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Hydrobiological Study of Aripal Stream in Tral Kashmir Valley

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ABSTRACT

The relationships between the macroinvertebrate communities and environmental attributes are essential to understand the ecological dynamics of stream ecosystems. The present study was carried out to have an insight into the water quality and macroinvertebrate dynamics of Aripal stream in the Tral area of the Kashmir Himalayan region**.** Five sites falling within the Aripal watershed were analyzed for macroinvertebrate communities and water quality during 2018. The study revealed that the Water Quality Index (WQI) of the stream was falling under excellent category and the stream was suitable for drinking and other desired uses. A total of 27 taxa of macroinvertebrate community were obtained and identified belonging to three phyla namely Mollusca, Annelida and Arthropoda which spread over 8 orders and 4 classes from the Aripal during the period of investigation. Arthropoda was found to be the most dominant phylum followed by Annelida and Mollusca. Hindu-Kush Himalayan index (HKH) revealed high to good water quality while as Saprobic index depicted slight to moderate pollution throughout the stream stretch. The non-metric multidimensional scaling (nMDS) depicted that sites based on macroinvertebrate assemblages were significantly different from each other. Distance based redundancy analysis showed that physico-chemical parameters have a prominent influence on the distributional pattern of macroinvertebrate communities. Principal component analysis (PCA) on the basis of water quality parameters revealed maximum variance of 91 % from Principal Component (PC) 1.

Key words: *Stream, Macro invertebrates, Annelida, Water Quality Index, Principal Component Analysis*

INTRODUCTION

Freshwater ecosystems harbor high levels of biodiversity and support important ecosystem services (Luo *et al.,* 2018; Song *et al.,* 2018), yet these ecosystems are currently being altered and stressed by various anthropogenic activities (Flitcroft *et al.,* 2019; Reid and Tippler, 2019). With the onset of Anthropocene, global economy increased 30-folds and the human population exceeding 7.6 billion (Steffen *et al*., 2015), anthropogenic activities have degraded the quality of freshwater and depleted its resources from finite to limited quantity. These anthropogenic activities include industrialization (Kim *et al.,* 2019, Mishra *et al.,* 2020), climate change (Chen, 2011, Carr *et al.,* 2019), urbanization (Zhang *et al.,* 2018) and intensive agriculture (Chen and He, 2014). Globally more than two thirds of river and stream ecosystems are highly impacted by human interference (Giller, 2005). Human interferences that induce drastic changes in riverine ecosystems include altering hydrological conditions (Zhao and Yang, 2009), habitat attributes (Maddock, 1999) and increasing pollution load (Pinto *et al.,* 2013). For the global sustainability of stream water ecosystems, it thus becomes imperative to adopt ecologically sound conservation and management practices (Sofi *et al.,* 2020).

Monitoring water quality is essential not only to assess the impacts of pollution but also to ensure better management of water resources and protecting aquatic life. In terms of evaluating the health status of a river ecosystem, aquatic organisms are used for ecological assessment of stream and river ecosystems in many parts of the world particularly, North America (Barbour *et al.,* 1999; Weigel *et al.,* 2002; Lento *et al.,* 2020), South America (Silveira *et al.,* 2005; Baptista *et al.,* 2007; Moya *et al.,* 2007; Zardo *et al.,* 2020), Europe (Sarremejane *et al.,* 2020), and South Africa (Ollis *et al.,* 2006; Dube, 2020; Elias, 2020). Macroinvertebrates show a wide variation of response to changing environmental conditions and have been widely used to evaluate the water quality and health of aquatic ecosystems (Singh and Sharma 2020). Macroinvertebrates are affected by pollution load, habitat and hydrological conditions, hence are appropriate indicators of ecosystem health (Johnson and Ringler, 2014; Arman *et al.,* 2019). From the past many years, species-based diversity indices such as taxon richness, evenness and relative abundance have been widely used as indicators of anthropogenic disturbances, including urbanization (Mackintosh *et al.,* 2015), pesticide contamination (Berenzen *et al.,* 2005) and habitat fragmentation (Krauss *et al.,* 2010). Macroinvertebrate habitats are relatively fixed, making their communities more vulnerable but equally valuable in assessing water quality (Kimmel and Argent, 2016). Hence macroinvertebrates can be used as bioindicators to obtain valuable information regarding wide range of impact of various anthropogenic pressures and environmental factors.

