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Variation in species composition and distribution of macrozoobenthos along an altitudinal gradient in Sindh river of Kashmir Himalaya

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Abstract: A limnological survey of the River Sindh, an important tributary of the River Jhelum was carried out at the three stretches (upper stretch, middle stretch and lower stretch) for a period of two years to assess the species composition, abundance, distribution of macrozoobenthos. All the three zones were determined with respect to some environmental variables. The pH fluctuated between 7.2 and 8.7. Water was found to be hard water type with total alkalinity fluctuating from 70 mg/l to 182 mg/l. Dissolved oxygen varied from 8 mg/l to 14 mg/l. The cations concentration followed the order Ca > Mg > Na > K while that of anions followed the trend HCO3->NO3-> PO4->Cl->SO42-. The relationships between abiotic components and macrozoobenthic community were statistically tested and have been discussed in the present contribution. Insects represented by the families Ephemeroptera, Trichoptera and Diptera dominated macrozoobenthos in the upper stretch while in thelower stretch annelids dominated the population.

Key words: River Sindh, River Jhelum, Macrozoobenthos.

Introduction

Macrozoobenthos represents one of the most important groups of animals particularly with respect to food of fishes and also play an important role in cycling of organic material. In addition they are sedentary, therefore body burdens reflects local conditions, allowing detection of a variety of perturbations in a range of aquatic habitats (Rosenberg and Resh, 1993; Turak and Waddell, 2001; Furse et al, 2006).Their distribution, abundance and diversity is affected by inter and intra specific competition as well as tolerance capacity of organisms to changing physico-chemical parameters of water. Because of their extended residency period in specific habitats and presence or absence of particular benthic species in a particular environment these can be used as bio-indicators of specific environment and habitat conditions (Welsiana et al, 2012).

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The important physico-chemical factors which regulated the occurrence and distribution of the river dwelling invertebrates include habitat characteristics, sediment quality, sediment grain size, bottom texture, velocity, temperature, dissolved oxygen, food resources, vegetation and dissolved substances and also by biological factors such as competition and predation. A lot of the work has been done throughout the world on different aspects regarding the macrozoobenthos (Siraj et al, 2007; Koperski, 2010; Welsiana et al, 2012; Chen et al, 2015;Kim et al, 2016; Siraj et al, 2017). Although the studies on the relationships between macrozoobenthos and environmental variables of Kashmir waters have increased in last decades but they are restricted to lentic waters and the lotic waters have received less attention except a few Bhat and Yousuf, 2004; Rashid and Pandit, 2008; Bhat et al., 2014. The present study aims to highlight some of the possible ecological factors that govern the growth and abundance of macrozoobenthos communities at the varied altitudinal gradients in River Sindh.

Material and methods

Study sites: River Sindh is a major tributary of River Jhelum in Kashmir valley arising in the Zojila mountain, flows towards the West and augments itself with the streams coming down from mountains on left and right sides from Holy Amarnath, Kolahai and Panjtarni snowfields. After flowing up to Ganderbal it spreads out near Harran and escapes into the Anchar lake, while the other merge with Jhelum at Shadipur. Sindh is a fast flowing torrential river in its upper and middle reaches, while as in the lower reaches it becomes calm and flows slowly.Three sampling sites were choosen from the river. Site S1 waschoosen in upper stretch, having an altitude of 2730 m a.s.l., hasrocky bottom and the velocity of water was quite high.Site S2, having an altitude of 1678 m a.s.l., waschosen in middle stretch having boulders, gravel and sand.The river is less torrential here as compared to upper stretch. This stretch gets the additional water from Wangat Nallah.Site S3, having an altitude of 1580m a.s.l, was chosen in lower stretch having the bottom containing mostly gravel and sand. In this stretch sand is extracted from the river in huge quantities almost throughout the year. Majority of effluents from the neighbouringareas drain into the river directly here.

