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Periphytic Algae of River Sindh in the Sonamarg Area of Kashmir Valley

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Summary

This study deals with the taxonomic composition of Periphytic algae of River Sindh in the Sonamarg area in terms of species composition and density carried out during 2009. Periphytic algal community was represented by 49 taxa belonging to four classes namely Bacillariophyceae (32), Chlorophyceae (9), Cyanophyceae (7) and Xanthophyceae (1). The number of common species recorded from all the sites were 11 while as genera/species like *Vaucheria* sp., *Navicula appendiculata, Meridion* sp., *Fragillaria* sp., *Brachysira virea, Rhizoclonium* sp., *Oedogonium capillare*, *Mougeotia* sp., *Oscillatoria* sp., *Merismopedia* sp., *Leptolyngbya* sp., *Ceolospharum* sp., *Calothrix* sp. were observed from only one particular site. Bacillariophyceae was the dominant group both in diversity and density and included 32 taxa contributing 87% of total periphytic algal population. Chlorophyceae forming the second dominant class was represented by 9 genera comprising 8.5% of the total periphytic algae. Cyanophyceae ranked third in its dominance pattern with 7 genera forming 4.5% of all the periphytic algae. Xanthophyceae was represented by only one species of *Vaucheria* sp. found only at Thajwas Grar. Amongst the study sites highest (2.64) values of Shannon Weiner Index was found at Baltal and lowest (1.99) at Sonamarg while as highest (0.77) and lowest (0.55) Sorensen's Similiarity coefficient were found between Baltal/Sonamarg and Yashmarh/ Thajwas Grar.

Key Words: Periphytic algae, River Sindh, Sonamarg, Bacillariophyceae, Kashmir valley

Introduction

Periphyton in streams and rivers are important components of aquatic ecosystems, providing food for aquatic organisms, in local and downstream ecosystems [1]. Although this community is frequently subjected to adverse physical conditions such as high stream velocities or high turbidity levels, it is characterized by a very rapid recovery. Because of its ubiquitousness and rapid turnover it provides both food and shelter for the benthic fauna of a stream. Since the organisms involved are not equipped with a means of procuring the essential elements from the stream bed, the production of this community is also closely related to the characteristics of the flowing water mass. Consequently, an evaluation of the periphyton community has long been recognized as a means of evaluating stream biodynamics. Growth of periphyton can be limited by light or nutrient, or both [2, 3] and is influenced by temperature [4]. Stream periphyton assemblages show variations in their nutritional quality. Evidences have suggested that the importance of periphyton in stream food webs is a function of quality than quantity [5]. Periphyton communities are found to deplete nutrients from waterways, assuming no additional inputs, and communities vary compositionally with nutrient concentrations[6].Periphyton community structure, species composition, and succession respond to environmental conditions and thus can be used to classify waterways [7,8]. Physical and chemical factors, extent of canopy cover and nutrient levels in streams are found to have profound influence on the resilience of the periphytic community. Streams with higher light intensities and nutrient concentrations have more resilient periphyton communities because higher light and nutrient resources shorten the recovery phase [9,10]. Excessive periphyton growth can occur in rivers and lakes as a result of high water temperatures from reduced managed flows or excess nutrient production from human development on the landscape, through releases from wastewater treatment facilities, agricultural operations, deforestation, and soil disturbance, and therefore can serve as an ecological indicator for these disturbances [3,11,12,13]. Increase in aquatic vegetation growth can change and negatively impact benthic macroinvertebrate abundance and species richness and their functional role in the ecosystem as consumers of organic material and prey to larger invertebrates and vertebrates [14,15, 16].

