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Phytoplankton as a Tool of Biomonitoring of Behlol Nullah, Jammu (J&K), India

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Abstract

This paper presents the results of a study that was conducted to determine the seasonal dynamics of phytoplankton population and nutrient status of water in Behlol nullah (Jammu). A total of 49 species belonging to four different groups (Euglenophyceae, Chlorophyceae, Bacillariophyceae and Cynophyceae) were recorded during the study period with a maxima in the winter season followed by summer and then monsoon. Percentage distribution of Euglenophyceae, Chlorophyceae, Bacillariophyceae and Cynophyceae individuals to total phytoplanktonic population were calculated. Heavily polluted sites exhibited lower phytplankton diversity and abundance as compared to least polluted sites. Shannon diversity and Marglef's species richness was highest at St. 1 while Simpson's dominance and Pielou's evenness was maximum at St. 4 and St. 5 respectively. Highest value of Sorenson's similarity was recorded between St. 3and St. 4 while Morisita Horn similarity was maximum between St. 1 and St. 3. Pearson correlation coefficient were used to analyze the data. Enlistment of higher concentration of Spirogyra sps. Stigeoclonium sps. and Oscillatoria species in the study area indicates organic pollution in the Behlol nullah which is mainly due to industrialization, domestic sewage and human activities which in course would finish the water body. A proper biological and chemical treatment of domestic sewage and industrial effluents before discharge to Behlol Nullah is, therefore suggested.

Keywords: Phytoplankton, Behlol Nullah, diversity indices, water quality.

Introduction

All living beings use water and it is an important component. In earth ecosystem, biosphere and biogeochemical cycles[1] it also performs unique and indispensible activities. In water quality and environmental changes in freshwater bodies many groups of organisms have been used as indicators including algae, macrophytes, protozoa, fish and other animals. All mixed group of tiny, living plants and animals that float, drift freely or feebly swim in water column independent of the shore and bottom[2] are known as plankton and occupy the basic level of food chain that lead up to commercially important fisheries have severally been used as bioindicators of water quality. In addition to this, these play a major role in the biogeochemical cycles of many important elements such as the carbon cycle, nitrification, denitrification and methanogenesis. These cycles bring about such processes as primary production and recycling. The study has been conducted to assess the water quality in relation to phytoplankton density so that a piece of information could be utilized to evaluate the present status of the Behlol Nullah.

Study Area: Behlol Nullah (74º 50´ E and 32º 40´ N), a tributary of river Tawi, has its origin through natural spring near village Parmandal of Jammu (J&K, India) (figure 1). Climate of the region is mainly sub-tropical with a well defined seasons viz. spring (March and April), summer (May to August), autumn (September and October) and winter (November to February). Perennial Behlol Nullah, all along its course is fed by a large number of springs, distributor of Ranbir canal and run off from agricultural fields. In its upper catchment area, it receives a number of perennial and seasonal fresh water nullahs. Behlol Nullah has been subjected to severe alterations in their habitat and in some areas deterioration of water quality is at rise due to the industrial effluents and municipal wastes from their catchment areas. Five sampling sites viz. S1, S2, S3, S4 and S5 were selected on Behlol Nullah based on the varying degree of anthropogenic pressure. Station 3 and Station 4 was subjected to intense level of anthropogenic stress due to the discharge of industrial effluents and domestic sewage in these sites respectively.

Material and Methods

Sampling: Phytoplankton were collected on a monthly basis by filtering 20 liters of water through a planktonic net (Bolting silk, 60-70µm mesh size) and were placed in 10 ml plastic vials to which 5% formalin was added for preservation.

Qualitative Analysis: Preserved samples of phytoplankton were scanned under compound microscope in the laboratory and were further identified[3-7].

Quantitative Analysis: The numerical count of phytoplankton was done by adopting Sedgwick-Rafter Cell method[6]. The preserved samples were centrifuged and concentrated to 5 ml. A coverslip was diagonally placed over the S-R cell and 1 ml of the concentrate was transferred into the cell with the help of a large broad dropper. The S-R cell cavity was covered by rotating the coverslip slowly. The S-R cell was allowed to stand for 15-20 minutes for settling the phytoplankton. The phytoplankton were then counted by field count method[8,9]. Phytoplankton were counted in 50 random fields. The number of phytoplankton per ml were calculated following N/ml = C X 1000/A X D X F, in which C is the number of organism counted, A is the area of field, D is the Depth of field (S-R cell depth = mm) and F is the number of field counted.