Sampling and sample processing: Water samples were collected on monthly basis using Rutner type water sampler. Temperature, transparency, pH and electrical conductivity were measured in the field. In order to determine the water quality, water samples were kept in 5 L polythene cans wrapped with carbon. The samples for Dissolved oxygen were fixed on the spot as per azide modification of Winkler's method. All water samples were stored in insulated cooler containing ice and delivered on the same day to laboratory and all the samples were kept at 4°C until processing and analysis. Free CO_2, total alkalinity, chloride were determined by titrimetric method. Phosphate (Stannous chloride method), Nitrate (Salicylate method), Nitrite (buffer color reagent method) and ammonia (Phenate method) were analyzed with the help of Systronics 106 Spectrophotometer in accordance with CSIR(1975), APHA (1998). Total hardness, Ca and Mg was done by tritrimetric method. COD was determined on the same day of the sampling by Open Reflux method.While as for evaluating BOD, five day incubation time at 20°C is a must and is measured by subtracting DO on fifth day from DO on first day multiplied by appropriate dilution factor. Colour was analysed visually by comparing the water samples with colour standards made of potassiumchloroplatinate (K_2PtCl_6) and cobaltous chloride ($CoCl_2.6H_2O$) in double distilled water (APHA, 1998).

Biodiversity Sampling : For the collection of macrozoobenthos the bottom sediment samples were collected with the help of Serber type sampler as described by Downing and Rigler (1984). The frame of this sampler was pressed against the bottom where it enclosed an area of 1600 cm^2.The material from inside the frame was removed and placed in a sieve for checking any macrozoobenthos. The organisms were sorted out manually using forcep and preserved in formalin, then visually counted (under a stereomicroscope for smaller animals, after staining with Bengal Rose if needed), and identified (to species or other taxonomic level) after mounting on Faure liquid. Identification of the various taxa was done with the help of standard taxonomical works of Edmondson (1958), Pennak (1978) and Engblom and

Table 1: Showing the range (Mean ±S.D) of different physico-chemical parameters at different stretches in River Sindh, Kashmir.

Parameters	Upper stretch	Middle stretch	Lower stretch
Air temperature (°C)	7-24 (15±6)	7 -24 (15± 6)	8- 28 (17±7)
Water temperature (°C)	5-15 (9±4)	4-16 (9±4)	4-21 (11±6)
Transparency (m)	0.1-0.3 (0.17±0.1)	0.2 -0.4 (0.2±0.1)	0.2-0.4 (0.3±0.1)
Velocity	158-202 (215±5)	135-163 (174±12)	85-107 (125±8)
Depth (m)	0.1-0.7 (0.3±0.2)	0.2-0.7 (0.4±0.2)	0.4-1.7 (1.0±0.5)
pH (units)	7.2-8.7 (8.0±0.4)	7.6-8.6 (8.1±0.3)	7.5-8.7 (8.1±0.4)
Conductivity (µS/cm)	218-372 (298±48)	291-364 (330±37)	277-386 (351±30)
DO (mg/l)	10-13 (11.6±1.2)	8-13 (8±2)	8-14 (10±2)
Free CO2 (mg/l)	2-15 (7.7±4)	2-16 (8.2±4.1)	4-12 (8±3)
Chloride (mg/l)	10-20 (13±3)	10-26 (15±5)	19-29 (24±3)
Total alkalinity (mg/l)	70-143 (105±20)	103-158 (118±19)	104-182 (151±22)
COD (mg/l)	13-31(20±6.7)	14-28 (19±5.5)	30-66 (50±11.8)
BOD (mg/l)	4-8(6±1)	5-8(6±1)	3-9 (6±1)
Total hardness (mg/l)	70-96 (84±8.2)	83-111(94±10)	90-134(110±16.3)
Ca (mg/l)	19-31 (25±3.9)	22-39 (27±4.9)	26-55 (36 ±9.9)
Mg (mg/l)	5-9 (6.4±1.4)	6-10 (7.4±1.5)	7-25 (11±4)
Ammonia (µg/l)	26-62 (49±10)	38-104 (70±17)	36-133 (86±34)
Nitrate (µg/l)	136-207(167±22)	118-163(1426±15)	198-347(276±48)
Nitrite (µg/l)	9-18 (12±2.5)	10-21 (14±3.2)	21-35 (25±4.3)
Orthophosphorus (µg/l)	8-14 (10±1.9)	12-16 (14.6±2.3)	20-34 (27±4.4)
Total Phosphorus (µg/l)	41-70 (56±13)	45-91 (68±15)	74-154 (116±27)
K (mg/l)	1-3 (1.7±0.5)	1-4 (2±0.9)	2-4 (3±0.9)
Na (mg/l)	2-10 (3±1)	3-10(2±1)	4-12(2±1)
Silicate (mg/l)	4-7 (5±1)	2-9 (4±2)	2-7 (4.1±1.8)
Sulphate (mg/l)	2-5 (3.2-1.2)	2-7 (3±1.5)	1-6 (3.3±1.5)

Lingdell (1999). Calculated densities were finally referred to as number of individuals per square metre of sediment surface. Various statistical analysis was also done for the present study.