Algal production in streams has recently received attention from different workers and the studies have demonstrated a greater importance for autochthonous matter in lotic food webs than was suggested in earlier models [1,17]. These studies further indicate that benthic algae consist of higher quality organic matter than that terrestrial matter, which is essential for consumers in stream food webs. Periphytic algae in urban streams may provide greater nutrition for benthic consumers [18]. Ecological variables such as nutrient supply, light availability, physical disturbance, and grazing are found to drive or limit algal production in streams and have been studied extensively, both through correlative and experimental approach [19]. Algal communities can and have been used as biotic indicators of ecological condition and change in condition in response to human and natural disturbance [3, 7, 20, 21]. Diatom assemblages on substrates are well suited for water quality assessment because they are taxonomically diverse, importance short regeneration time and many species have a specific sensitivity to ecological characteristics. It is in this context of the relative importance of the algal community in stream ecology that the present periphytic community of a lesser known Himalayan river Sindh was undertaken.

Study area and sites

River Sindh locally known as SENDH originates from the Panjtarni glacial fields at an altitude of 4,250 m (a.s.l) at the base of Saskut, a peak (4,693 m a.s.l) in the Ogput Range running parallel to the North-West to South-East. River Sindh drops steeply north westward to reach the main strike valley. Gathering momentum, the river runs towards Sonamarg between steeply towering mountain areas, over a boulder stream bed, emerging into the pleasant upland serenity of the Sonamarg, as if to rest before it plunges roaring headlong torrent sharply to the Southwest through the Gagangir gorge, 4000 ft (1,230 m) deep. It has a catchment area of 1,556 km^2 which extends between the geographical co-ordinates of 34° 07' 40" to 34° 27' 46" N latitude and 74° 40' 37" to 75° 35' 15" E longitude. There is abundant Triassic limy shale and slaty limestones in the headwater region of the Sindh valley, while as in the middle granite and sandstone replace them as a dominant rock type [22].

Four sampling sites (Fig.1) were selected to carry out sampling. The sites varied in altitude, temperature, current velocity, depth, and many other characteristics. Site I was located at Baltal. Site II was located at Yashmarg. Site III was located at Sonamarg, a famous hill station and site IV was located at Thajwas Grar, a left bank tributary of Sindh stream. Geographical attributes of the sites are given in Table 1.

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

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

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

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

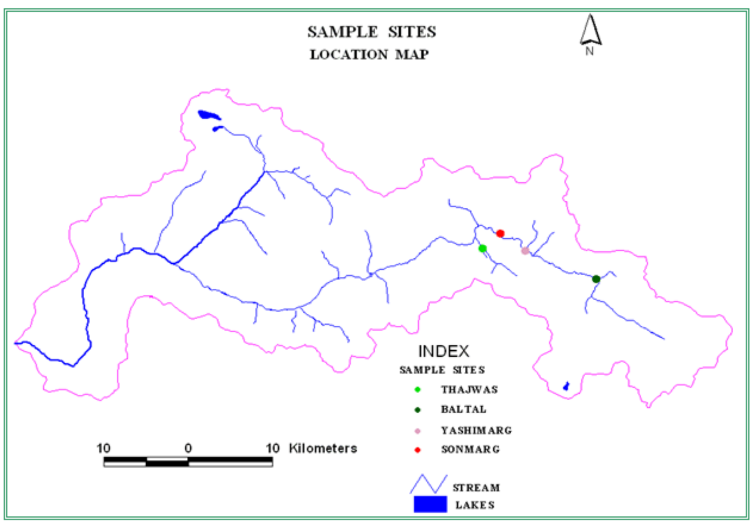

Fig. 1. Map of study area showing position of sampling sites

Table 1. General characteristic of four study sites

Site	Code	Altitude	Latitude	Longitude	Substrate type
Baltal	I	2,850 m	34^0 15' N	75^0 24' E	Cobble, Gravel, Pebbles
Yashmarg	II	2,712 m	34^0 17' N	75^0 19' E	Cobble, Sand
Sonamarg	III	2,705 m	34^0 18' N	75^0 15' E	Mud, Sand and Pebbles
Thajwas Grar	IV	2,617 m	34^0 17' N	75^0 15' E	Gravel, Pebbles, Sand and leaf litter

Material and Methods

Sampling was carried out on monthly basis from July to December 2009 at the four selected sites. Periphyton were collected by scrapping 5 cm^2 surface area of boulders using blade and brushes. It was washed into a tray and then transferred into a vial of suitable volume [23]. The rinsed sample was preserved with 1ml Lugols iodine and three drops of 4 % formalin. The sample was then raised to 100 ml [24]. Identification was carried out with the help of standard keys [23,24,25, 26,27,28,29,30,31,32,33].