Himalayas - considered as “water tower for Asia” (Immerzeel *et al.,* 2010), collectively serve 47% of the global populations water demand (Pomeranz, 2013). In Asia, stream and river assessment with benthic invertebrates as indicators is still in its infancy (Stubauer *et al.,* 2010; Ofenbock *et al.,* 2010; Barbour and Paul, 2010). Despite the fact that the Himalayas are home to a remarkable riverine biodiversity in addition to endemic and endangered species, still less attention has been paid towards it by the scientific community (Dudgeon *et al.,* 2006; Li *et al.,* 2012; Sabha *et al.,* 2020). For instance, streams of Indian Himalayans have biodiversity of global importance (Ormerod *et al.,* 1994; Nautiyal *et al.,* 2004), however, studies on benthic macroinvertebrate have been restricted mostly to small patches of streams (Badola and Singh, 1981; Negi and Singh, 1990; Gusain, 1994; Nautiyal *et al.,* 1996; Julka *et al.,* 1999). Similarly, in the Kashmir Himalayas limited scholarly work has been carried with emphasis on the spatio-seasonal structure of benthic macroinvertebrates (Engblom and Lingdell, 1999; Mahdi *et al.,* 2005; Bhat and Pandit, 2006; Rashid and Pandit, 2008; Bhat and Pandit, 2009; Bhat *et al.,* 2011; Habib and Yousuf, 2012; Parey and Saina, 2012; Bhat *et al.,* 2014; Pandher and Chandra, 2019; Sheikh and Parey, 2019; Sabha *et al.,* 2020). To address this research gap, we carried out this work in Aripal stream of Tral sub-division which provides drinking water to about 1,101,96 persons and is a major source of irrigation for agriculture and related activities. The major objectives of this study were 1) Exploration of macroinvertebrate composition and variation through the stream stretch. 2) Exploration of environmental variables influence on the benthic macroinvertebrate composition throughout the stream stretch.

STUDY AREA

Tral town is a sub-district in Pulwama district of Jammu and Kashmir, situated 11 km from NH1 Awantipora. Tral is located at 33.93°N and 75.1°E and has an elevation of 1662 m amsl. The place is having an average area of about 110 km^2. The stream under study is located in Aripal watershed and is the lone source of drinking water and irrigation for horticulture and agriculture purposes for the Tral tehsil. The Aripal stream originates in the northern ridge of greater Himalaya (4000m amsl). The Aripal stream receives its waters from Laam nallah and Khangund spring and finally it meets with river Jhelum near Chursoo Awantipora. A total of five sites namely Site I (Khangund), Site II (Laam), Site III (Batagund), Site IV (Nowdal), Site V (Chursoo) (Fig.1 and Table 1) were selected for the evaluation of stream health utilizing macroinvertebrate composition as a biomonitoring tool.

Table 1. Description of samplings points of Aripal stream

Site	Latitude	Longitude	Elevation	Usage
Site I Khangund	34°01′402″ N	75°04′130″ E	1919 m	Drinking, washing and agricultural
Site II Laam	34°01′468″ N	75°05′675″ E	1994 m	Drinking, washing and agricultural
Site III Batagund	33°57′225″ N	75°05′310″ E	1720 m	Drinking, washing and agricultural
Site IV Naudal	33°55′229″ N	75°04′751″ E	1641 m	Drinking, washing and agricultural
Site V Charsoo	33°53′255″ N	75°01′042″ E	1594 m	Drinking, washing and agricultural

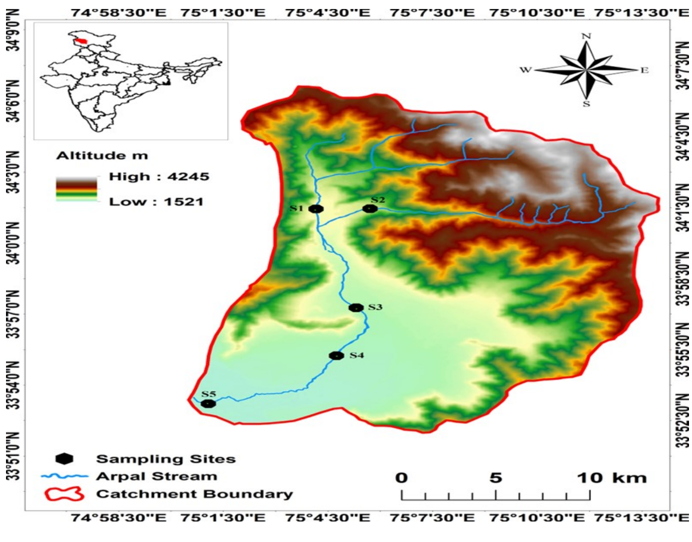

Fig. 1. Geographical representation of different study sites.