Results

The range of physico-chemical characteristics of different stretches of Sindh river are presented in Table 1. The air temperature in the river varied from 7°C (Jan and Feb) to 28°C (July) while the water temperature varied from 4°C (Jan and Feb) to 21°C (July). The river showed significant variation in its depth vis-a`-vis the volume of water throughout the year. The maximum depth (high volume) in the river was recorded in the month of July (1.7 m), while the minimum depth (low volume) was recorded during December and January (0.1 m). The average values of transparency in the river at upper stretch, middle stretch and lower stretch were 0.17, 0.2 and 0.3 m respectively. Mean velocity of the water in upper stretch was 215 m/sec, 174cm/sec in middle stretch and 125 cm/sec in lower stretch. Mean pH of the river varied from 7.3 in May to 8.7 in August. The values of conductivity varied from 218 µS/cm to 372 µS/cm in upper stretch, from 291 µS/cm to 364 µS/cm in middle stretch and from 277 µS/cm to 386 µS/cm in lower stretch. The chloride values varied from 10 mg/l in upper and middle stretch to 29 mg/l in lower stretch. The concentration of free CO_2 varied from 2 mg/l in upper stretch to 16 mg/l in middle stretch. Total alkalinity varied from 70 mg/l to 143 mg/l in upper stretch, from 103 mg/l to 158 mg/l in middle stretch and from 104 mg/l to 182 mg/l in lower stretch. Dissolved oxygen concentration varied from 8 mg/l to 14 mg/l in the river. The value of COD varied from 13 mg/l to 31mg/l, 14mg/l to 28 mg/l and 30 mg/l to 66 mg/l and that of BOD values varied from 4 mg/l to 8 mg/l, from5 mg/l to 8 mg/l and from 3 mg/l to 9 mg/l in upper, middle and lower stretch respectively. The average Ammonical-N concentration varied from26 µg/l to 62 µg/l in upper stretch, 38 µg/l to 104 µg/l in middle stretch and from 36 µg/l to 133 µg/l in lower stretch. The average concentration of Nitrate–N varied from 136 µg/ l to 207 µg/ l in upper stretch, 118 µg/l to 163 µg/l in middle stretch and from 198 µg/l to 347 µg/l in lower stretch respectively. The concentration of nitrite-N vary from 9 µg/l to 18 µg/l, 10 µg/l -21 µg/l and from 21 µg/l to 35 μg/l at upper, middle and lower stretch respectively.

Table 2: List of macrozoobenthos recorded from three stretches of Sindh river during study period

Upper stretch	Middle stretch	Lower stretch
Arthopoda **Ephemeroptera** *Baetis* sp. *Ecdyonurus* sp. *Epeorus* sp. *Caenis* sp. *Batiella* sp. **Trichoptera** *Hydropsyche* sp. *Nectopsyche* sp. *Rhyacophila* sp. *Stenopsyche* sp. **Diptera** *Atherix* sp. *Simulium* sp. *Diamessa* sp. **Plectoptera** *Perlida* sp. *Hydrophilus* sp. **Coleoptera** *Elmida* sp. **Hemiptera** *Gerris* sp. **Amphipoda** *Gammarus pulex*	**Arthopoda** **Ephemeroptera** *Baetis* sp. *Ecdyonurus* sp. *Epeorus* sp. **Trichoptera** *Hydropsyche* sp. *Nectopsyche* sp. *Rhyacophila* sp. *Stenopsyche* sp. **Diptera** *Diamessa* sp. *Atherix* sp. *Simulium* sp. **Plectoptera** *Perilida* sp. *Hydrophilus* sp. **Coleoptera** *Elmida* sp. **Hemiptera** *Gerris* sp. **Amphipoda** *Gammarus pulex*	**Arthopoda** **Diptera** *Chironomus* sp. *Chaoborus* sp. *Monodiamessa* larva **Coleoptera** *Hydrophilus* sp. **Hemiptera** *Gerris* sp. **Amphipoda** *Gammarus pulex*
Annelida **Hirudinea** *Erpobdella* sp. *Glossiphonia* sp	**Annelida** **Hirudinea** *Erpobdella* sp.	**Annelida** **Hirudinea** *Erpobdella* sp. *Glossiphonia* sp. **Oligochaeta** *Tubifex tubifex* *Limnodrilus* sp. *Nais* sp. *Branchiura sowerbyi*
		MOLLUSCA **Gastropoda** *Lymnaea auricularia* *L. columella* *L. stagnalis* **Pelecyopoda** *Promenetus* sp. *Planorbula* sp. *Corbicula* sp.