Results

Periphytic algae in the present study exhibited a modest diversity in species number across different sampling sites. A total of 49 taxa of periphytic algae belonging to Cyanophyceae (07), Chlorophyceae (09), Bacillariophyceae (32) and Xanthophyceae (01), were recorded across four different sites during the period of investigation (Table 2). The number of common species recorded from all the sites were 11 while as taxa like *Vaucheria* sp., *Navicula appendiculata, Meridion* sp., *Fragillaria* sp., *Brachysira virea, Rhizoclonium* sp., *Oedogonium capillare*, *Mougeotia* sp., *Oscillatoria* sp*.,* *Merismopedia* sp., *Leptolyngbya* sp., *Ceolospharum* sp., *Calothrix* sp. were restricted to only one particular site. Amongst 49 genera, the highest number of taxa (31), were found at site III, followed by site IV (29), site II (28) and site I (27). Comparative analysis revealed that Cyanophyceae, Chlorophyceae and Bacillariophyceae contributed 3, 3, and 21 respectively at site I. At site II 2 genera belonged to Cyanophyceae, 4 to Chlorophyceae and 22 to Bacillariophyceae. At site III 3 genera belonged to Cyanophyceae, 5 to Chlorophyceae and 23 to Bacillariophyceae. However, a similar pattern in terms of contribution to algal taxa was observed at site IV with 3 taxa belonged to Cyanophyceae, 6 to Chlorophyceae, 19 to Bacillariophyceae and 1 to Xanthophyceae. Both qualitatively and quantitatively Bacillariophyceae was the most dominant algal class at all the sites being followed by Chlorophyceae, Cyanophyceae and Xanthophyceae in a decreasing order.The most numerically dominant genera found during the entire study period were: *Coelospharum* sp, *Lyngbya* sp., *Oscillatoria* sp., and *phormedium* sp., *among* Cyanophyceae; *Closterium* sp, *Diadesmis* sp, *Ulothrix zonata and Zygnema* sp*.* among Chlorophyceae; *Amphora ovalis, Amphora pediculus, Amphora veneta, Cymbella aspera, Cymbella kappi, Cymbella kappi, Cymbella lanceolata, Diatoma mesodon, Epithemia sorex, Gomphonema germinatum, Gomphonema truncatum, Hannaea arcus, Navicula* sp*. and Tabellaria* sp*.* among Bacillariophyceae.The sriking feature of the present study was the presence of *Vaucheria* sp. being restricted to site IV (Thajwas Grar) only.

Cyanophyceae

The population density of Cyanophyceae reached its highest peak (5504 ind./cm^2) at Site IV in September while as the lowest population density (32 ind./cm^2) was obtained at site II in September. However on spatial basis the group depicted maximum mean population (1877 ind./cm^2) at site IV against its minimum (38 ind./cm2) at site II. Genera like *Phormidium* sp. *Lyngbya* sp. and *Coelospharum* sp. were the most dominant species contributing the major portion to the overall density of cyanophycean group. (Table 3 and Figure 2).

Chlorophyceae

Among the sites studied the population density of Chlorophyceae fluctuated from a minimum of 96 ind./cm^2 at site IV in October to a maximum of 8480 ind./cm^2at site III in December. The highest mean population density of Chlorophyceae was noticeable at site III (2958 ind./cm^2) and minimum density at site I (214 ind./cm^2). The life-forms which contributed their major share in the overall density of Chlorophyceae were *Zygnema* sp. *Closterium* sp. *Diadesmis* sp. and *Ulothrix* zonata (Table 3 and Fig. 2).