Physico-chemical Parameters: All the physico-chemical characteristics of water were determined at the sampling sites. The water and air temperature was recorded by a mercury bulb thermometer, depth by a meter rod and transparency by secchi disc. pH of the water was determined by using a portable pH meter (Hanna, model HI 98130). Dissolved oxygen of the water was estimated by sodium azide modification of Winkler's method, FCO2 by Titrimetric method, chlorides by Argentometeric method[9]. Carbonates and bicarbonates were also determined[10,9,6].

Statistical Methods: Species diversity was determined by applying Shannon-Weiner Diversity Index[11] $H' = -\Sigma^{s}_{i=1}$ pi.ln(pi), in which H' is the information content of sample (bits/individuals), S is the number of species and pi is the proportion of total species belonging to i^{th} species. Simpson's Index of dominance[12] $C = \Sigma^{s}_{i=1} pi^{2}$ where pi is the proportion of total number of individuals of each species. Species richness was determined applying Marglef's Index[13] $d' = S - 1/Log_n (N)$, in which S is the total number of species, N is the total number of individuals in sample and Log_n is the Natural log. Evenness was calculated using the Pielou's Index, $E = H'/\ln S$[14] where H' is the Index of diversity of Shannon-Weaver, ln is the Natural log and S is the total number of species. Percentage similarity of the icthyofauna in different seasons was calculated by Sorenson's Quotient of Similarity[15], Q/S = 2j/a + b 100, where j is the number of species common to both samples, a is the total number of species in sample 1 and b is the total number of species in sample 2. Morisita-Horn Index[16] was applied to determine the similarity of icthyofauna in different seasons in terms of abundance using the formula: $MH = 2\ \Sigma^{n}_{i=1}$ (Nia Nib)/ (da +db) NaNb, in which Nia and Nib number of individuals of species 'i' in the samples for site a and b, Na & Nb are the number of individuals in the samples from sites a and b and n is the total number of species. Community characteristics and physicochemical parameters were correlated using Karl Pearson's Coefficient of Correlation which was tested at 5% level using Student-t test. Correlation Coefficient and Student-t test was calculated with the help of Microsoft Excel (MS Office, 2007) and SPSS Software (Ver. 16.0).