The concentration of ortho phosphorous varied from 8 μg/l to 14 μg/l, from 12 μg/l to 16 μg/l and from 20 μg/l to 34 μg/l while that of total phosphorous varied from 41 μg/l to 70 μg/l, from 45 μg/l to 91 μg/l, from 74 μg/l to 154 μg/l in the three stretches respectively. Total hardness increased downwards with the values ranging from 70 mg/l to 96 mg/l in the upper stretch, 83 mg/l to 111 mg/l in the middle stretch and from 90 mg/l to 134 mg/l in the lower stretch. Calcium, magnesium, sodium and potassium concentrations increased significantly downwards. The concentration of Ca varied from 19 mg/l to 31mg/l, from 22 mg/l to 39 mg/l and from 26 mg/l to 55 mg/l in the three stretches respectively. The concentration of Mg varied from 5 mg/l to 9 mg/l, 6 mg/l to 10 mg/l and 7 mg/l to 25 mg/l respectively at the three stretches. K and Na varied from 1 mg/l to 4 mg/l and 2 mg/l to 12 mg/l at different stretches respectively.

Macrozoobenthos: A total of 32 taxa of macrozoobenthos were recorded from the Sindh river during the present study (Table 2). Out of which 20 belonged to arthopoda, 6 taxa each to Mollusca and Annelida.

Group arthopoda was dominated by insecta in the upper and middle stretch of the river with Ephemeroptera, Trichoptera, Plectoptera, Diptera, Coleopteran, Hemiptera contributing about 75% of the total macrozoobenthos recorded at these two stretches with dominance pattern as shown in fig 2.

In upper and middle stretch from the order Ephemeroptera, *Baetis* sp, *Ecdyonurus* sp mostly occurred in winter and autumn while *Epeorus* sp was present throughout the year. *Caenis* spand *Batiella* sp were recorded only in upper stretch recording less population density. From the Trichoptera,*Hydropsyche, Nectopsyche, Rhyacophila* were recorded throughout the year in upper and middle stretch showing highest population density during late spring and early summer. In the lower stretch