Bacillariophyceae

The population density of Bacillariophyceae varied from a low of 159 ind./cm^2at site II in July to a high of 65920 ind./cm^2 at site III in December. Pronounced mean population density was noted at site I with values ranging from a minimum of 4261 ind./cm^2 to a maximum of 31258 ind./cm^2 at site III. Different genera like *Amphora ovalis, Amphora pediculus, Amphora veneta, Diatoma mesodon, Gomphonema germinatum, Gomphonema truncatum, Hannaea arcus, Navicula* sp*. and Tabellaria* sp*.* were the major contributors to the overall density (Table 3 and Fig. 2).

Relative density (Percentage composition)

Bacillariophyceae dominating both in diversity as well as density was comprised of 32 taxa forming 87% of total periphytic algal population in the studied area (Fig. 4). Chlorophyceae formed the second dominant class representing 9 genera and making 8.5% of total periphytic algal population. Cyanophyceae ranked third in the order of dominance and registered 7 genera forming 4.5% of the periphytic algae of the stream. Xanthophyceae was represented by lone restricted to only at Thajwas Grar. The diversity of different algal classes did not vary much among the sites yet the density showed almost an increasing trend downstream from site I to site III showing highest mean density of 34447 Ind/cm^2. Thajwas stream presented a different view in relative density than River Sindh where Chlorophyceae and Cyanophyceae showed about 13% of relative density compared to River Sindh where it ranged between 0-9 % (Fig. 3). The Shannon Weiner index value incorporates both taxa richness and evenness of number of individuals in each taxa. Highest (2.64) value of diversity index was observed for Baltal site and lowest(1.99) for Sonamarg site (Fig. 4) Sorensen's similarity index (Table 4) revealed maximum similarity interms of taxonomic composition of periphytic algae between Baltal and Sonamarg (0.77) and lowest between Yashmargh and Thajwasgrar(0.55).

Table 2. Population density (Ind/cm^{-2}) of various families of Periphytic flora at different sites in the Sindh River System from July -2009 to December 2009

S.No.	Genera	Sites	Months				Mean	S.D
Cyanophyceae								
			July	Sep	Oct	Dec		
		Baltal	n.s	0	0	n.s	0	0
1	*Calothrix* sp.	Yashmarg	0	16	0	0	4	8
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	0	0	n.s	0	0
2	*Coelospharum* sp.	Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	640	0	n.s	213	369
		Baltal	n.s	0	0	n.s	0	0
3	*Leptolyngbya* sp.	Yashmarg	0	16	0	0	4	8
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	36	0	n.s	18	25
4	*Lyngbya* sp.	Yashmarg	0	0	0	120	30	60
		Sonamarg	n.s	32	0	0	11	18
		Thajwas Grar	27	2176	40	n.s	748	1237
		Baltal	n.s	144	0	n.s	72	102
5	*Merismopedia* sp.	Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	0	0	n.s	0	0
6	*Oscillatoria* sp.	Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	64	133	240	146	87
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	18	0	n.s	9	13
7	*Phormidium* sp.	Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	0	120	40	69
		Thajwas Grar	27	2688	32	n.s	916	1535
	Total	Cyanopyceae	54	5830	205	480		

	Chlorophyceae							
8	Unknown green unicells	Baltal	n.s	0	0	n.s	0	0
		Yashmarg	0	540	0	0	135	270
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	0	n.s	0	0
9	*Closterium* sp.	Baltal	n.s	0	0	n.s	0	0
		Yashmarg	53	640	665	360	429	287
		Sonamarg	n.s	32	0	8120	2717	4679
		Thajwas Grar	0	64	12	n.s	25	34
10	*Diadesmis* sp.	Baltal	n.s	0	0	n.s	0	0
		Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	0	360	120	208
		Thajwas Grar	27	256	24	n.s	102	133
11	*Geminella* sp.	Baltal	n.s	0	114	n.s	57	80
		Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	128	0	n.s	43	74
12	*Mougeotia* sp.	Baltal	n.s	0	0	n.s	0	0
		Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	133	0	44	77
		Thajwas Grar	0	0	0	n.s	0	0
13	*Oedogonium capillare*	Baltal	n.s	0	0	n.s	0	0
		Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	16	n.s	5	9
14	*Rhizoclonium* sp.	Baltal	n.s	0	0	n.s	0	0
		Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	32	4	n.s	12	17
15	*Ulothrix zonata*	Baltal	n.s	0	40	n.s	20	28
		Yashmarg	106	16	133	0	44	60
		Sonamarg	n.s	0	100	0	33	58
		Thajwas Grar	0	0	0	n.s	0	0
16	*Zygnema* sp.	Baltal	n.s	216	57	n.s	136	112
		Yashmarg	26	16	133	0	44	60
		Sonamarg	n.s	128	0	0	43	74
		Thajwas Grar	826	4096	40	n.s	1654	2151
	Total	Chlorophyceae	1038	6164	1638	8840		