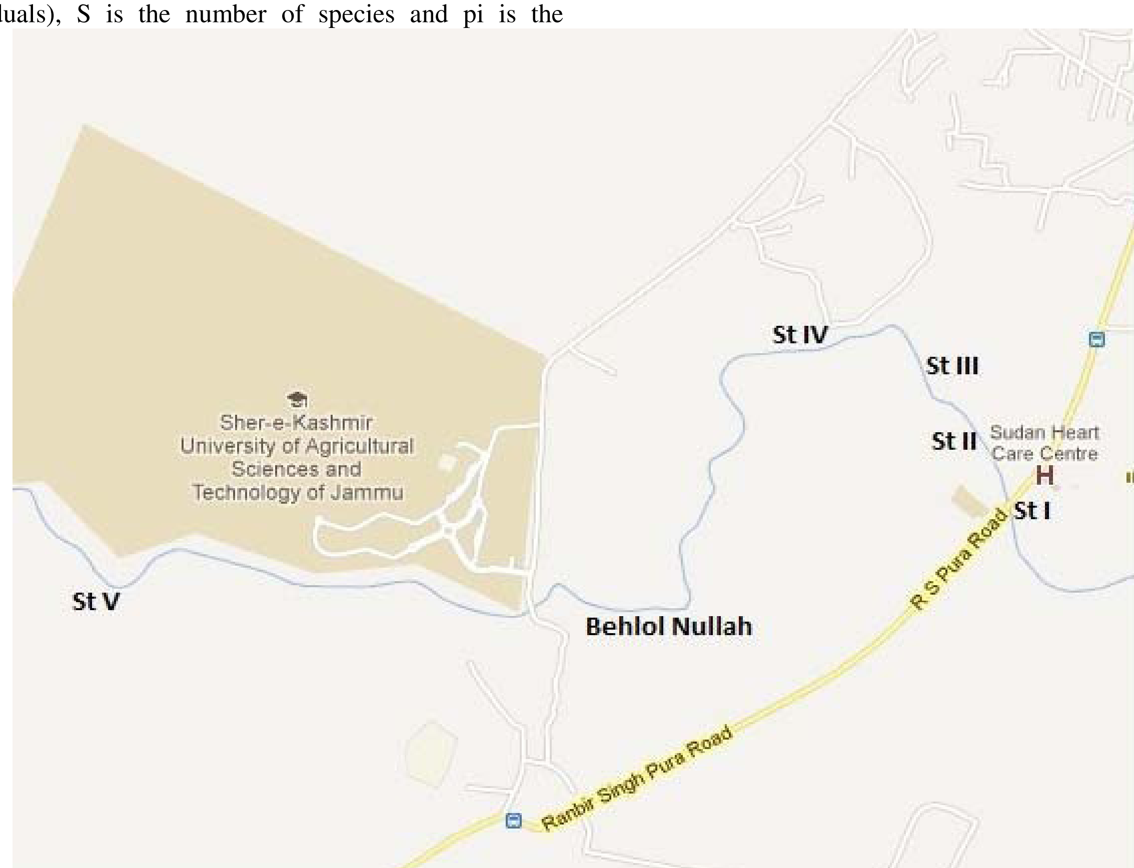

Figure- 1
Map of study area

Results and Discussion

Monthly variations in physico-chemical and phytoplankton characterstics of Behlol nullah have been tabulated in table 1-3. The average range of air temperature varied between 20.6ºC and 40.4ºC with a mean value of 29.50±7.018. The minimum value of air temperature was recorded in the month of December (winter) and maximum in May (summer). Water temperature varied between 14.4ºC and 35.2ºC with a mean value of 24.2±7.00. The minimum value of water temperature was recorded in December (winter) and maximum in May (summer). The result show that water temperature varies with the atmospheric temperature, and a direct relationship between air and water temperature was also found. During the summer season, solar radiations are and clear sky condition enhanced the atmospheric temperature. Where the during monsoon season, rainfall and cloudy-skies brought down the atmospheric temperature and subsequently the water temperature to minimum[17]. pH of Behlol nullah varied between 7.0 (May) to 8.6 (August). The mean value of pH was recorded 7.34±0.43. Increase in pH in monsoon (August) may be due to constant water movements which bring changes in the level of free carbon dioxide[18]. pH is an important factor for carbonate and bicarbonate system and contributes significantly in the formation of algal bloom.

Dissolved oxygen between 3.7mg/l (June) and 10.8mg/l (August) with a mean value of 6.89±2.83. High dissolved oxygen content in monsoon may be attributed to agitation of water due to heavy rainfall, increased day length, enhanced photosynthesis and strong wind action[19-21]. Free carbon dioxide ranged between 0mg/l to 24mg/l with higher values in summer and lower in monsoon[17,22,23]. The value of carbonates fluctuated between 0mg/l (September- April) and 27.6mg/l (August) with a mean value of 2.7±7.62. Absence of carbonates in most of the months of the year was attributed to the presence of free carbon dioxide[24]. An inverse relationship of free carbon dioxide and carbonates[25,26] has also been reported. The range of bicarbonates varied between 154.94 (June) to1238.3 (January) with mean value of 615.13±303.10[2,27]. Calcium content ranged between 21.64mg/l (May) to 105.05mg/l (January). The minimum value of calcium was recorded in May and maximum in January. The mean value of chloride was 57.49±24.35[22,28] and reduction of calcium reported during summer may be due to decreased solubility at high temperature[28].

The range of magnesium varied between 16.81 (May) to 76.68 (November) with a mean value of 48.73±15.09[29,30]. Chloride content ranged between 16.75mg/l (December) to 73.47mg/l (June). The minimum value of chloride was recorded in winter and Maximum in summer. The mean value of chloride was 45.09±15.83[2,31-33].

