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Research Article

Population structure and diversity of the periphyton community in the glacier-fed stream Balkhila at Siron from Garhwal Himalaya

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Abstract
The stream Balkhila is a glacier-fed and originates at higher altitudes from the Lal Mati glacier, flows through the famous Mandal valley of Garhwal Himalaya and finally merges with the Alaknanda River in Chamoli district of Uttarakhand. The present study aimed to assess the population structure, density and diversity of the periphyton community along with some detrimental ecological parameters in the glacier fed stream Balkhila for a period of two years on a monthly basis from November 2018 to October 2020. The stream Balkhila was represented by 17 periphytic genera belonging to 3 classes, namely, Bacillariophyceae, Chlorohyceae and Cyanophyceae. The class Bacillariophyceae was represented by 10 periphytic genera (*Cymbella, Navicula, Fragilaria, Nitzschia, Ampohora, Diatoma, Synedra, Tabellaria, Cocconeis* and *Meridion*), and Chlorophyceae (green algae) was represented by 6 algal genera (*Chlorella, Ulothrix, Zygnema, Oedogomium, Spirogyra* and *Stigeoclonium*). The class Myxophyceae was represented by a single genus (*Phormidium*). The maximum periphytic density (individuals/cm^2) was found to be 316.7±7.1 x 10^3 in January, and the minimum density (12.5±3.5 x 10^3) was recorded in August. The SIMPLER test indicated 18.58% dissimilarity of periphytic communities between the two years of study. The Shannon–Wiener diversity index values were high (2.358 and 2.388) in December and January and minimum (0.2484 and 0.3534) in July and August during the first and second years of the study, respectively. Multivariate canonical correspondence analysis (CCA) suggested that most of the periphytic genera were closely associated with the winter season (December, January and February). The various ecological parameters of our study indicated that the Balkhila stream is a conducive habitat for periphyton communities.

Keywords: Balkhila stream, Canonical correspondence analysis (CCA), Diversity, Glacier, Periphyton

INTRODUCTION

Periphyton is the benthic algal group found on various submerged objects (stone, wood, stick, etc.) in an aquatic ecosystem. Periphyton plays a crucial role in photosynthesis, the food chain, and the food web and acts as an important source of natural food for various aquatic organisms. Periphyton communities are the preferred food for fish (Srivastava, 2019; Bahuguna and Baluni, 2019, Bahuguna *et al.,* 2021) and benthic insects (Bahuguna and Negi, 2018; Bahuguna *et al.,* 2019). Periphyton diversity and distribution patterns greatly impact the occurrence of aquatic mites (Bahuguna and Dobriyal, 2020; Negi *et al.,* 2021). The density and distribution pattern of periphytic communities depends on the various abiotic factors of the aquatic environment. An optimum level of all the factors is very important for the proper growth and development of periphytic communities, and any perturbation in these factors can have negative consequences. According to Sharma *et al*., (2008) the combined impact of various physico-chemical factors in an aquatic ecosystem, viz. The current velocity of water, dissolved oxygen, water temperature, turbidity, hydromedian depth and total dissolved solids, influenced the diversity of periphyton. As pH increased, there was a decrease in periphytic community dominance, but taxonomic richness increased, and even the community composition became more variable (Bray *et al.,* 2008). They also found that the taxonomic richness of periphyton was low in the stream with low pH while studying the periphytic communities in the acid mine drainage impacted streams. Villeneuve *et al.* (2010) suggested that the changes in the periphyton community structure and diversity were related to physical factors with low-level differences. The higher discharge and turbidity of water during warmer months of the year reduces the light penetration, decreasing the growth of periphytic communities (Baba *et al.,* 2011).