MATERIAL AND METHODS

Physico-chemical parameters

Water samples were collected on a monthly basis from July-November 2018 at five sampling points from Aripal stream. A portable GPS (Garmin Montana 650) was used to measure the geographical position of sampling points. Sampling, preservation and transportation of samples to the laboratory was performed as per the standard methods (APHA, 2012). Measurements of water temperature (WT), pH, conductivity (Cond), total dissolved solids (TDS) was carried out with a multi-parameter probe (Eutech PCSTEST35-01x441506) calibrated with standard solutions. Other water quality parameters were analyzed in laboratory following the standard protocols (APHA, 2012). Dissolved oxygen (DO) was determined by Winkler's method, total hardness (TH), calcium hardness (CaH), magnesium hardness (MgH) by EDTA titrimetric method, total alkalinity (TA) by Phenolphthalein method and chloride ion (Cl^-) by Argentometric method. The parameters that were analyzed spectrophotometrically using Motras Scientific, UV Visible Spectrophotometer, include: nitrate nitrogen (NO_3-N) (salicylate method), ammoniacal nitrogen (NH_3-N) (phenate method) and total phosphorus (TP) (stannous chloride method), sulphate (SO_4^{-2}) (turbidimetric method) and total iron (Fe) (phenanthroline method).

Macro invertebrates

Macroinvertebrates were collected with the help of D-net (30 cm wide base and 30 cm long) with 0.5 mm mesh size (Barbour *et al.,* 1999; Ligeiro *et al.,* 2020). The bottom substrate was disturbed for 1 minute by kicking method to dislodge the substrate (Malmqvist and Hoffsten, 2000; Ilmonen and Paasivirta, 2005). The procedure was repeated at different locations within a 15 meter stream reach and covered a variety of habitat types until a total area of 1 m^2 was sampled. Rock pick method was also used for examination of invertebrates in order to cover all the measured area. Preservation of soft bodied invertebrates was carried out using 70% alcohol while for shelled organisms like molluscs 4% formalin was used. Macroinvertebrates were observed under binocular microscope (Magnus MS24 stereoscopic binocular microscope) (x 6 magnification) to the genus level and identified as per the key references (Edmondson, 1959; Pennak, 1978; McCafferty and Provonsha, 1983; Borror *et al.,* 1989; Ward, 1992; Engblom and Lingdell, 1999; Bouchard, 2004; Subramanian and Sivaramakrishnan, 2007). The various biotic and diversity indices were calculated like Shannon-Weiner diversity index, Simpson's Diversity Index (D), Menhinick's Diversity Index, EPT Index, Biological Monitoring Working Party (BMWP), Average Score Per Taxon (ASPT), and HKHbios, Weighted average score per taxon (ASPTw), (Shannon-Weiner, 1949; Simpson, 1949; Menhinick, 1964; Hartmann *et al.,* 2008).

Data analysis

Based on the Bray-Curtis similarity index, ordination of macroinvertebrate community data was carried out with non-metric multidimensional scaling (nMDS). In order to down-weigh the influence of the dominant class, the data was transformed by the fourth-root transformation. The stress value was used to test the depictions according to the nMDS solutions (Clarke and Warwick, 2001). Thus, with no misinterpretation, a stress value of < 0.05 gives an outstanding representation. Physico-chemical variables were analyzed using PCA in order to find out the dominant variables across the study sites with presentations under two PCs. nMDS, PCA and RDA were performed using Primer v 6 (Clarke and Warwick, 2001). ANOVA was carried using SPSS and other graphs were prepared in Origin 8 software.

For computing Water Quality Index (WQI), mean of various physico chemical parameters were used. WHO standards for drinking water quality were considered and WQI was calculated as per the method proposed by Horton (1965).

RESULTS AND DISCUSSION

Physico- chemical parameters

Variations in the value and range of physico-chemical parameters at various sampling points are shown in Figure 2 (a-h). WT ranged from 13ºC (Site II and IV) during November to 26ºC (Site III) in the month of August with an increase downstream due to decrease in altitude (Sheikh *et al.,* 2010), less canopy cover in the riparian zone resulting in warming of water column and decrease in flow velocity (Imevbore *et al.,* 1970). The normal range of pH for surface waters varied from 6.5 to 8.5 (Gbarakoro *et al.,* 2020) and in the present study pH at all the selected sites was found to be on the alkaline side ranging from 7.6 (Site II) to 8.6 (Site IV) without much wider fluctuations throughout the study period. Stream water has the capacity to maintain pH within narrow range due to their buffering capacity (Kamal *et al.,* 2007). Alkaline pH can be due to the increase in buffering substances of carbonates of calcium and magnesium due to prevailing anthropogenic activities in riparian zone. Slightly higher pH in lower sites may be due to sewage discharge from human habitations prevailing within the catchment (Bansal and Khare, 1990).

Values of conductivity fluctuated from 69 µS/cm (Site II) to 439µS/cm (Site V) while TDS ranged from 40mg/l (Site II) to 310mg/l (Site V). TDS followed same trend as that of conductivity with an increase downstream, which may be attributed to the change in temperature (Dubey *et al.,* 2020) and anthropogenic impacts like agricultural activities and human settlements in downstream catchment (Clenaghan *et al.*, 1998; Lenat and Crawford, 1994; Gray, 2004).