Phytoplankton composition identified in Behlol nullah is constituted by Chlorophyceae, Bacillariophyceae, Cynophyceae and Euglenophyceae. In total 49 species of phytoplanktons were recorded from the Behlol nullah. Of these 27 species belonged to Chlorophyceae, 17 species to Bacillariophyceae, 3 species to Cynophyceae and 2 species to Euglenophyceae (table 2).

Chlorophyceae constituted the largest single group claiming 55.10% of phytoplankton genera. Next in order were Bacillariophyceae, Cynophyceae and Euglenophyceae each constituting 34.6, 6.1 and 4.08% respectively (table 4). Based on their density Chlorophyceae occupies the first place (27.22±22.38nos/l) followed by Cynophyceae (18.35±23.66), Bacillariophyceae (14.46±17.89nos/l) and Euglenophyceae (1±1.11nos/l) with an average total density of 80.46±66.74nos/l during the study period. Phytoplankton exhibited marked seasonal variation. The total density of phytoplankton varied monthly between 0.72nos/l (September) and 254.1nos/l (April) during the study period. The appreciable total phytoplankton density was observed in the month of April (254.1nos/l), March (143.9nos/l), January (116.2nos/l) and February (110.1nos/l). Maximum number of total phytoplankton density during summer and winter indicates good physico-chemical conditions[1].

Table-1
Range of variation mean and standard deviation of the physico-chemical characterstics of water of Behlol Nullah during May 2009 to April 2010

Parameters	Range of variation		Mean ± SD
	Minimum	Maximum	
Air temp. (ºC)	20.6 (December)	40.4 (May)	29.50 ± 7.018
Water temp. (ºC)	14.4 (December)	35.2 (May)	24.2 ± 7.00
Depth (cm)	20.2 (March)	34.2 (July)	27.45 ± 3.65
DO (mg/L)	3.7 (June)	10.8 (August)	6.89 ± 2.83
pH	7.0 (March)	8.6 (August)	7.34 ± 0.43
Free CO2 (mg/L)	0 (August)	24 (March)	6.71 ± 5.93
Carbonates (mg/L)	0 (September -April)	27.6 (August)	2.7 ± 7.62
Bicarbonates (mg/L)	154.94(June)	1238.3 (January)	615.13±303.10
Calcium (mg/L)	21.64 (October)	105.05 (January)	57.49 ± 24.35
Magnesium (mg/L)	16.81 (October)	76.68 (November)	48.73 ± 15.09
Chloride (mg/L)	16.75 (December)	73.47 (June)	45.09 ± 15.83

Table- 2
Phytoplankton population in Behlol nullah during May, 2009 to April, 2010

Chlorophyceae	Bacillariophyceae	Cynophyceae	Euglenophyceae
Chlorococcum macrostigmatum	*Cyclotella* sp.	*Microcystis* sp.	*Euglena* sp.
Coelastrum sphericum	*Achnanthes* sp.	*Spirulina* sp.	*Phacus* sp.
Chlorosarcina minor	*Navicula dicephala*	*Oscillatoria* sp.	
Pediastrum simplex	*Navicula pupula*		
Pediastrum duplex	*Pinnularia* sp.		
Pediastrum tetras	*Stauroneis anceps*		
Pediastrum clathratum	*Gyrosigma* sp.		
Pediastrum boryanum	*Frustulia* sp.		
Closteriopsis longissima	*Diatoma vulgaris*		
Trochiscia sp.	*Fragilaria* sp.		
Treubaria sp.	*Synedra* capitata		
Scenedesmus dimorphous	*Synedra ulna*		
Scenedesmus quadricauda	*Cymbella* sp.		
Scenedesmus obliqus	*Gomphonema gracile*		
Scenedesmus acuminatusew	*Nitzschia* acicularis		
Scenedesmus brasiliensis	*Nitzschia angustata*		
Scenedesmus arcuatus	*Nitzschia longissima*		
Scenedesmus obtusus			
Closterium sp.			
Cosmarium sp.			
Cosmarium granatum			
Cosmarium reniforme			
Cosmarium pyramidatum			
Spirogyra sp.			
Ulothrix sp.			
Microspora sp.			
Stigeoclonium sp.			