Periphytic communities are a very important biological indicator of water pollution and are used for the assessment of water quality by several researchers all over the world. Most periphytic species have a short life cycle, and these communities respond to perturbations in the physico-chemical parameters of an aquatic ecosystem (Rosen, 1995). The morphological abnormalities in diatoms are crucial changes and can be used as effective tools for biomonitoring the heavy metal pollution of water (Pandey *et al.,* 2014). Singh *et al.* (2017) reviewed the biomonitoring of water pollution by using periphyton productivity. They concluded that environmental factors greatly influenced the growth of periphyton. Many researchers have successfully used diatoms as biological indicators of pollution worldwide (Wood *et al.,* 2019; Park *et al.,* 2020; Sigh and Parikh, 2020; Dalu *et al.,* 2020).

Several studies on the density, diversity and distribution patterns of algal communities have been carried out by several researchers in various streams and rivers throughout the world, but glacial streams have not been explored to a greater extent. Some of the important studies have been carried out by Niedrist *et al.* (2018) in Austrian streams, Kumar and Nautiyal (2019) in the Bhagirathi River, and Andino *et al.* (2021) in Tropical High-Andean streams.

As the periphytic communities are very important in aquatic ecosystems, there is a great need for significant ecological studies on their density, diversity, and distribution patterns. In India, studies on various aspects of periphytic communities have been carried out by several researchers (Nautiyal, 1986; Dobriyal and Singh, 1989; Khanna *et al.,* 1993; Nautiyal *et al.,* 1996, Badoni *et al.,* 1997; Nautiyal, 2005; Gurumayum and Goswami, 2013; Negi *et al.,* 2013; Harkal and Mokashe, 2015; Dutta *et al.,* 2018; Sagir and Dobriyal, 2020). The present work aimed to assess the periphytic variations and their relationship with the abiotic factors of the glacier-fed stream Balkhila.

MATERIALS AND METHODS

Study area

The stream Balkhila is glacier fed and is originates at a higher altitude from the Lal Mati glacier (Fig. 1). It is an important tributary of the Alaknanda River and joins the Chamoli district of Uttarakhand. It flows through the famous Mandal valley of Garhwal Himalaya before it merges with the Alaknanda River. The present study was carried out at Siron, which is located within a latitude of 30° 24' 22'' N and longitude 79° 18' 26'' E at an altitude of approximately 1061 masl. The sampling station Siron was selected for the present study because it is located at a higher altitude with minimum human interference. There is a mixed vegetation type in the catchment area supported by the alpine and subalpine forests on the peaks. Sampling was performed for a period of two years on a monthly basis from November 2018 to October 2020.

Analysis of physico-chemical parameters

The physico-chemical parameters of the stream viz. Water temperature, current velocity pH, dissolved oxygen, total alkalinity, total hardness and turbidity were analysed as per the standard methods suggested by Welch (1948) and APHA (2012). The surface water temperature was analysed by dipping the centigrade thermometer directly into the stream. The current velocity of the water was measured by the float method. In the float method, a light weight float is attached to the rope of 10-20 m length, which can be easily drifted along with water current, and then the float is released at a particular point in the stream and time is noted down, when the rope covered the full distance of its particular length again time is noted and finally the reading are converted into m/sec. The pH was recorded by a portable electronic pH meter (Hanna pHep pocket sized pH meter) on the spot. The dissolved oxygen was analysed on the spot by Winkler's method.

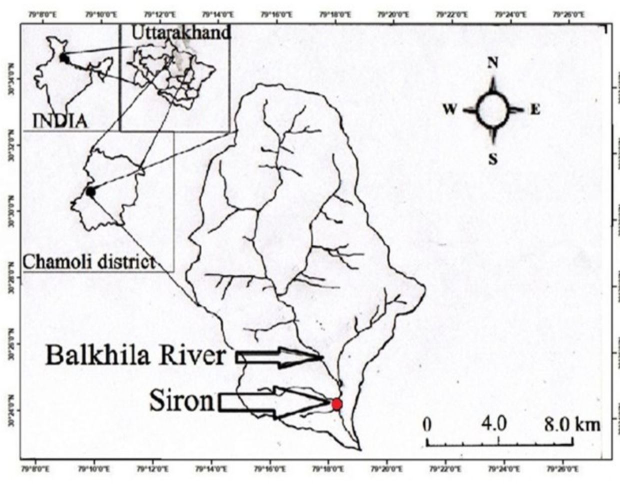

Fig. 1. *Location map of the study area*

Total alkalinity and total hardness were analysed by the Welch method. The turbidity was measured by using a digital turbidity meter (Model 331, Electronic India).