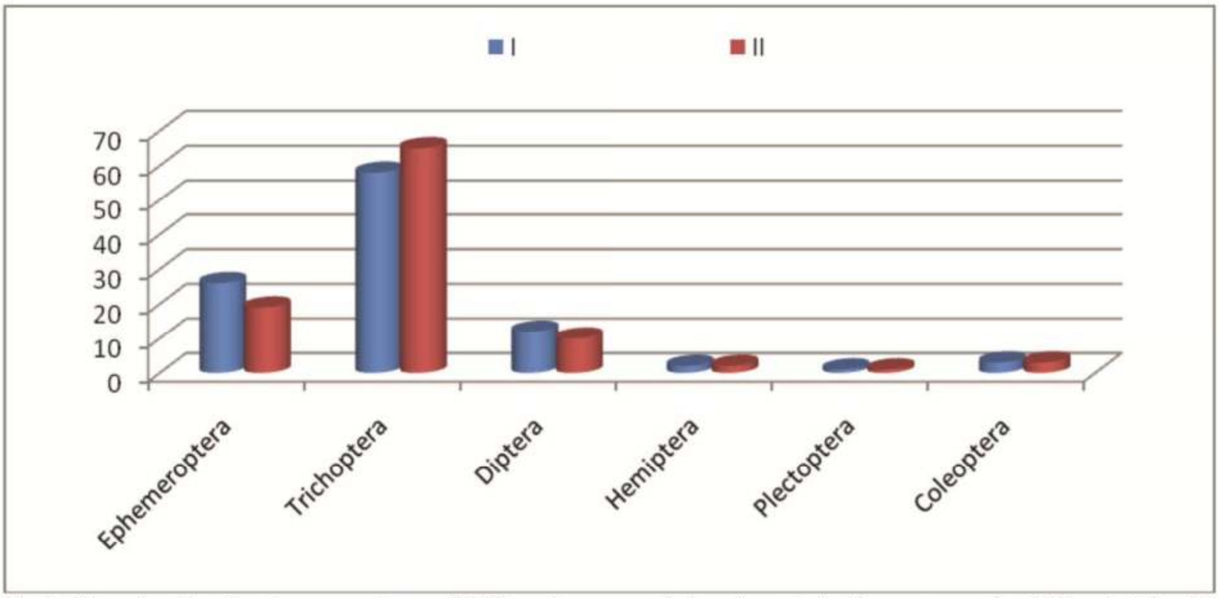

Fig 2: Showing the dominance pattern of different groups of class insecta in the upper and middle stretch of the river.

no taxa belonging to Ephemeroptera and Trichoptera was recorded. From the diptera *Chironomus* sp and *Chaoborus* sp was recorded showing the mean population density of 92 ind/m^2 and 10 ind/m^2. *Gerris* sp from the Hemiptera was recorded at all the three stretches particularly in autumn showing a highest mean population density of 4 ind/m^2, 2 ind/m^2 and 4 ind/m^2 respectively. Crustacean represented by *Gammarus pulex* was almost present throughout the year in all the three stretches of the river showing the mean population density of 39 ind/m^2, 37 ind/m^2 and 104 ind/m^2 respectively.

From the group annelida, *Erpobdella* sp was recorded from all the three stretches showing the mean population density of 62 ind/m^2, 66 ind/m^2 and 34 ind/m^2 respectively. *Glossiphonia* sp was recorded in the upper stretch during autumn only showing mean population density of 5 ind/m^2 while in the lower stretch it showed its presence continuously from spring to autumn with a mean population density of 17 ind/m^2. *Tubifex tubifex*, *Nais* sp, *Limnodrilus* sp, *Branchiura sowerbyi* were recorded only in the lower stretch showing a mean population density of 173 ind/m^2, 3 ind/m^2, 9 ind/m^2 and 26 ind/m^2 respectively. Mollusca were recorded only

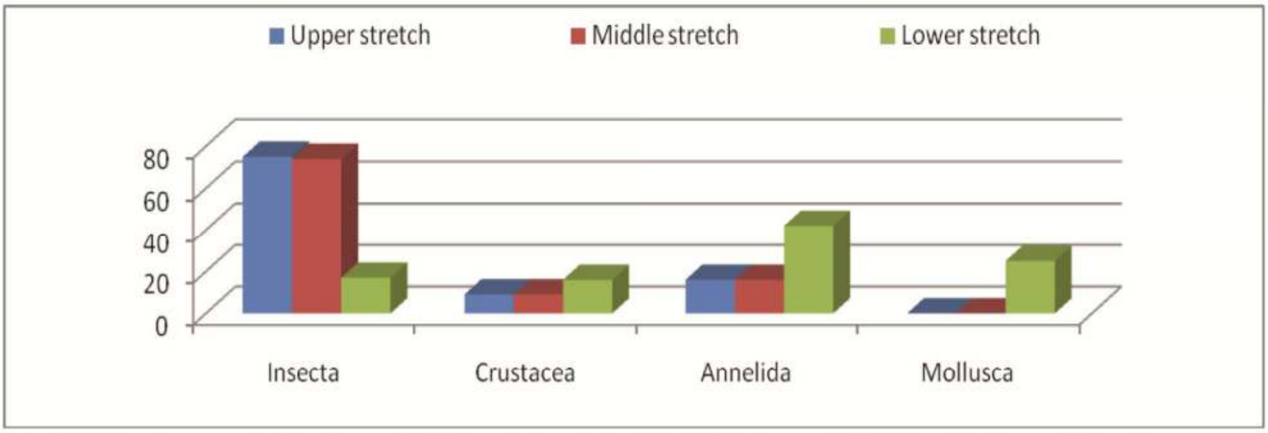

Fig 4: Percentage contribution of different groups to total density at different stretches of the river.