Table- 3
Monthly mean variation of phytoplankton group (nos/l) in Behlol nullah during May, 2009 to April, 2010

Months	Chlorophyceae	Bacillariophyceae	Cynophyceae	Euglenophyceae	Total Phytoplankton
May	8.02	7.63	36.64	1.64	53.89
June	4.70	1.3	27.78	0.64	34.42
July	1.07	6.12	23.36	2.11	88.31
August	18.06	4.86	0.57	-	23.49
September	0.6	0.12	-	-	0.72
October	28.49	6.80	10.51	-	24.21
November	28.49	8.02	5.88	0.45	42.84
December	50.76	12.66	6.16	3.78	73.36
January	76.77	31.54	0.24	-	116.2
February	22.34	67.31	19.68	0.85	110.1
March	37.29	19.32	86.76	0.6	143.9
April	50.11	7.88	2.77	1.93	254.1
Mean±Sd	27.22±22.38	14.46±17.89	18.35±23.66	1±1.11	80.46±66.74

Different months of the year had different dominant plankton composition. Chlorophyceae peak was noted in January (76.77nos/l) while their decline was recorded in September (0.6nos/l). Higher values of Chlorophyceae during winter and lower in September[2,34,35]. The high density of Bacillariophyceae was recorded in the month of February (67.31nos/l) and low in the September (0.12nos/l)[2,35]. Cynophyceae were abundant in the month of March (86.76nos/l) and May (36.60nos/l). The minimum density of this group was recorded in the August (0.15nos/l) and September (0) (table 3). Maxima recorded during early summer may be due to high air as well as water temperature[36]. Euglenophyceae peak was observed in December (3.78nos/l) and absent in monsoon.

The water having a major percentage of Cynophyceae is indicative of eutrophic nature[37]. The algal genera as *Euglena* sps., *Navicula* sps., *Nitzschia* sps., *Microcystis* sps., *Oscillatoria* and *Scenedesmus* species are found in organically polluted water[38,1] and similar genera were also recorded in the present study. The epiphytic and epilithic algae may form excellent indicators of water pollution[39]. In the present study the occurrence of *Oscillatoria* species as epilithic algae and *Gomphonema* species as epiphytic Bacillariophyceae were recorded. Presence of pollution indicator species viz. *Oscillatoria* sp. and *Spirulina* sp. among Cyanophyceae, *Pediastrum simplex, P. duplex, P. tetras, Scendesmus dimorphus, Scendesmus quadricauda* and *Pandorina* sp. among Chlorophyceae, *Achanthes* sp., *Navicula* sp., *Nitzschia* sp. and *Syndra* sp. among Bacillariophyceae, *Euglena* sp. and *Phacus* sp. among Euglenophyceae and such species has already been identified as pollution indicator species[2,40].

Chlorophyceae recorded a positive and significant correlation with dissolved oxygen (r= 0.608, p= 0.05), calcium (r= 0.496), magnesium (r= 0.531), bicarbonate (r= 0.545) and negative with air temperature (r= -0.812), water temperature (r= -0.700), depth (r= -0.675) chloride (r= - 0.518). Bacillariophyceae recorded a negative but significant correlation with air temperature (r= -0.522) and positive with calcium (r= 0.497), bicarbonate (r= 0.768) and Cyanophyceae showed a positive relation with air temperature (r= 0.538, p= 0.05), water temperature (r= 0.504), chloride (r= 0.456) and negative with dissolved oxygen (r= -0.640) (table7).

Shannon index of diversity was found highest at St.1 (2.1) while lowest at St.4 (1.7). Marglef's richness dropped from 5.72 (St.1) to 2.90 (St.2). Highest Simpson's dominance was observed at St.4 (0.35) while lowest at St.2 (0.14). Evenness values were recorded maximum at St.1 (0.6) and minimum at St.4 (0.50) (table 5). The diversity of a community depends on the species richness and species Evenness[41]. Species richness is the aspect of diversity that bothers on the number of species present in the community whereas species evenness as the name explains, bothers on the evenness with which the individuals are apportioned among the species. Diversity was strongly affected by the higher values for Simpson's dominance index at Station 3 and Station 4 where diversity was much low. Although both Shannon-weiner and Simpson's index takes into account the proportional abundance of species but Shannon-weiner index is more sensitive to rare species and Simpson's index puts more emphasis on commonly occurring species and observed an inverse relationship between Shannon-weiner and Simpson's dominance index [42,43].