Analysis of periphyton

The periphyton samples (two to three replicates) were collected from the bottom substrates (pebble, cobble and stone) in a 1 cm^2 area with the help of a scrapper. Then, periphyton was carefully collected in a sample tube and preserved in 4% formalin. The preserved samples were then carried to the Departmental Laboratory of Zoology for further quantitative and qualitative analysis. The key morphometric parameters were the body organization, the shape of chloroplasts, cell wall characteristics, system and symmetry of raphe. Dilute HCl was also used for clarity in the case of diatom identification whenever required. Before analysis, the preserved sample was shaken thoroughly, and 1 ml of it was placed on a Sedgewick-Rafter counting slide. The analysis of periphyton was carried out by the formula mentioned below:

$$n = a \times c \times 1000 \qquad \text{Eq.1}$$

(where n = is the number of units of periphyton in a specified area (1 cm^2), a = average number of units in 1 chamber of 1 mm^3 capacity and **c** = total amount of preservative 50 ml or 100 ml). The identification of the different algal groups was carried out in the laboratory under a microscopic image processing system (MIPS) with the help of various standard keys and monographs (Edmondson, ed. Freshwater biology, 1992, Wards and Whipple 1992, APHA, 2012).

Statistical analysis

The statistical analysis was made by using Microsoft Excel 2007. Multivariate canonical correspondence analysis (CCA), cluster analysis and SIMPLER tests were performed by using Past 3 software. The other indices, such as the Shannon–Wiener diversity index and Sorenson similarity index, were also calculated by using Past 3 software.

RESULTS AND DISCUSSION

The average monthly variation in the physico-chemical parameters of the stream Balkhila at Siron during the year 2018-20 are given in Table 1. The stream's average maximum (18.05±4.6 °C) water temperature was found in June, whereas the minimum (10.25±0.07 °C) temperature was recorded in January. Similar trends of low temperature during winter months and high temperature during summer and monsoon months were also reported by Selakoti and Rao (2015) in the Kosi River and Bahuguna and Negi (2018) in the stream Kyunja Gad, Kumar and Nautiyal (2019) in the Bhagirathi River. The stream's water temperature was lower than a typical spring-fed river because of the glacier at the snout. The average current velocity of the water was found to be maximum (1.59±0.01 m/sec.) in July and minimum (0.51±0.01 m/sec.) in January. Similar trends of high current velocity during the monsoon were also reported by Singh and Agarwal (2014) in the Assiganga stream and Bisht *et al.* (2019) in the Pinder River. Current velocity is an important factor in aquatic ecosystems, as it greatly influences biota. Biggs and Gerbeaux (1993) found that there is a peak in the biomass of periphytic communities where the current velocity is intermediate. The pH of the stream was highest (8.10±0.0) in January and lowest (7.20±0.14) in July. Several researchers have suggested that pH is high during winter months (7.9-8.2) due to algal growth

Table 1. Average monthly variations in the physico-chemical parameters of the stream Balkhila at Siron during the two years of study 2018-20

