature found to be related to elevation and a decline in it at higher elevation may be corroborated with lower ambient temperature. The pH value high in winter and low in summer and monsoon may be due to photosynthetic activity as also recorded by Nautiyal[31] and Singh[32] in other rivers of the Himalaya. The free carbon dioxide is either absent or present in different months, which reflects less load of organic matter in the water. Ganpati[33] attributed that

TABLE 1 : Showing the average values of Physico-chemical parameters of River Yamuna at sampling sites 1, 2 and 3 from August 2011- March 2012

Sampling Sites	Sampling Site 1	Sampling Site 2	Sampling Site 3
Parameters	Avg ± S.D	Avg ± S.D	Avg ± S.D
Temperature °C	17.12±1.88	17.62±2.06	18.25±1.90
Transparencycm	16.46±9.25	26.62±22.36	31.26± 22.59
Velocity m/s	1.84±0.70	2.21±0.57	0.41±0.09
Turbidity JTU	236.31±382.56	252.50±403.29	203.75±324.24
Conductivity $\mu mhocm^{-1}$	0.183±0.007	0.177±0.023	0.134±0.005
TS mg/l	537.5±370.08	575.0±349.49	487.5±274.84
TDS mg/l	250.0±169.03	300.0±160.36	237.5±118.77
TSS mg/l	287.5±223.20	275.0±205.29	250.0±169.03
pH	8.10±0.09	8.16±0.14	8.18±0.12
Total alkalinity mg/l	182.75±21.21	145.37±7.61	170.75±15.49
Total Hardness mg/l	94.37±16.29	85.83±7.98	94.62±8.97
Calcium mg/l	46.18±5.37	37.93±4.377	30.15±4.46
Magnesium mg/l	11.75±2.84	11.69±1.77	15.72±2.83
Chloride mg/l	29.43±4.58	36.16±3.50	31.71±2.81
Free CO_2 mg/l	1.42±0.15	1.66±0.21	1.44±0.18
D.O mg/l	11.32±0.83	10.80±0.59	10.95±0.42
B.O.D mg/l	2.80±0.33	2.66±0.23	2.55±0.20
C.O.D mg/l	4.92±0.60	4.78±0.56	4.94±0.57
Phosphates mg/l	0.534±0.054	0.555±0.092	0.652±0.123
Nitrates mg/l	0.468±0.078	0.516±0.034	1.112±0.238

P = 0. 975, Significant at 0.05 confidence level

TABLE 2 : Showing the Pearson correlation coefficient between the Physico-chemical parameters