Bacillariophyceae								
		Baltal	n.s	0	0	n.s	0	0
17	*Amphipleura* sp.	Yashmarg	0	0	1	0	0.25	0.5
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	8	n.s	3	5
		Baltal	n.s	306	113	n.s	210	136
18	*Amphora ovalis*	Yashmarg	0	256	533	2520	827	1149
		Sonamarg	n.s	544	460	2520	1175	1166
		Thajwas Grar	0	32	12	n.s	15	16
		Baltal	n.s	0	50	n.s	25	35
19	*Amphora pediculus*	Yashmarg	53	0	0	0	13	26
		Sonamarg	n.s	320	0	0	107	185
		Thajwas Grar	53	0	0	n.s	18	31
		Baltal	n.s	234	0	n.s	117	165
20	*Amphora veneta*	Yashmarg	0	0	400	0	100	200
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	76	n.s	25	44
		Baltal	n.s	0	0	n.s	0	0
21	*Astronella ralfsii*	Yashmarg	0	0	0	240	60	120
		Sonamarg	n.s	0	0	240	80	138
		Thajwas Grar	0	0	12	n.s	4	7
		Baltal	n.s	18	0	n.s	9	13
22	*Bacillaria paradoxa*	Yashmarg	0	18	0	0	4	9
		Sonamarg	n.s	32	33	0	22	19
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	0	0	n.s	0	0
23	*Brachysira virea*	Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	27	96	116	n.s	80	47
		Baltal	n.s	0	0	n.s	0	0
24	*Cocconeis placentula*	Yashmarg	0	0	0	120	30	60
		Sonamarg	n.s	32	0	120	51	62
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	0	0	n.s	0	0
25	*Cymbella aspera*	Yashmarg	0	0	0	3600	900	1800
		Sonamarg	n.s	0	66	0	22	38
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	0	567	n.s	283	401
26	*Cymbella kappi*	Yashmarg	0	864	2667	1440	1243	1119
		Sonamarg	n.s	1280	100	4440	1940	2244
		Thajwas Grar	133	896	52	n.s	360	466
		Baltal	n.s	270	113	n.s	191	111
27	*Cymbella lanceolata*	Yashmarg	26	336	0	0	90	164
		Sonamarg	n.s	96	766	360	407	337
		Thajwas Grar	0	0	0	n.s	0	0

		Baltal	n.s	0	113	n.s	56	80
28	*Diatoma ehenbergii*	Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	132	0	44	76
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	0	0	n.s	0	0
29	*Diatoma hyemalis*	Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	396	0	132	229
		Thajwas Grar	0	96	80	n.s	59	51
		Baltal	n.s	144	736	n.s	440	419
30	*Diatoma mesodon*	Yashmarg	0	32	1199	480	428	559
		Sonamarg	n.s	96	766	360	407	337
		Thajwas Grar	0	128	48	n.s	59	65
		Baltal	n.s	0	57	n.s	28	40
31	*Diatoma vulgaris*	Yashmarg	0	0	1599	0	400	799
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	0	n.s	0	0
32	*Epithemia prostatum*	Baltal	n.s	16	0	n.s	8	11
		Yashmarg	0	0	700	0	175	350