DO is considered as a key parameter for the pollution of water (Gbarakoro *et al.,* 2020) and a range of 5-14mg/l is considered suitable for natural waters depending on the turbulence, temperature, salinity and altitude (Dubey *et al.,* 2020). The DO values in the present study ranged from 7.6mg/l to 11.8mg/l. The highest concentration of dissolved oxygen was found in the month of November at all sites because low water temperature has more retention capability of oxygen and there is also less diffusion of oxygen from water to air (Andem *et al.,* 2019). Bicarbonates, carbonates and hydroxides are mainly responsible for alkalinity (Dallas and Day, 2004) and ranged from 28mg/l (Site II) to 170mg/l (Site V) in the stream with an increase towords downstream. However, Site II showed very low concentration of TA as compared to rest of sites. Concentration of Cl^- during the study period fluctuated from 3mg/l (Site III) to 13mg/l (Site IV and V). However the presence of Cl^- ions in the water depends on its source from the catchment loaded with animal wastes, fertilizer inflow, runoff events and sub-surface flow. Value of TH ranged from 62mg/l (Site I) to 178mg/l (Site V) indicating slightly hard nature of the water (Moyle, 1945). CaH ranged from 38mg/l (Site II) to 107mg/l (Site V) while MgH ranged from 22mg/l (Site I) to 75.6mg/l. Increase in hardness may be due to more addition of hardness causing ions (calcium and magnesium) from increased subsurface flow down the gradient (Hussain and Pandit, 2012) and eroded municipal wastes from the catchment (Abubakar *et al.,* 2020).

Values of NH_3-N ranged from 306 µg/l (Site I) to 369µg/l (Site V) and were the second most dominant form of nitrogen after NO_3-N (679µg/l at Site I to 1096µg/l at Site V) across the study sites. A similar progression of nitrogen compounds was reported by Bhat (2003). Concentration of NH_3-N and NO_3-N displayed increased value downstream. TP varied from 220µg/l (Site I) to 494µg/l (Site V) and higher concentration of TP in July and August months is due to the higher suspended planktonic material in water body. Increased concentration of nitrogen and phosphorus downstream may be due to domestic sewage and agriculture runoff in lower reaches (Alam *et al.,* 2007; Mohan *et al.,* 2011; Walter *et al.,* 2016)

SO_4^{-2} during the entire study period varied between 1.05mg/l (Site I) to 3mg/l (Site V). Overall concentration of SO_4^{-2} seems to be very low, however, its presence in the study area may be attributed to dissolution of rock containing sulphate material like gypsum, ($CaSO_4$) (Hem, 1985).Value of Fe fluctuated between 14.5µg/l (Site I) to 236 µg/l (Site V) and showed an increasing trend down the stream with head waters usually showing less concentration. However, higher concentration at site V (252µg/l) may be due to anthropogenic activities.