	Temperature °C	Transparency cm	Velocity m/s	Turbidity JTU	Conductivity μmhocm^{-1}	T.S mg/l	TDS mg/l	TSS mg/l	pH	Total alkalinity mg/l	Total hardness mg/l	Calcium mg/l	Magnesium mg/l	Chloride mg/l	Free CO_2 mg/l	D.O mg/l	BOD mg/l	COD mg/l	Phosphate mg/l	Nitrate mg/l
Temperature °C	1																			
Transparency Cm	0.96	1																		
Velocity m/s	-0.79	-0.59	1																	
Turbidity JTU	-0.70	-0.48	0.99	1																
Conductivity μ mhocm^{-1}	-0.94	-0.81	0.95	0.90	1															
TS mg/l	-0.62	-0.38	0.97	0.99	0.85	1														
TDS mg/l	-0.25	0.02	0.78	0.86	0.56	0.91	1													
TSS mg/l	-0.99	-0.92	0.86	0.78	0.97	0.71	0.37	1												
pH	0.94	0.99	-0.54	-0.42	-0.77	-0.31	0.09	-0.89	1											
Total Alkalinity mg/l	-0.25	-0.50	-0.38	-0.51	-0.09	-0.60	-0.87	0.12	-0.57	1										
Total Hardness mg/l	0.09	-0.18	-0.67	-0.77	-0.42	-0.83	-0.98	-0.21	-0.25	0.94	1									
Calcium mg/l	-99	-0.98	0.740	0.64	0.90	0.55	0.17	0.97	-0.97	0.33	-0.01	1								
Magnesium mg/l	0.89	0.73	-0.98	-0.95	-0.99	-0.91	-0.66	-0.94	0.68	0.21	0.53	-0.85	1							
Chloride mg/l	0.27	0.52	0.37	0.49	0.07	0.58	0.86	-0.14	0.58	-0.9	-0.93	-0.34	-0.19	1						
Free CO_2 mg/l	0.01	0.28	0.60	0.70	0.32	0.77	0.96	0.11	0.34	-0.97	-0.99	-0.09	-0.44	0.96	1					
D.O mg/l	-0.64	-0.82	0.04	-0.09	0.34	-0.20	-0.57	0.54	-0.86	0.90	0.70	0.70	-0.22	-0.91	-0.77	1				
B.O.D mg/l	-0.99	-0.99	0.70	0.60	0.88	0.51	0.12	0.96	-0.98	0.37	0.04	0.99	-0.82	-0.39	-0.14	0.73	1			
C.O.D mg/l	0.18	-0.09	-0.74	-0.82	-0.50	-0.88	-0.99	-0.30	-0.17	0.90	0.99	-0.09	0.60	-0.89	-0.98	0.63	-0.05	1		
Phosphates mg/l	0.96	0.84	-0.93	-0.87	-0.99	-0.82	-0.51	-0.98	0.80	0.03	0.37	-0.93	0.98	-0.01	-0.27	-0.39	-0.91	0.45	1	
Nitrates mg/l	0.92	0.78	-0.96	-0.92	-0.99	-0.87	-0.60	-0.96	0.74	0.13	0.46	-0.89	0.99	-0.11	-0.37	-0.30	-0.86	0.54	0.99	1
Sodium mg/l	0.74	0.53	-0.99	-0.99	-0.92	-0.98	-0.83	-0.82	0.47	0.46	0.73	-0.68	0.96	-0.44	-0.66	0.03	-0.65	0.79	0.90	0.94
Potassium mg/l	0.99	0.91	-0.86	-0.79	-0.97	-0.72	-0.38	-0.99	0.88	-0.12	0.22	-0.97	0.94	0.13	-0.12	-0.53	-0.96	0.31	0.98	0.96

the changes in the values of bicarbonates are related with the rate of photosynthetic activity. There is a progressive increase in the total hardness in winter and summer and decrease in monsoon. A wide variation in hardness indicates that water of this channel may not be characterized as permanently hard as also reported by others[34]. The rivers of Indian subcontinent including those draining the Himalaya show seasonal variations[35-37]. A combination of many factors in the fluvial water, such as runoff, erosion, vegetation cover, nitrogenous compounds, fertilizers and domestic wastes including organic matter responsible for variation of the nitrates and phosphates in the river[38]. The maximum amount of solids was recorded during monsoon which indicates poor quality of water in the season[39]. An increase in temperature of water results in decrease of DO and an increase in sediment concentration hampers the photosynthesis and reduces DO level[40]. Torrential nature of river and its gradient resulted in variation of DO from upstream to downstream in the water. An inverse relationship between DO and free carbon dioxide in fresh water bodies reported by Raina[41]. The values of BOD and COD showed variation in months, season and altitude in the water[42]. However the results obtained from the study showed that most of the physico-chemical parameters were within the observed range and were

TABLE 3 : Showing qualitative and quantitative distribution of macrozoobenthos (ind/m^2) in river Yamuna at sampling sites 1, 2 and 3 from August 2011-March 2012