		Sonamarg	n.s	32	0	0	11	18
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	20	170	n.s	95	106
33	*Epithemia sorex*	Yashmarg	0	0	2330	120	612	1146
		Sonamarg	n.s	32	62	0	31	53
		Thajwas Grar	0	32	264	n.s	99	144
		Baltal	n.s	0	57	n.s	28	40
34	*Fragilaria capucina*	Yashmarg	0	16	0	0	4	8
		Sonamarg	n.s	160	66	0	75	80
		Thajwas Grar	0	256	0	n.s	85	148
		Baltal	n.s	0	849	n.s	424	600
35	*Fragilaria* spp.	Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	90	0	n.s	45	64
36	*Fragilariforma virescens*	Yashmarg	0	16	0	0	4	8
		Sonamarg	n.s	0	0	120	40	69
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	0	0	n.s	0	0
37	*Gomphoneis* sp.	Yashmarg	0	352	0	0	88	176
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	92	n.s	31	53
		Baltal	n.s	540	397	n.s	468	101
38	*Gomphonema germinatum*	Yashmarg	80	1920	10400	1440	3460	4692
		Sonamarg	n.s	832	13298	4320	6150	6431
		Thajwas Grar	80	4896	3756	n.s	2911	2517
		Baltal	n.s	360	170	n.s	265	134
39	*Gomphonema truncatum*	Yashmarg	0	2880	5066	840	2196	2263
		Sonamarg	n.s	352	6100	1440	2631	3053
		Thajwas Grar	53	3424	3344	n.s	2274	1923
		Baltal	n.s	1008	963	n.s	985	32
40	*Hannaea arcus*	Yashmarg	0	0	6000	9000	3750	4500
		Sonamarg	n.s	1216	300	40000	13839	22661
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	0	0	n.s	0	0
41	*Meridion* sp.	Yashmarg	0	0	0	360	90	180
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	0	0	n.s	0	0
42	*Navicula appendiculata*	Yashmarg	0	0	0	240	60	120
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	72	397	n.s	234	230
43	*Navicula* spp.	Yashmarg	0	208	0	0	52	104
		Sonamarg	n.s	128	100	480	236	212
		Thajwas Grar	81	3360	56	n.s	1166	1900
		Baltal	n.s	18	0	n.s	9	13
44	*Neidium iridis*	Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	32	0	n.s	11	18
		Baltal	n.s	0	56	n.s	28	40
45	*Nitzschia* sp.	Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	33	3600	1211	2069
		Thajwas Grar	0	0	36	n.s	12	21
		Baltal	n.s	0	0	n.s	0	0
46	*Surirella* sp.	Yashmarg	0	0	0	120	30	60
		Sonamarg	n.s	0	100	0	33	58
		Thajwas Grar	0	0	0	n.s	0	0
		Baltal	n.s	0	113	n.s	56	80
47	*Synedra ulna*	Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	100	480	193	253
		Thajwas Grar	0	0	52	n.s	17	30
		Baltal	n.s	504	0	n.s	252	356
48	*Tabellaria fenestrate*	Yashmarg	0	352	267	5640	1565	2721
		Sonamarg	n.s	256	366	7440	2687	4116
		Thajwas Grar	27	1280	160	n.s	489	688
	Total	Bacillariophyceae	613	30786	67491	92080		

Xanthophyceae								
49	*Vaucheria* sp.	Baltal	n.s	0	0	n.s	0	0
		Yashmarg	0	0	0	0	0	0
		Sonamarg	n.s	0	0	0	0	0
		Thajwas Grar	0	0	4	n.s	1	2
	Total	Xanthophyceae	0	0	4	0		

n.s- not sampled

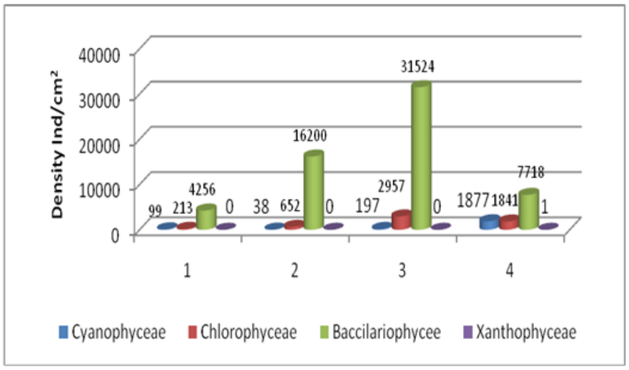

Fig. 2 Spatial Variations in mean density (Ind/cm^2) of periphytic flora of different classes during July to Dec, 2009