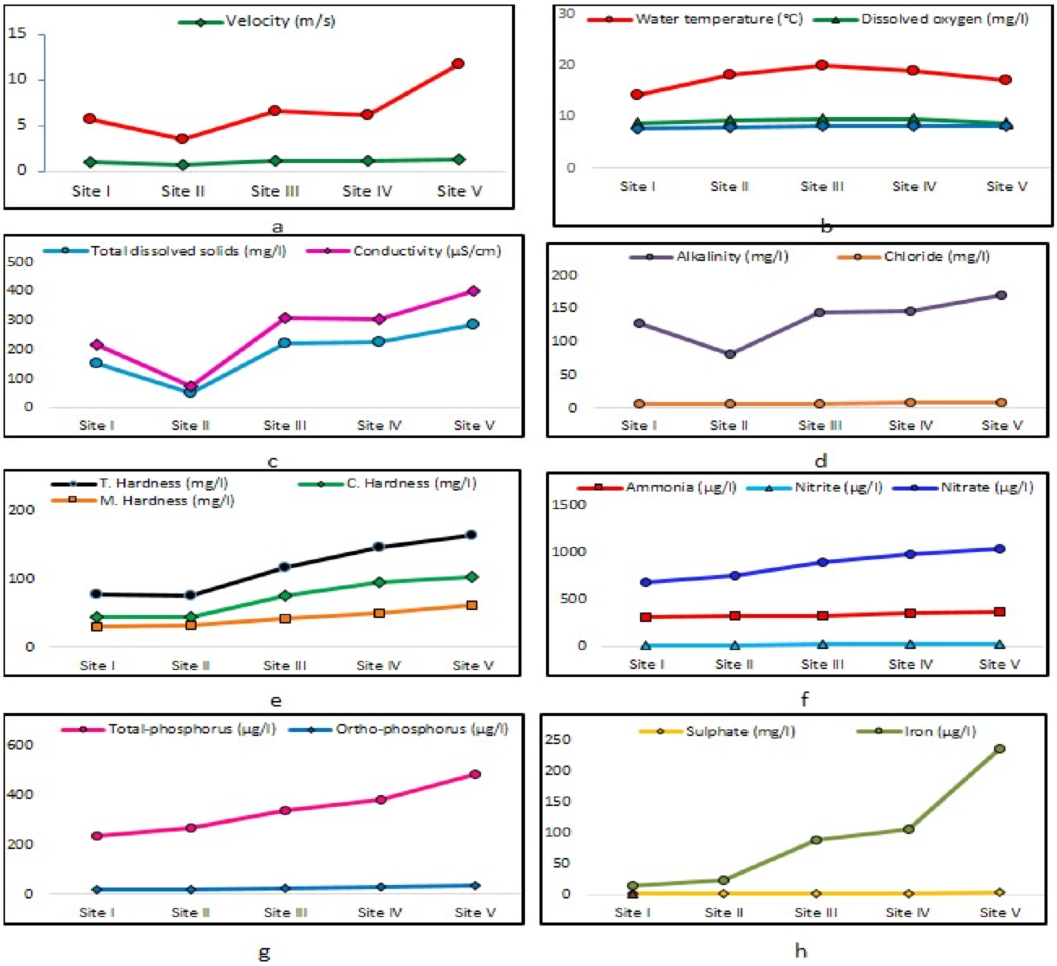

Fig. 2 (a-h). Mean values of various physico chemical parameters of Aripal stream from July to November 2018.

Comparison of physico-chemical parameters with WHO standards for drinking water quality revealed values of all parameters within the prescribed limit. Water Quality Index (WQI) also revealed that the water of the stream fall under excellent category (<50) with all the sites (Site I, 29.94; Site II, 25.16; Site III, 36.94; Site IV, 39 and Site V, 44.5) having a value of WQI between 25.16 to 44.50. Summing up the whole discussion, it was observed that all the stream water is suitable for drinking purpose besides other desired uses.

Macroinvertebrates

The benthic macroinvertebrates presented diversity and abundance across the sampled sites. Macro-invertebrates taxa collected composed of insects as well as non- insects and 27 taxa were recorded from five different study sites. The most dominant group being Arthopoda, which comprised of 25 species followed by Annelida and Mollusca with one species each. Amongst 27 taxa identified, the greatest number of taxa were noted for site II (23 taxa), site III (17 taxa), site IV (13 taxa), site I (6 taxa) and site V (4 taxa) (Table 2).

Table 2. List of macro-invertebrates recorded in Aripal stream from July to November 2018

Phylum	Class	Order	Taxa/genus/family	Authority
Annelida	Hirudinae	Arhynchobdellida	*Erpobedellaoctoculata*	Linnaeus, 1758
Arthropoda	Insecta	Ephemeroptera	*Ecdyonurous* sp.	Eaton, 1868
			Baetisrhodani	Pictet, 1843
			Drunella submontana	Needham, 1905
			Alainites muticus	Linnaeus, 1758
			Nigrobaetisgracilis	Bogoescu and Tabacaru, 1957
			Epeorus sp.	Eaton, 1881
			Caenis sp.	Stephens, 1835
			Baetiella sp.	Ueno, 1931
		Trichoptera	*Hydropsyche*sp.	Curtis, 1835
			Brachycentridae	Ulmer, 1903
			Limnephilus sp.	Linnaeus, 1758
			Rhyacophila sp.	Pictet, 1834
			Glossosoma sp.	Wallengren, 1891
		Coleoptera	*Stenelmis* sp.	Dufour, 1835
			Elmidae sp.	Curtis, 1830
			Staphylinidae	Lameere, 1900
		Diptera	*Diamesinae* sp.	Pagast, 1947
			Tabanus sp.	Linnaeus, 1758
			Bibiocephala sp.	Osten-Sacken, 1874
			Simulium sp.	Latreille, 1802
			Ceratopogonidae sp.	Newman
			Chironomus sp.	Meigen, 1803
		Plecoptera	Perlidae sp.	Latreille, 1802
			Chloroperlidae sp.	
	Malacostraca	Amphipoda	*Gammaruspulex*	Linnaeus, 1758
Mollusca	Bivalvia	Veneroida	*Corbicula* sp.	Megerle von Muhlfeld, 1811