from the lower stretch and were present almost throughout the year. Among the six species recorded here *Lymnaea stagnalis* was the dominant one showing mean population density of 41ind/m^2.Overall percentage contribution of different groups to total density at different stretches is as shown in Fig. 4

Statistical analysis

A significant correlation was found between arthopoda density with pH ($p<0.01$, $r=0.451$), alkalinity ($p<0.01$, $r=0.484$), total hardness ($p<0.05$, $r=0.434$), phosphate ($p<0.01$, $r=-0.851$) and COD ($p<0.05$, $r=-0.491$). Statistically annelida showed positive correlation with pH ($p<0.05$, $r=0.48$) and total alkalinity ($p<0.01$, $r=0.451$) and total hardness ($p<0.01$, $r=0.63$) while Mollusca showed positive correlation with pH ($p<0.05$, $r=0.43$) and alkalinity ($p<0.01$, $r=0.56$).

The Shannon Weiner diversity index (H') of the macrozoobenthos was highest in upper stretch (2.49) followed by middle and lower stretch (Fig 5). At upper stretch the minimum and maximum diversity was recorded in the month of January (0.82) and August (1.97) respectively. For middle stretch it was maximum in July (2.32) and minimum in January (0.77) while for lower stretch it was maximum in July (1.6) and minimum in January (0.90).

Bray Curtis similarity analysis of physico-chemical parameters at three stretches in the river showed three major clusters. Highest percentage similarity in occurrence was found between DO and pH followed by total hardness and total alkalinity. Depth and transparency showed a separate cluster (Fig.6)

Discussion

Macrozoobenthos, a major biological component of the aquatic ecosystems, are valuable indicators of environmental quality because of their short generation times and comparatively stable mode of life (Yanygina, 2017). Several factors such as speed, water depth, temperature, water chemistry, dissolved solids, nature of substratum, food availability, macrophyte density, areas and habitat heterogeneity have been suggested to affect the composition and seasonality of macrozoobenthos. All this has been found true for the benthic fauna in the Sindh river as their density showed variation along the three stretches and months having variation in different parameters. The distribution, abundance and diversity of macrozoobenthos is affected by inter and intraspecific competition as well as tolerance capacity of organisms to