Sampling Sites	Sampling Site 1		Sampling Site 2		Sampling Site 3		Sampling Sites	Sampling Site 1		Sampling Site 2		Sampling Site 3	
Macro Benthos	Avg±	S.D	Avg±	S.D	Avg±	S.D	Macro Benthos	Avg±	S.D	Avg±	S.D	Avg±	S.D
Ephemeroptera							*Hemiptera*						
Ephemera	21.125	12.87	8.5	8.384	15.1	11.27	*Micronecta*	5.38	3.739	15.8	11.42	11.3	7.26
Baetis	17.25	11	14.9	11.51	17.4	12.78	*Heleoceris*	11.5	7.211	10.8	8.067	11	9.13
Caenis	19.125	15.38	12.1	10.58	14.6	10.16	*Gerris*	9.63	7.501	10	7.746	9.38	8.55
Leptophlebia	22.25	13.93	10.5	7.502	10	8.089	Total	26.5	17.9	36.5	26.9	31.6	23.62
Cleon	16.625	9.782	10.5	10.04	8.5	7.709	*Plecoptera*						
Heptagenia	30.625	16.41	16.4	11.04	9.25	7.815	*Perla*	7.25	4.803	12.4	9.841	11.3	9.099
Total	127	77.1	72.9	55.64	74.9	57.07	*Isoperla*	5.0	4.175	14.5	11.22	9.5	7.171
Diptera							*Capnia*	14.1	9.877	10.1	8.132	7.75	7.741
Dixa	12.4	6.739	9.38	8.158	8.75	6.798	Total	26.4	17.57	37	28.28	28.5	23.22
Chironomous	3.13	2.031	1.0	1.195	1.5	1.512	*Odonata*						
Simulium	3.63	2.504	10.6	7.782	9.5	8.435	*Corixa*	12.3	8.049	10	7.672	9	8.018
Antoch	12.9	9.493	10	7.407	10.1	7.791	*Agrion*	1.75	2.375	10.3	10.1	9.63	7.577
Bibiocephala	10.6	6.823	10.8	8.631	10	8.701	*Matrona*	6.13	4.824	8.25	7.517	9.88	7.864
Total	42.6	24.82	41.8	31.06	39.9	30.1	Total	20.1	14.54	28.5	24.59	28.5	22.1
Coleoptera							*Trichoptera*						
Laccobius	9.25	6.409	9.63	8.484	8.38	6.567	*Hydrosyche*	8.13	8.357	8.88	8.026	6.13	5.249
Hydraticus	9.5	7.171	10.6	9.07	8.75	9.208	*Glossoma*	7.63	6.232	8.38	6.163	10	7.597
Hydrophilus	12.9	9.493	12.0	10.13	11.1	9.37	*Hydroptila*	8.75	9.377	10	8.35	10.5	8.124
Dryops	8.25	6.756	10.3	8.697	10.5	8.089	Total	24.5	23.21	27.3	22.26	26.6	20.68
Total	39.9	29.14	42.5	35.25	38.8	30.36							

TABLE 4 : Showing Pearson correlation coefficient between macrozoobenthos and physico-chemical parameters

	Temperatue	Transpareny	Velocity	Turbidity	Conductiviy	TS	TDS	TSS	pH	Total Alkalinity	Total Hardness	Calcium	Magnesium	Chloride	Free CO2	DO	BOD	COD	Phosphate	Nitrate
Ephemeroptera	-0.81	-0.94	0.29	0.16	0.57	0.05	-0.4	0.73	-0.96	0.76	0.51	0.85	-0.46	-0.78	-0.59	0.96	0.88	0.42	-0.61	-0.53
Diptera	-0.99	-0.90	0.88	0.81	0.98	0.74	0.41	0.99	-0.87	0.08	-0.25	0.96	-0.95	-0.10	0.16	0.50	0.95	-0.33	-0.99	-0.97
Coleoptera	-0.35	-0.08	0.85	0.91	0.65	0.95	0.99	0.46	-0.01	-0.82	-0.96	0.27	-0.73	0.80	0.93	-0.49	0.22	-0.94	-0.60	-0.68
Hemiptera	0.45	0.68	0.18	0.32	-0.12	0.42	0.75	-0.34	0.73	-0.98	-0.85	-0.52	-0.001	0.98	0.90	-0.97	-0.57	-0.79	0.17	0.07
Plecoptera	0.12	0.68	0.51	0.62	0.22	0.7	0.93	0.002	0.45	-0.99	-0.98	-0.20	-0.34	0.98	0.99	-0.83	-0.25	-0.95	-0.17	-0.27
Odonata	0.83	0.95	-0.32	-0.2	-0.59	-0.1	0.33	-0.76	0.97	-0.75	-0.48	-0.87	0.48	0.76	0.56	-0.96	-0.90	-0.39	0.63	0.55
Trichoptera	0.67	0.85	-0.09	0.05	-0.38	0.16	0.54	-0.58	0.88	-0.88	-0.68	-0.73	0.26	0.89	0.75	-0.99	-0.77	-0.60	0.43	0.34

found to be within tolerable limits for species richness of macro -vertebrate survival.