Sorenson's Quotient of similarity (Q/S) revealed that St.1 and St.5 were found more similar with highest value of 77.14% whereas low similarity (50%) was calculated between St.3 and St.4. Morisita-Horn Index, which is based on counts of individuals, showed maximum values of similarity between St.1 and St.4 (MH = 0.919) while minimum similarity was found among St.1 and St.2 (MH = 0.525) (Table 6). Morisita -Horn Index below 0.50 indicate low similarities in the relative abundance of species, whereas index above 0.75 indicate high similarities[44]. The present observations clearly indicated that the similarities among all the stations were higher but the most similar stations were St.3 and St.4 which receives the pollutants from industrial effluents and domestic sewage respectively and were considered the highly disturbed sites.

Conclusion

Species diversity variations in sampling sites indicated that the heavily polluted habitats (St.3 and St.4) supported less biological communities while less disturbed sites (St.1 and St.5) were characterized by a diverse phytoplanktonic fauna. Anthropogenic activities in the form of discharge of pollutants from various industries and domestic households had a crucial role in the decline of phytoplankton diversity at the polluted sites (St.3 and St.4). The present study on Behlol Nullah will facilitate to formulate sustainable strategies to save phytoplankton community of this lotic system.

Table- 4
Percentage distribution of phytoplankton genera in Behlol nullah during May, 2009 to April, 2010

Group	No. of genera	Percentage (%)
Chlorophyceae	27	55.10
Bacillariophyceae	17	34.69
Cynophyceae	3	6.12
Euglenophyceae	2	4.08

Table- 5
Diversity Indices of phytoplankton community in the stations

Diversity Indices	St.1	St.2	St.3	St.4	St.5
Total number of species	36	28	24	32	34
Simpson's index	0.19	0.14	0.21	0.35	0.17
Shannon-wiener index	2.16	2.13	1.88	1.74	2.13
Margalef index	5.72	2.90	3.43	5.42	5.45
Equtability index	0.60	0.69	0.59	0.50	0.60

Table-6
Different similarity indices to compare the community structure of the stations of Behlol Nullah from May, 2009 to April, 2010

Compared Stations	Sorenson's Quotient	Morisita-Horn Index
2009-2010		
St.1 vs. St.2	65.51%	0.525
St.1 vs. St.2	56.66%	0.760
St.1 vs. St.4	76.47%	0.919
St.1 vs. St.4	77.14%	0.872
St.2vs. St.3	60.86%	0.918
St.2 vs. St.4	51.85%	0.637
St.2vs. St. 5	64.28%	0.373
St.3 vs. St. 4	50%	0.680
St.3 vs. St. 5	55.17%	0.680
St.4vs. St. 5	72.72%	0.834

Table-7
Correlation coefficient (significant at p<0.05) between the different families of phytoplankton fauna and physico-chemical parameters of Behlol Nullah (* marked correlations are significant)

Parameters	Euglenophyceae	Chlorophyceae	Bacillariophyceae	Cyanophyceae
Air temperature	-0.191	-0.812*	-0.522*	0.538*
Water temperature	-0.178	-0.700*	-0.341	0.504*
Depth	-0.209	-0.675*	-0.438	-0.096
Ph	-0.331	-0.380	-0.318	-0.105
Free carbon dioxide	-0.023	-0.186	-0.132	0.356
Dissolved oxygen	-0.213	0.608*	0.350	-0.640*
Calcium	-0.236	0.496*	0.497*	-0.384
Magnesium	0.390	0.531*	0.431	-0.364
Chloride	-0.08	-0.518*	-0.007	0.456
Carbonate	-0.449	0.127	-0.052	-0.421
Bicarbonate	0.146	0.545*	0.7680*	-0.155

*Values significant at 5%

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