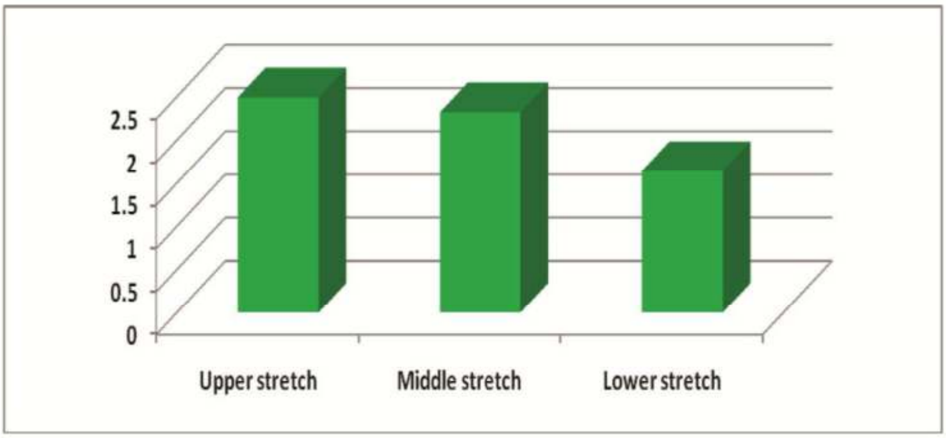

Fig 5: Mean Shannon Diversity Index values at different stretches in Sindh river

changing physico–chemical parameters of water. The important factors which regulate the occurrence and distribution of river dwelling invertebrates include speed of water, temperature and dissolved substances etc. (Barman and Gupta, 2015;Yanygina, 2017). Velocity of water, being an important parameter, plays a significant role in the distribution and abundance of the macrozoobenthos because they rely on it for feeding and respiratory requirements (Ward, 1992; Wetzel, 2001) and also has its influence on the range of temperature difference between air and water, with higher difference in fast flowing area (upstream) and less in slow flowing area (downstream). Dissolved oxygen concentration in the Sindh river was very close to saturation. The dissolved oxygen showed negative correlation with water temperature at all stretches, which was significant at $P<0.01$ level. In upstream the low temperature and high dissolved oxygen of the water has led to the abundance of Insects as compared to downstream which is confirmed by the significant negative correlation of *Hydropsyche, Nectopsyche, Rhyacophila*sp with water temperature ($P<0.01$) and significant positive correlation with DO_2 ($P<0.05$). Absence of Ephemeroptera and Trichoptera in the lower stretch may be attributed to their intolerance to warmer water (Significant at $P<0.005$), fluctuation in water current, type of substratum, increase in nutrient load which is in conformity with the findings of Bhat and Yousuf (2004) while working on several lotic systems of Kashmir. Dominance of *Baetis* sp, *Ecdyonurus* sp, *Batiella* sp, *Hydropsyche* sp, *Nectopsyche* sp, *Rhyacophila*spin upper reaches is related to habitat suitability as these insects show preferences for clean water with rocky and stony substratum whileas *Caenis* sp, *Gammarus fasciatus,Limnodrilus* sp. occur in the run habitats characterized by intermediate flows and sandy silt sediments (Kim, 2016; Kang et al,2017). Their assumptions are supported by the present study as upstream insects formed 97% of the population density mostly dominated by Trichoptera and Ephemeroptera and in downstream due to change in water quality which was statistically found significant. In the present study species like *Chironomus* sp, *Chaoborus* sp showed significant positive correlation with water temperature, conductivity, nitrate and total phosphate phosphorus hence these species occurred in good numbers in downstream. Dominance of *Chironomus* sp, particularly in summer seems to be due to low range of oxygen, rapid larval development, rich organic matter (Szymelfenig et al. 2006; Hassan et al, 2014). Forsyth and Fox (1976) concluded that a high population of chironomids is due to the mud and organic ooze on the substratum.*Chironomus* sp. are basically detritivorous, i.e. able to live in the sediment (Callisto *et al.*, 1996) and in the detritus of plants in the littoral zone of aquatic ecosystems (Lencioni et al,2012). This is also supported by the observation of Bisht and Das (1980,b) that the preferred substrate for web spinning and case building in chironomids is silt and organic ooze.

Various allochthonous and autochthonous factors like leaf material, light availability, catchment characteristics, nutrient load, type of substratum, turbidity, current, velocity and life cycle of the organism have been found by far the most important factors responsible for seasonal variation of benthic fauna in a river.Ephemeroptera and Trichoptera species have been reported to feed mostly on the periphytic algae and mosses, this can be one of the reasons that in upper stream the abundance of such food has favoured their