Macro-vertebrate diversity of river Yamuna

The qualitative and quantitative data on the macrozoobenthos of River Yamuna are given in TABLE 3. Benthic aquatic insects are sensitive indicators of environmental changes in streams because they express long term changes in water and habitat quality rather than instantaneous conditions[38]. Physico-chemical variables, such as water temperature, dissolved oxygen, discharge, nutrients and substrate, influence community structure and function of aquatic insects[43-44]. The macro-invertebrates dwelling in the river Yamuna were mostly represented by the larvae (immature stages of aquatic insects). These larvae belong to the orders of Ephemeroptera, Plecoptera, Hemiptera, Coleoptera, Trichoptera, Diptera and Odonata. Analysis of the monthly abundance of macroinvertebrates in the river also revealed that the maximum abundance of macro-invertebrates was recorded at the sampling site S1 and minimum at S3. The sequence of abundance of macro-invertebrates in all the three sites was S1 >S2 >S3 with decreasing altitude. Thus the density of macro-invertebrates was found decreased along the decreasing altitude. Altogether benthic fauna was comprised of 27 genera belonging to 7 orders which mostly include *Ephemeroptera, Diptera, Coleoptera, Hemiptera, Plecoptera, Odonata and Trichoptera*. The total benthic diversity was found highest at S1 (307 ind/m2) followed by S2 (286.5) and S3 (268.8) respectively. The species of macro benthos found during the study were *Ephemera, Baetis, Caenis, Leptophlebia, Cleon, Heptagenia, Dixa, Chironomous, Simulium, Antoch, Bibiocephala, Laccobius, Hydraticus, Hydrophilus, Dryops, Micronecta, Heleoceris, Gerris, Perla, Isoperla, Capnia, Hydrosyche, Glossoma and Hydroptila.* The maximum diversity was recorded to be of Ephemeroptera at all the three sites. The percentage composition of macro-invertebrates contributed by various taxa has revealed that the major contribution was made by Ephemeroptera (53%) followed by Hemiptera (28%), Diptera (24%), Plecoptera (27%), Coleoptera (23%), Trichoptera (23%) and Odonata (22%).

The macro-benthos showed a good and positive relation with most of physico-chemical parameters that were good for the growth and survival of the benthos but also showed an inverse relation with the parameters that does not have any significant effect on the macrozoobenthos. Inspite of the factors, the macro-invertebrate diversity at all the three sites remains fairly high, suggesting that the water quality of the Yamuna is fairly good and supports diverse and well-balanced macroinvertebrate communities in the river Yamuna of the Doon Valley suggesting that the water quality is not much affected. Among all the Macroinvertebrates the diversity of Ephemeroptera was maximum followed by Diptera, Coleoptera, Plecoptera, Hemiptera, Odonata and Tricoptera respectively. From the present study the total diversity recorded in the River Yamuna in Doon Valley was good enough to indicate that the physico-chemical conditions of river and provide a healthier environment for the growth and survival of biological communities, but it does not mean that the river is free from pollution and it is important to monitor it regularly.