Months	WT (^{0}C)	CV (m.sec^{-1})	pH	DO (mg.l^{-1})	TA (mg.l^{-1})	TH (mg.l^{-1})	T (NTU)
Nov.	12.70±0.0	0.74±0.12	7.85±0.07	12.95±0.35	46.3±0.14	70±2.83	23±1.41
Dec.	11.05±0.07	0.62±0.01	7.85±0.07	13.15±0.07	52.4±0.57	75±1.41	7.5±0.71
Jan.	10.25±0.07	0.51±0.01	8.10±0.0	13.70±0.28	54.1±0.14	77±1.41	5.0±0.0
Feb.	13.15±0.07	0.53±0.01	8.0±0.14	11.80±0.14	48.3±0.14	72±2.83	6.5±0.71
Mar.	14.30±0.0	0.63±0.03	7.85±0.21	11.0±0.28	49.0±0.28	59±1.41	10.5±2.12
Apr.	16.05±0.21	0.71±0.01	7.70±0.14	10.55±0.64	39.4±4.45	57±1.41	12.5±0.71
May	16.70±1.84	0.88±0.11	7.70±0.42	9.40±0.0	37.8±2.26	54±2.83	15.5±0.71
Jun.	18.05±4.60	1.25±0.06	7.25±0.07	9.25±0.07	33.1±1.27	56±2.83	30.0±2.83
Jul.	17.30±3.82	1.59±0.01	7.20±0.14	9.15±0.07	32.8±0.57	59±1.41	34.0±2.83
Aug.	15.45±1.77	1.56±0.04	7.25±0.07	9.25±0.07	35.3±0.99	61±1.41	68.0±8.49
Sep.	15.10±1.56	1.54±0.03	7.45±0.07	9.35±0.07	33.4±0.85	63±1.41	66.0±14.1
Oct.	13.75±0.21	0.89±0.12	7.60±0.14	12.75±1.48	38.1±5.52	65±1.41	36.0±0.0

WT= water temperature, CV= current velocity, DO= dissolved oxygen, TA= total alkalinity, TH= total hardness, , T= turbidity and low (7.2-7.4) during the monsoon season (Dobriyal and Singh, 1988; Singh *et al.,*1994; Bahuguna and Dobriyal, 2018).

The dissolved oxygen content of water was found to be maximum (13.70± 0.28 mg.l^{-1}) in January and minimum (9.15±0.07 mg. l^{-1}) in July. High dissolved oxygen during winter months and low during monsoon months were also reported by Sharma and Sharma (2016) in the Alaknanda River and Matta *et al.* (2020) in the Henwal River. The dissolved oxygen of water is crucial for aquatic organisms, and any abrupt decrease in it would be lethal. Total alkalinity is another essential factor in an aquatic ecosystem and neutralizes the acid present. The total alkalinity of the stream was found to be maximum (54.1±0.14 mg.l^{-1}) in January and minimum (32.80±0.57 mg.l^{-1}) in the month of July. Similar results in alkalinity were also reported by Dobriyal (1983) and Selakoti and Rao (2015). Total hardness is a crucial factor representing the calcium and magnesium ions present in water. The total hardness of the stream was high (77±1.41 mg.l^{-1}) in January and low (54±2.83 mg.l^{-1}) in May. Bahuguna and Negi (2018) found that the total hardness was high (134.5 mg.l^{-1}) during winter in January. The turbidity of the stream was recorded at a maximum (68±8.49 NTU) in August and minimum (5±0.0 NTU) in January, which corroborates the findings of Sharma and Sharma (2016), and Rana *et al.* (2016) in the Alaknanda River and Bisht, *et al.,* (2019) in the Pinder River. An increase in turbidity during the monsoon season is due to the influx of soil and other materials after flash floods.