The present study showed that the Phylum Arthropoda was dominant phylum across all the study sites. It is known to be the most dominating freshwater order, because they are present in every heterotrophic niche in benthic and pelagic habitats of most permanent as well as temporary aquatic ecosystem (Throp and Covich, 1991; Williams and Feltmate, 1992). Mostly, this group is known to be dominant at the sites where bottom substrate is present as hard stones (Emere and Nasiru, 2007; Arimoro and Meye, 2007) which is true for all the sites in the present study where boulders and cobbles presented a suitable environment for macro invertebrates. Within the phylum Arthropoda, class Insecta was dominating due to the better competitive abilities of class insect which represents most of the functional feeding groups, varying from predators, shredders, grazers to filter feeders and gatherers (Ramirez and Gutierrez, 2014). Phylum Annelida was presented by a single species (*Erpobdella octoculata*). Leeches are considered as an important component of benthos of freshwater (Sawyer, 1986) and its meagre contribution in present study may be because oligochaete communities have been observed to thrive more in soft depositing substrate in comparison to stony beds (Syrovátka *et al.,* 2009). *Erpobdella octoculata has* greater power of utilizing the organic matter present below the surface of bottom sediments making them less dependent on immediate food inflow (Learner *et al.,* 1978; Syrovátka *et al.,* 2009). According to Collier *et al*. (1998) higher diversity in stream ecosystem is dependent on the variability of substrate.

Ephemeroptera was found to be the most dominating group at most sampling sites. This may be due to the optimum environmental conditions which favored the growth and development of these organisms. The dominance pattern is also related to the bottom substrate as these species showed their presence on habitats such as sand, gravel, cobble, boulders or moss (Medupin, 2020). They exhibit diverse feeding habits as they are herbivores or detritivores, feeding on algae, diatoms or detritus and predators. The Diptera was followed by the order Trichoptera, which also showed its dominance in the stream. This may be due to favorable environmental conditions and no significant change in physico chemical characteristics for all sampling periods. They are better inter and intra specific competitors. This is clear from their diverse feeding habits varying from collectors, gatherers, scrappers, shredders to predators (Mackie, 2001).

Site I was represented by 6 taxa. The low number of taxa recorded at this site is because of the fact that this site is subjected to desiccation and having spring as a main water source and was dry for two sampling periods (September and November). This site supported the good number of Amphipoda. Site II was represented by 23 taxa. The highest invertebrate diversity can be the result of availability of the food and composition of the bottom substrate, being mainly dominated by boulders, cobbles, gravel and pebbles which provide a stable habitat for macro invertebrates. Plecopterans were also found at this site. This may be attributed to the low temperature regime and well oxygenated and swifter water at site II. Three species of Coleoptera were recorded at this site because of their tendency to live in lotic waters where water is clear with high oxygen content (Elliott, 2008). About 17 taxa were recorded at site III which may be because of the suitable environmental conditions for benthic invertebrates to survive in. Site IV was represented by 13 taxa. This may be attributed to the optimum pH and temperature conditions and low organic input. Site V was represented by only 4 taxa during the entire study. Such a low density was due to the composition of bottom substrate which was mostly dominated by sand and mud (Bhat *et al*., 2011). Mollusca were found only at site V because of the high organic matter in the form of leaf litter.

The diversity during summer month was found more than winters and was in conformity with the study of Lamp and Haube (2004). The seasonal difference in the abundance of major taxa in high altitude streams is dependent on temperature (Gupta and Michael, 1983). Optimum temperature favors conductive conditions and decomposition rate of organic matter. In the presence of sufficient dissolved oxygen and substrata, many benthic organisms are known to accelerate the rate of decomposition of dead organic matter (Cummins *et al*., 1995). The streams are characterized by not only outside source of energy in the form of allochthonous derived leaf and woody debris but also by the inside source of energy in the form of aquatic algae (Allan, 1995). Cowell *et al*. (1997) stated that that the more densities of benthos in high order streams are mostly due to greater algal and macrophyte productivity, mostly when the streams are wide enough to reduce the effect of canopy shade. Lower densities during winter may be because the larval population observed during summer is high in compared to actual number of organisms that survive and finally emerge as adults (Stark and Armitage, 2000).

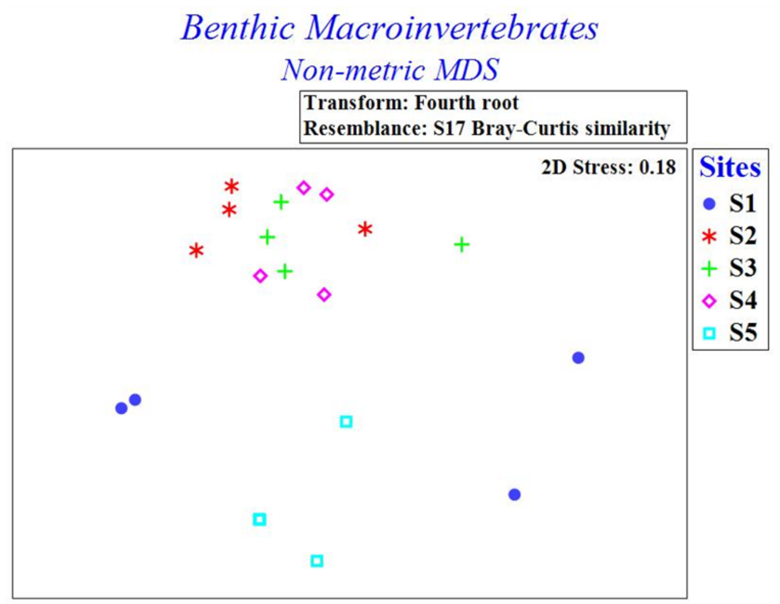

Fig. 3 nMDS ordination plots of benthic macroinvertebrates between various sites.