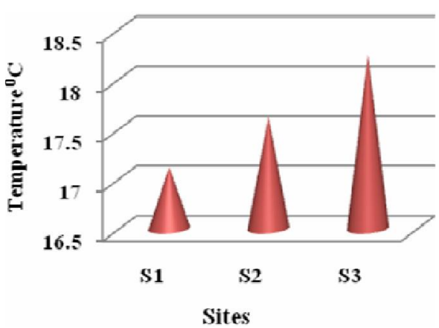


Figure 1

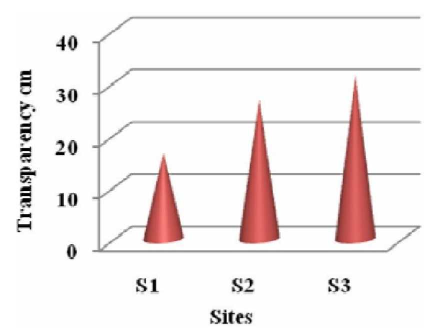
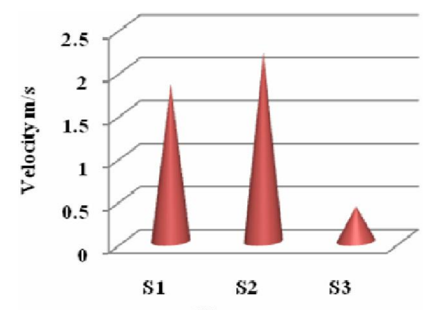


Figure 2



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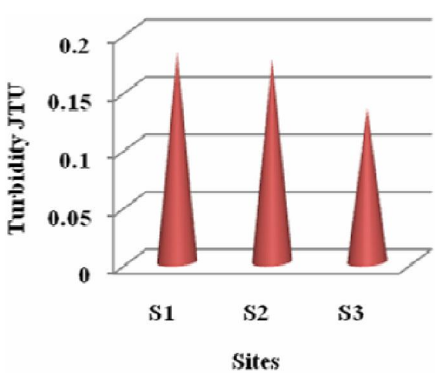

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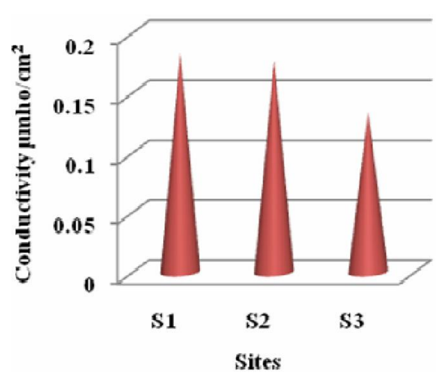

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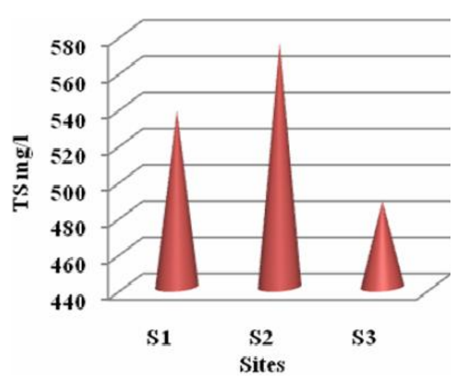

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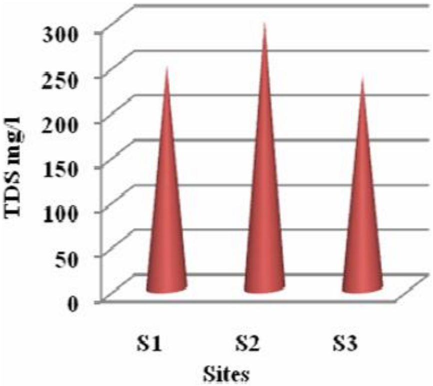

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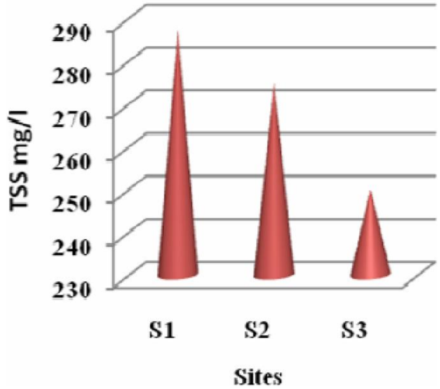

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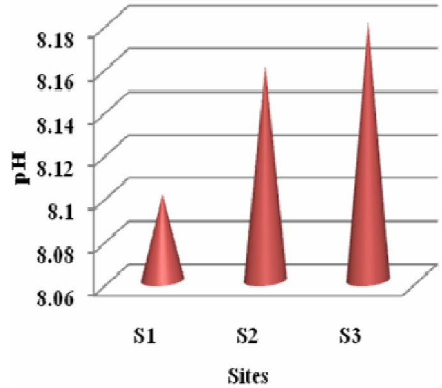