The stream Balkhila was represented by 17 periphytic genera belonging to 3 classes, namely, Bacillariophyceae (*Cymbella, Navicula, Fragilaria, Nitzschia, Ampohora, Diatoma, Synedra, Tabellaria, Cocconeis* and *Meridion*), Chlorophyceae (*Chlorella, Ulothrix, Zygnema, Oedogomium, Spirogyra* and *Stigeoclonium*) and Cyanophyceae (*Phormidium*). The average monthly density of periphyton in stream Balkhila at Siron during 2018-20 is presented in Table 2. The maximum periphytic density (individuals/cm^2) was found to be 316.7±7.1 x 10^3 in January, and the minimum density (12.5±3.5 x 10^3) was recorded during the monsoon in August. The maximum density during the winter months (December, January and February) was due to the stable environmental factors, and the density was minimum during the monsoon (July, August and September) due to the perturbed ecological setup. Similar trends of fluctuation in the periphytic density were also reported by Baba *et al.* (2011) in the river Sindh and Moza (2014) in the river Ravi. The class Bacillariophyceae was dominant in the stream, followed by Chlorophyceae and Cyanophyceae. The dominance of periphytic communities belonging to Bacillariophyceae was also reported in the glacier-fed streams of the Himalayan region by Rashid and Pandit (2008) in the Sindh River, Sharma *et al.* (2008) in the Bhagirathi River, and Srivastva *et al.* (2019) in the Ganga River. Similar trends of dominance were also reported in the spring-fed Himalayan streams by Baluni *et al.* (2017) in the Laster Gad stream, Baluni *et al.* (2018) in the Khankra stream, and Bahuguna *et al.* (2021) in the Mal Gad stream of Garhwal Himalaya.

The average dissimilarity of periphyton of the stream Balkhila at Siron between the two years of study 2018-20 are given in Table 3. The overall average dissimilarity of periphyton between the two years of the study was 18.58%. The values of the Sorenson similarity index during the first and second years of the study are mentioned in Tables 4 and 5. The maximum similarity was

Table 2. Average monthly density of periphyton of the stream Balkhila at Siron during the two years of study 2018-20 (units x 10^3. cm^{-2})

Months	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total periphyton
NOV.	184.2±1.2	14.2±8.3	2.5±1.1	200.9±5.9
DEC.	220±16.5	14.2±5.9	6.7±4.7	240.9±15.3
JAN.	285±14.1	24.2±12.9	7.5±8.2	316.7±7.1
FEB.	234.2±17.7	12.5±5.9	6.7±9.4	253.3±21.2
MAR.	161.7±4.7	5.9±5.9	0.9±1.2	168.3±0.0
APR.	112.1±11.2	2.9±4.1	Nil	115.0±7.1
MAY.	48.4±2.3	0.9±1.2	Nil	49.2±3.5
JUN.	36.7±2.3	0.9±1.2	Nil	37.5±3.5
JUL.	30±7.1	Nil	Nil	30±7.1
AUG.	12.5±3.5	Nil	Nil	12.5±3.5
SEP.	41.7±11.8	0.9±1.2	Nil	42.5±13
OCT.	131.7±33	7.5±8.2	Nil	139.2±41.2

Table 3. Average dissimilarity of periphyton of the stream Balkhila at Siron between two years of study 2018-20

Taxon	Av. dissim	Contrib. %	Cumulative %	Abundance 2018-19	Abundance 2019-20
Diatoma	3.645	19.62	19.62	162	281
Synedra	3.247	17.48	37.09	250	144
Cymbella	2.831	15.24	52.33	305	398
Nitzschia	2.748	14.79	67.12	222	132
Cocconeis	1.564	8.417	75.54	56.7	108
Ulothrix	0.8386	4.513	80.05	13.4	40.8
Navicula	0.6886	3.706	83.76	260	238
Spirogyra	0.6397	3.443	87.2	0	20.9
Zygnema	0.5081	2.734	89.94	5	21.6
Fragilaria	0.4101	2.207	92.14	90	103
Phormidium	0.3581	1.927	94.07	30	18.3
Chlorella	0.3091	1.664	95.73	11.7	21.8
Tabellaria	0.2571	1.384	97.12	132	123
Oedogonium	0.2051	1.104	98.22	5	11.7
Meridion	0.1285	0.6918	98.91	13.4	9.2
Stigeoclonium	0.1255	0.6753	99.59	10	5.9
Amphora	0.07652	0.4118	100	11.7	14.2
Overall average dissimilarity	18.58				

Table 4. Sorensen similarity index of periphyton between different months in the Balkhila stream at Siron during the year 2018-2019