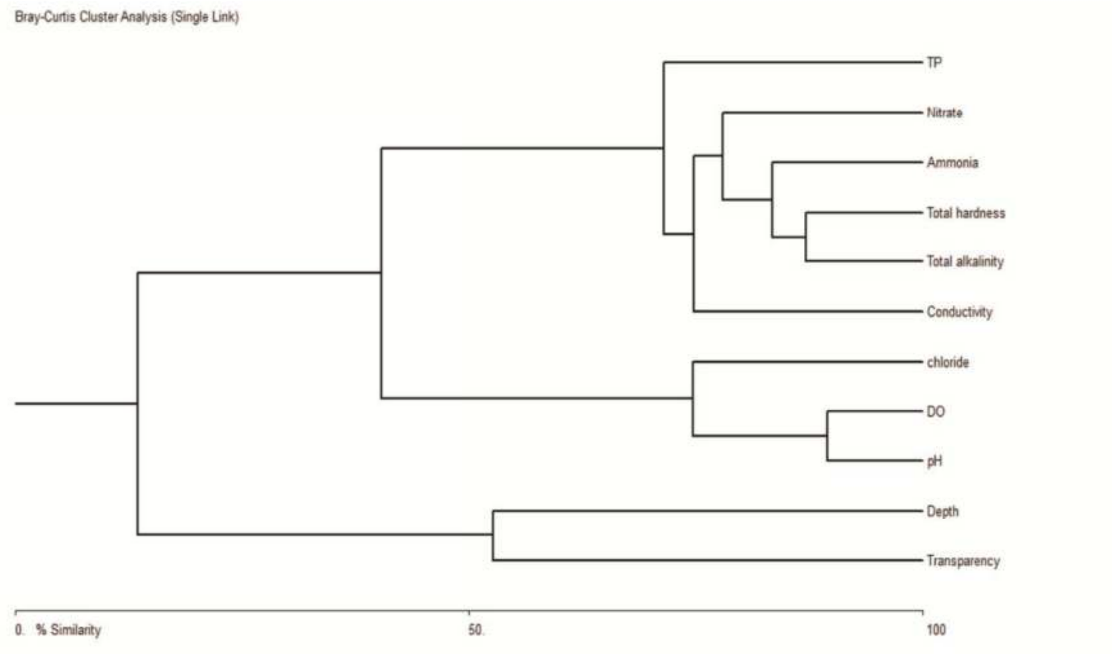

Fig. 6: Bray–Curtis Cluster analysis of physico-chemical parameters at different stretches in Sindh river.

population in all seasons. *Monodiamessa* spwas recorded only in lower stretch and was present only during the spring. Among Trichoptera, *Hydropsyche* sp, *Rhyacophilia* sp, *Nectopsyche* sp were present during the whole year showing highest population density during the autumn months and it has been reported that their abundance is always associated with the case making materials and good water quality. Downstream bank cutting and river degradation has provided a greater amount of sand grains than in the upstream, that is the reason they were present in good numbers although water quality has slightly changed.

Annelida, represented by Hirudinae and Oligochaetes, are considered to be the inhabitants of organically polluted water bodies (Rodriguez et al, 2001) and has also been linked with the effect of water current (Mahdi *et al.*, 2005), disturbance (Sloreid, 1994) organically rich substrate (Bhat and Yousuf, 2004), nature of substratum and inflow of sewage (Koperski,2010). During the present study Oligochaetes were represented by *Tubifex tubifex, Branchiura sowerbyi, Limnodrilus* sp., *Nais* sp.and *Aelosoma* sp., with the first as dominant one. All these species have been identified as good pollution indicators (Nocentini *et al.,* 2001, Rodriguez et al,2001;Mahdi *et al.,* 2005).

Hirudinae was represented by *Glossiphonia* sp. and *Erpobdella* sp recording highest population density in warmer months which is in conformity with the findings of Bhat and Yousuf (2004). Mollusca were represented by *Lymnaea columella, L. auricularia, L. stagnalis* (gastropoda), *Promentus* sp., *Corbicula* sp.and *Planorbula* sp. (Pelecypoida) and all of them showed their presence in downstream with highest population density of *Corbicula* sp. probably due to increased level of organic matter and high values of total hardness as these species require calcium for their shells.

In the Sindh river lowest population density was recorded in spring which seems to be related with the fact that the high and variable water flow together with the high content of suspended particles caused a great disturbance to the bottom sediments which affected the benthic fauna. Only a few species e.g. *Epeorus* sp., *Rhyacophila* sp. were able to maintain certain densities. This is further supported by the fact that highest population densities were recorded in autumn when the current was slow and there was less turbulence and more copious food. It was found that most of the animals appeared to breed during the summer months (as indicated by the presence of large number of young individuals during the summer months) due to which new individuals were recruited into the population during that period producing the peak towards autumn. The pronounced winter season trough in the population could either be due to the mass mortality of macrobenthos due to low water temperature.

Thus from the present study it was concluded that altitudinal variation as well as different physico-chemical parameters at different study sites varies composition of macrozoobenthos fauna. Richness of Ephemeroptera, Trichoptera and Plectoptera was proven to be sensitive to oxygen concentration and so it can be used in biological assessment as a metric of river pollution and as a parameter responding along gradients of land use.

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