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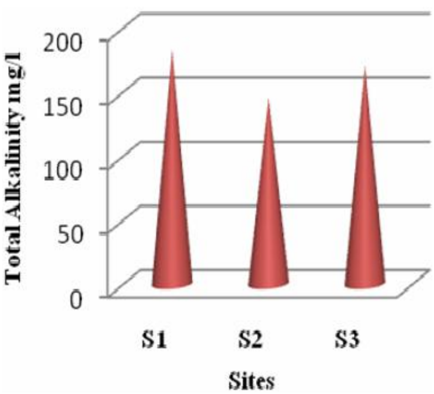

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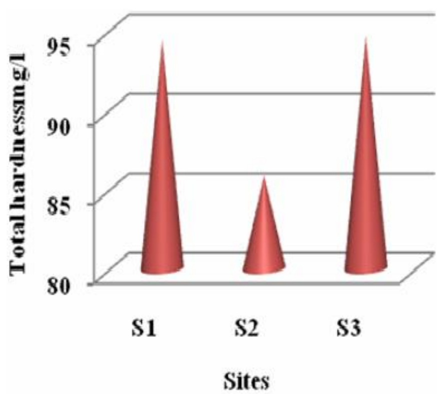

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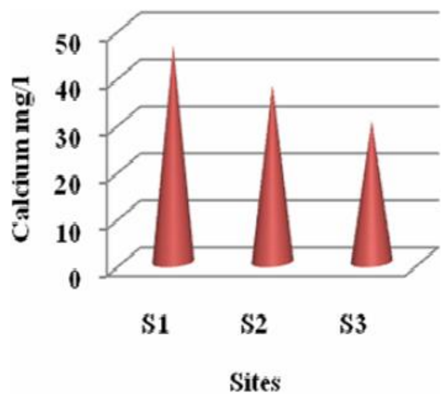

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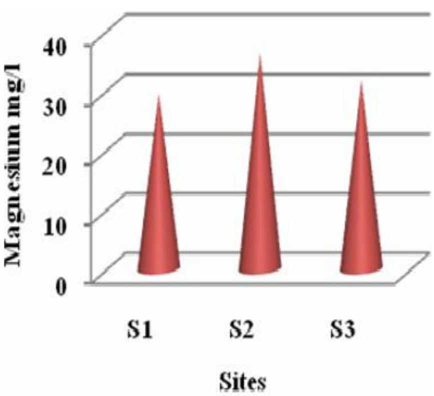

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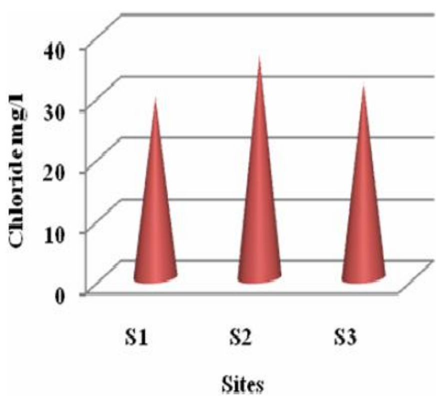

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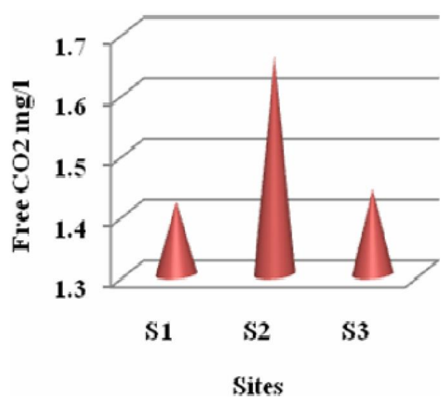

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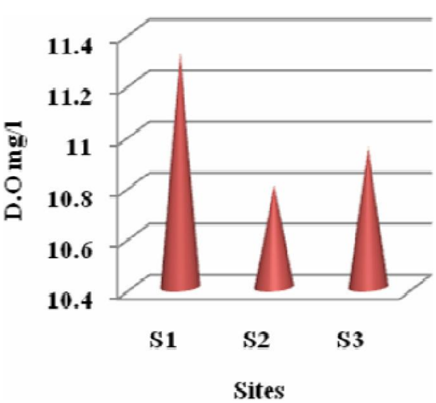