Table 3. Spatio-temporal variation in density (Ind./cm^2) of periphytic flora at different sites in the Sindh River System from July -2009 to December 2009

Class	Site	July	September	October	December	Mean
Cyanophyceae	I	n.s	198	0	n.s	99
	II	0	32	0	120	38
	III	n.s	96	133	360	196
	IV	54	5504	72	n.s	1877
Chlorophyceae	I	n.s	216	211	n.s	214
	II	185	1212	931	360	672
	III	n.s	160	233	8480	2958
	IV	853	4576	96	n.s	1842
Bacillariophyceae	I	n.s	3600	4921	n.s	4261
	II	159	7250	31961	26160	16383
	III	n.s	5408	22445	65920	31258
	IV	454	14528	8164	n.s	7715

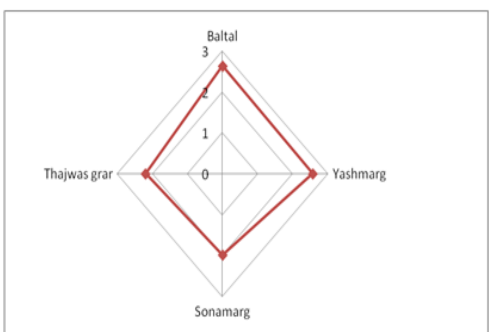

Fig. 3 Shannon Weiner index value of periphytic algae at different study sites

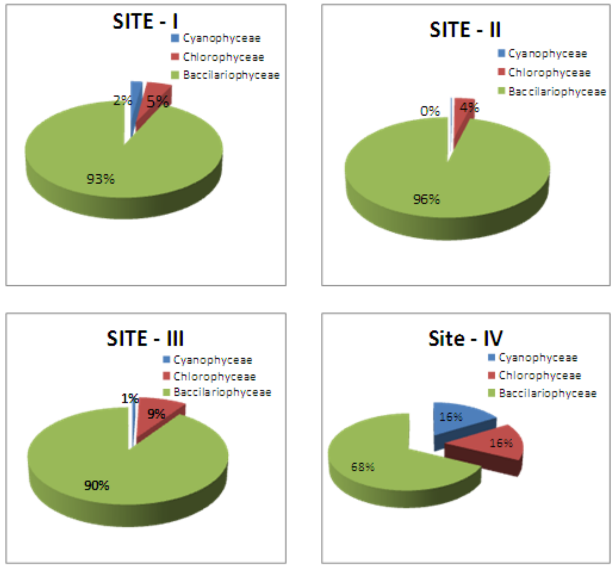

Fig. 4. Relative density of periphytic flora at different Sites during July to Dec, 2009

Table 4. Similarity coefficient (Sorenson index) between different selected sites on the basis of periphytic algae

	Yashmarg	Sonamarg	Thajwas grar
Baltal	0.66	0.77	0.66
Yashmarg		0.73	0.55
Sonamarg			0.63

Discussion

In terms of taxonomic composition, Bacillariophyceae was found the most dominant taxa in terms of density as well as diversity represented by 32 taxa followed by Chlorophyceae (9) and then Cyanophyceae (7) and lastly by Xanthophyceae (1). The quantitative increase of Cyanophyceae typically at site IV is attributable to the relatively higher temperature and lower values of conductivity, alkalinity and hardness [34].The growth and abundance of Chlorophyceae in the present study also reflects the oligotrophic nature of the river sindh as also reported earlier [34, 35].