Statistical Analysis

The ordination of the abundance data using nMDS in two dimensional space resulted in a clear separation between the locations of the sites. Site I being at the left side and site V in the bottom whereas, sites II, III and IV form the cluster at the center top. The stress value of 0.18 was observed (Fig. 3). One way ANOSIM resulted in significant difference between benthic macro invertebrates at different sites. Pairwise ANOSIM test précised the sites were significantly different. This significant level (0.1) was observed depicting the similarity between site II, III and IV whereas, site I and II being clearly different.

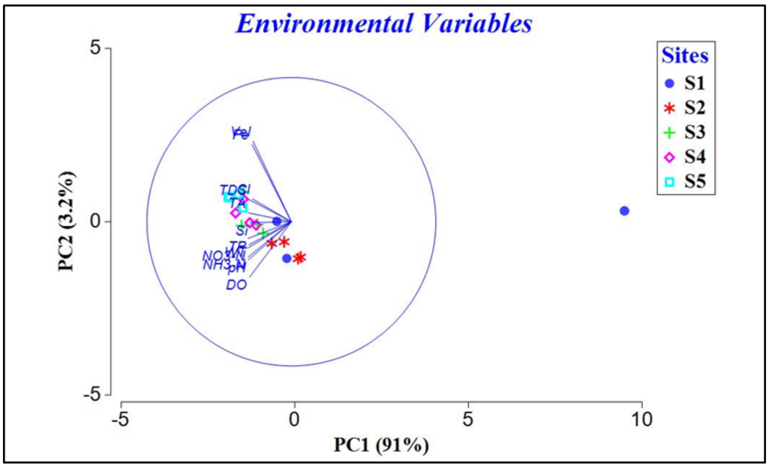

Fig. 4 PC of physico chemical variables at various sites

PC 1 accounted for 91% for the overall variance and was most heavily weighed on Velocity, Fe, TDS, DO, Silica, pH, TP, NH_3-N and NO_3-N (Fig. 4). These physico chemical variables directly impact the stream water quality. The result also explains Site I has the major differences from site II, III, IV and V.

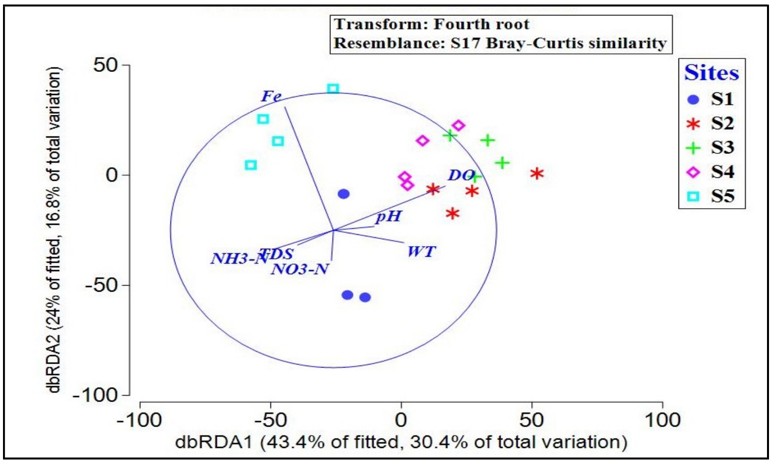

Fig. 5. Ordination plots of distance-based redundancy analysis (dbRDA) of stream benthic macroinvertebrates at various sites.

In order to model the relationship between benthic faunal assemblages with measured environmental variables among the different times, distance-based redundancy analysis (dbRDA) was carried out (Anderson *et al.,* 2008). The number of environmental parameters which explain variation in macroinvertebrate assemblage structure differ at various sites. Fe, DO, pH, WT (Water temperature), TDS, NH_3-N and NO_3N were the main drivers of variation (Fig. 5). Variability of stream changed among various sites.