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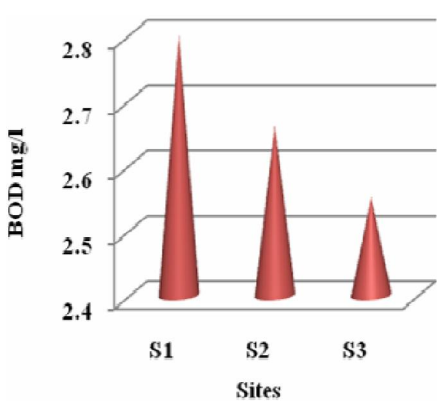

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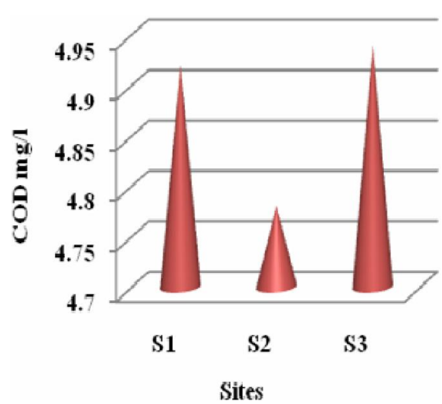

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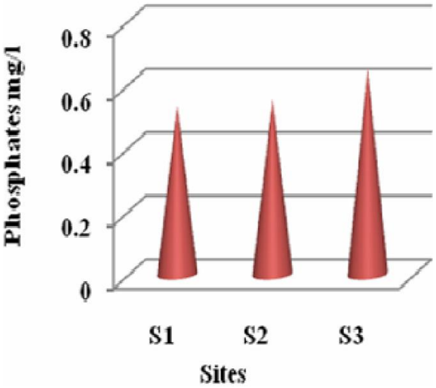

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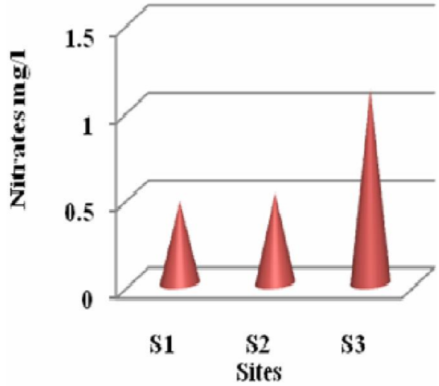

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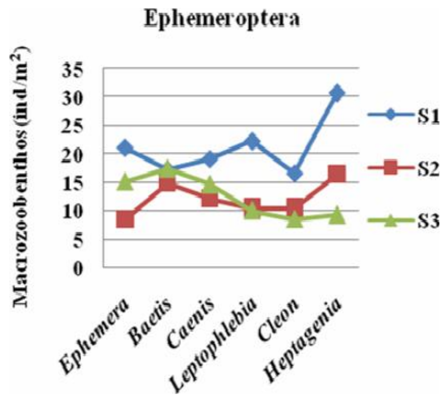

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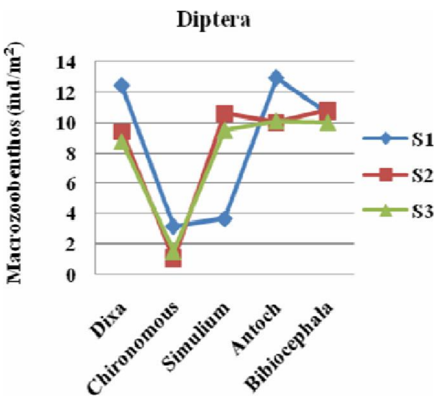

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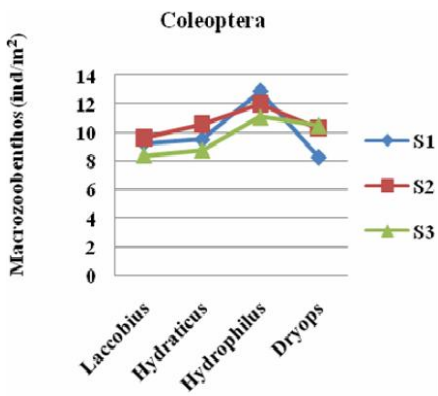