Bacillariophyceae has been reported to be dominant among periphytic flora in a number of streams studied for periphyton composition [35,36,37,38]. Dominance of Bacillariophyceae may be attributed to the presence of good concentration of SiO_2 in water bodies which probably helps in the frustule formation [39] and its ability to thrive well in cold waters [40,41]. Diatom communities have been extensively used in the assessment of past and present ecological conditions in the aquatic habitats in which they live [42]. Their indicative utility resides in that sediments and many species form characteristic assemblages under different trophic or diversely contaminated conditions [43, 44, 45]. Diatoms to some extent in streams of Kashmir Himalaya have been poorly studied and a review of the literature reveals that only a fraction of this literature is purely taxonomic in nature, which hinders the potential use of diatoms for bioindication or biomonitoring. Only a few articles have focused on the diatoms from the bioindication point of view which are insufficient to cover vast and extensive array of habitats in Kashmir Himalaya.

Gomphonema was found sometimes growing in masses by long or short mucilage stalks that enable them to withstand water currents. A fairly common epiphyte, usually in moderate to high conductivity streams. Further genus is sensitive to moderate levels of pollution [26] and is usually dominant at low conductivity waters of Thajwas Grar. *Gomphonema* spp. and *Hannaea* spp. in the present study were observed to contribute good share in the overall percentage of diatoms.

Bacillaiophyceae was the most dominant followed by Chlorophyceae and Cyanophyceae which is generally the trend found in the lotic systems [46]. However, the Chlorophyceae and Cyanophyceae relatively were moderately better represented at sites III and IV. In terms of density variation along the downstream gradient, the maximum density of periphytic algae in Sindh stream was obtained at site III. The increase in the density downstream in the studied area can be explained due to enrichment of the water by nutrients[47,48] because of more of the drainage basin draining into the stream in the downstream area, uptake of dissolved organic nutrients resulting in very high and localized concentration of biomass[46]. The other probable reason is that the Sindh stream at site III was comparatively wider which lowered the overall depth of the body in the study area and thus making more of sunlight available to the stream bottom for the periphytic algae to proliferate [46,47,48].

Bacillariophyceae was found to be the most dominant in the month of December while as Cyanophyceae has been found to be the most dominant in the month of September. Similar results which showed that generally diatoms dominate during winter and continue to be major component of periphytic algae in spring and early summer and green algae become abundant in summer[46,49].

Maximum density of total periphytic algae in the Sindh stream was obtained in the month of December which can be attributed to the factors like decreased amount of water available during this month and drier climate, except for snow which allows more of the radiation to pass through the column promoting lesser discharge in the stream thus providing more stability in terms of variation of discharge and also less turbidity, both of which provide a stable habitat for the growth of periphytic algae. The peak populations of periphytic algae during December has also been reported by other workers from Kashmir Himalyan waters and elsewhere [37,50, 51,52, 53] who observed diatoms to develop profusely during relatively low temperatures. The decrease in periphyton density during warmer months seems related with higher discharge and turbidity of water reducing the light penetration and in turn reduces growth of periphyton. The seasonality of periphytic flora is found to be governed by many factors especially discharge, light and the release and availability of plant nutrients during these periods. In July, the density of periphytic algae was observed to be very low at all the sites. It may be because of high discharges during summer that cause higher shear stress [51,54,55,56] thereby preventing periphytic algae to grow. Burial and washout by heavy flows has been observed to be the main cause of periphytic algal loss [57]. In general, there was a seasonal trend in the periphytic algae with lowest periphyton density usually recorded during cold months and the highest in warmer months.

Conclusion

The periphytic flora from river sindh is diverse and comprises a variety of cosmopolitan species adapted to alkaline habitats. Many of the species especially from diatoms observed in collected samples could not be identified properly because of the lack of taxonomic description available in our area. This study shows that the periphytic flora can vary in response to discharge and substrate sampled. The myriad of factors governing the periphytic flora at a variety of scales suggests that the variance at temporal scale in species composition is more interesting and this feature deserves further investigation with greater replication and extended sampling to evolve a holistic picture of the stream ecosystem.

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