Table 3. Biotic index for benthic macro invertebrate community of Aripal stream

Taxa	Site1	Site 2	Site 3	Site 4	Site 5
Taxa	6	23	17	13	4
Individuals	74	118	45	57	12
Shannon-weiner index	1.61	2.04	2.50	1.90	0.96
Simpson index	0.59	0.74	0.90	0.76	0.52
Equtability index	0.60	0.65	0.88	0.74	0.69
Berger-Perker	0.51	0.48	0.16	0.45	0.65
Ephemeroptera	2	6	6	5	0
Plecoptera	0	2	0	0	0
Trichoptera	2	5	3	2	1
EPT	4	13	9	7	1
Eveness	0.48	0.33	0.72	0.51	0.65
Dominance	0.41	0.26	0.10	0.24	0.48
Menhinick	0.70	2.12	2.54	1.72	1.16
Margalef	1.16	4.61	4.21	2.97	1.21
Fisher alpha	1.54	8.52	10.00	5.25	2.10

Biotic indices

The biodiversity indices showed a high diversity for site III, followed by site II, site IV, site I and then by site V (Table. 3). Even though the number of individuals was more at site II, the diversity was more at site III because site II was dominated by the *Simulium* sp. On the other hand, the taxa were evenly distributed at site III and no taxon dominated at this site. The EPT value was highest for site II (13) which indicates that the water quality of the site was good. This could be due to the presence of high diversities, bottom substrate of cobbles, gravel and pebbles. EPT value for site I was less because of the fact that site I received water from a non – perennial source and was dry for two sampling months. Had there been water for all the sampling months, the EPT value could have been more for this site. The site V had the lowest EPT value (1) which is an indication of poor water quality. This could be due to nearby human settlements that might have increased the organic load and also the bottom substrate of mud and sand didn't support more diversity. The biodiversity indices has proven to be the most effective and efficient means to know the status of aquatic ecosystems (Patang, 2018) and our study supports its usage.

Table 4. HKHbios values for Water quality classification of Aripal Stream.

HKHbios	Water quality classes	Ecological status classification	WQ characteristics degree of organic pollution	S 1	S II	S III	S IV	S V
6.00-10.00	I	HIGH	None tovery slight organic pollution	7.33	8.17	6.8	7.3	-
5.00-5.99	II	GOOD	Moderate pollution	-	-	-	-	5.5
4.00-4.99	III	MODERATE	Critical pollution	-	-	-	-	-
2.50-3.99	IV	POOR	Heavy pollution	-	-	-	-	-
1.01-2.49	V	BAD	Extreme pollution	-		-	-	-

HKHbios is used for scoring the indicator taxa. Indicator taxa were ranked on a 10-point scoring system reflecting the sensitivity of taxa towards organic pollution (oxygen depletion), to chemical pollution. Taxa having high scores indicate high sensitivity towards stressors, while taxa with low scores indicate high tolerance towards stressors (Moog, 2007). The method of HKHbios includes determination of average score per taxon (ASPT) of the indicator species present in a sample of macro-invertebrates. Only taxa that showed a clear preference to very good conditions (score 8-10) or to very bad condition (score=1) were assigned, whereas a weight of three was assigned to strong indicators, a weight of 5 for very strong indicators. Weighted average score per taxon ($ASPT_W$) was also calculated. The individual taxon's score was multiplied by the corresponding taxa weight. The products of these multiplications were summed for the entire sample and this sum was then divided by the total sum of weights. The highest HKHbios ($ASPT_W$ score) was calculated for site II (8.17) and lowest for site V (5.5). These indices reveal that the water quality of Aripal stream as of now is from good to high indicating that there is slight to moderate organic pollution present in the stream (Table 4).

Table 5. Sarprobic score for water quality of Aripal stream

Range of Saprobic Score (0-10)	Range of Diversity Score (0-1)	Water Quality	Biological Water Quality Class	Indicator color	Site I	Site II	Site III	Site IV	Site V
7 or more	0.2-1.0	Clean	A	Blue	-	-	-	-	-
7 to 6	0.5-1.0	Slight pollution	B	Light Blue	-	6	-	-	-
6 to 5	0.3-0.9	Moderate pollution	C	Green	5.2	-	5.3	5.2	-
5 to 2	0.4-less	Heavy pollution	D	Orange	-	-	-	-	4.25
2-0	0-0.2	Severe pollution	E	Red	-	-	-	-	-

Saprobic score involves a quantitative inventory of macro-invertebrate benthic fauna up to family/ genus level of taxonomic precision. All possible families having the sarprobic indicator value are classified on a score scale of 1 to 10 according to their preference for sarprobic water quality. The families which are most sensitive get a score of 10 while those which are pollution sensitive get a score of 1 and 2. The other intermediately sensitive families are placed inbetween the scoring scale of 10-1. The sarprobic score in present study was found high for site II (6) and lowest for site V (4.25). The scores reveal that the Aripal stream has slight to moderate pollution at most of the sites while somehow pollution was recorded at only downstream site V. This could be due the nearby human settlement which increases the organic load in the water (Table 5).

CONCLUSION

Results obtained from WQI revealed that the water quality of the stream was of excellent category and hence suitable for various purposes. Physico chemical parameters were found to have influence on macroinvertebrate distribution. On the basis of biotic indices, the overall water quality of Aripal stream was found good with all sites having none to very slight organic pollution while as site V had moderate organic pollution indicating overall good stream health.

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