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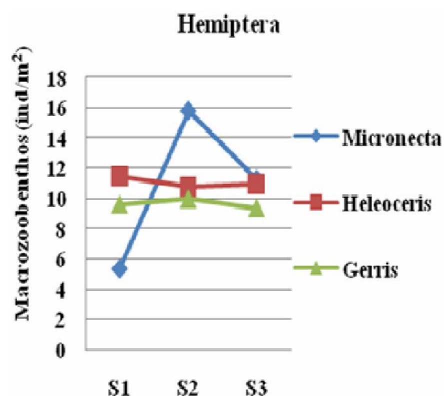

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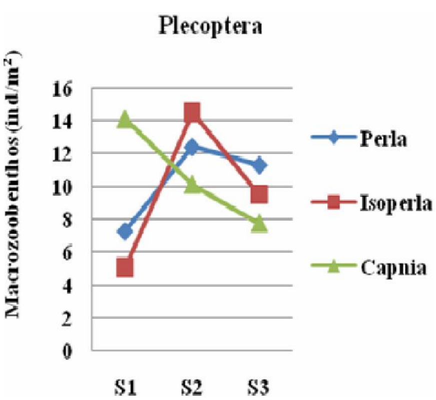

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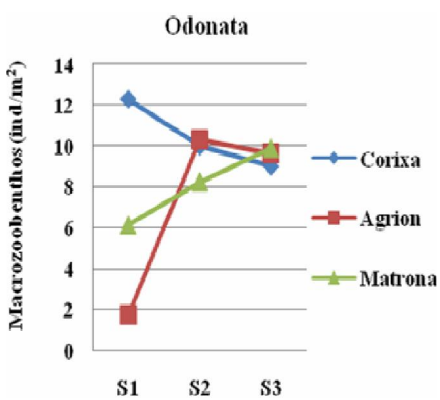

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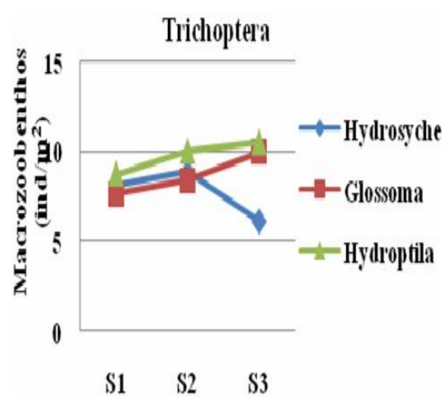

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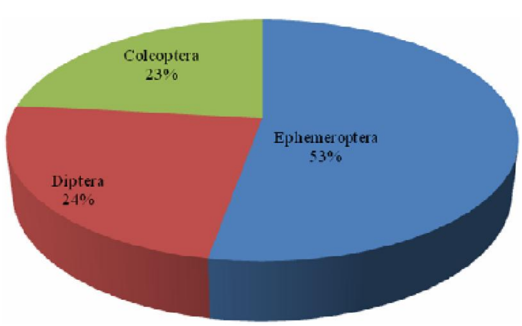

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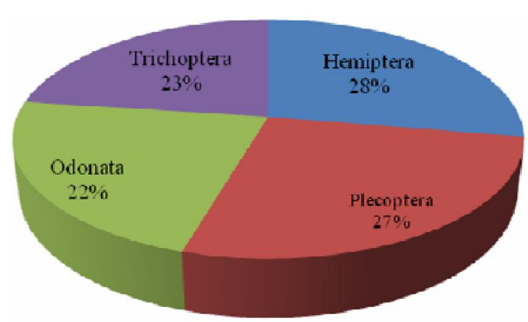

Figure 29

Note: Figures 1-29 showing the graphical representation of the data collected from the three sampling sites (S1, S2 and S3); (1-20, Physico-chemical Parameters; 21-27, Macrozoobenthos density and diversity; 28-29, Percentage of Macrozoobenthos

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