MONTHS	NOV.	DEC.	JAN	FEB	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.
NOV.	1	0.929	0.867	0.897	0.846	0.600	0.632	0.267	0.267	0.267	0.375	0.762
DEC.		1	0.938	0.903	0.857	0.545	0.571	0.235	0.235	0.235	0.333	0.696
JAN			1	0.970	0.867	0.583	0.522	0.211	0.211	0.211	0.300	0.640
FEB				1	0.897	0.609	0.545	0.222	0.222	0.222	0.316	0.667
MAR.					1	0.700	0.632	0.267	0.267	0.267	0.375	0.667
APR.						1	0.769	0.444	0.444	0.444	0.400	0.800
MAY.							1	0.500	0.500	0.250	0.667	0.857
JUN.								1	0.500	0.000	0.400	0.400
JUL.									1	0.500	0.000	0.400
AUG.										1	0.000	0.400
SEP.											1	0.545
OCT.												1

found between the winter months during both years of the study. This is because similar conducive environmental characteristics during different sampling periods show close positive similarities. Similar trends in similarity were also found by Dobriyal *et al.* (2011) in the Nayar River of Garhwal Himalaya during the close winter months.

The values of the Shannon–Wiener diversity index during both study years are presented in Figs. 2 and 3. The Shannon–Wiener diversity index values were high (2.358 and 2.388) during winter in December and January and minimum (0.2484 and 0.3534) during the monsoon in July and August during the first and second years of the study, respectively. This indicates a good diversity of species in winter months and limited diversity in the monsoon months. The multivariate cluster analysis showing the similarity of periphyton during different seasons is presented in Fig. 4. The dendrogram formed thus suggested that summer and monsoon were similar and spring and autumn were also similar. The winter season is different from these similar kinds of groups.

The canonical correspondence analysis (CCA) of periphyton among different seasons during both years of the study is presented in Figs. 5 and 6. During the first year of study 2018-2019, axes 1, 2, 3 and 4 represent-

Table 5. Sorensen similarity index of periphyton between different months in the Balkhila stream at Siron during 2019-20

MONTHS	NOV.	DEC.	JAN	FEB	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.
NOV.	1	0.741	0.815	0.800	0.769	0.769	0.800	0.667	0.308	0.308	0.500	0.667
DEC.		1	0.938	0.867	0.903	0.903	0.640	0.522	0.222	0.111	0.381	0.828
JAN			1	0.933	0.903	0.903	0.720	0.609	0.222	0.222	0.476	0.828
FEB				1	0.897	0.897	0.783	0.667	0.250	0.250	0.526	0.815
MAR.					1	1	0.750	0.636	0.235	0.235	0.400	0.857
APR.						1	0.750	0.636	0.235	0.235	0.400	0.857
MAY.							1	0.875	0.364	0.364	0.571	0.818
JUN.								1	0.444	0.444	0.667	0.700
JUL.									1	0.500	0.286	0.267
AUG.										1	0.286	0.267
SEP.											1	0.556
OCT.												1

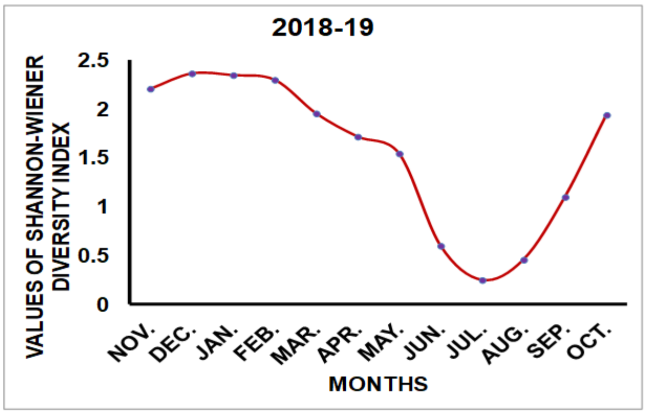

Fig. 2. *Shannon-Wiener diversity index values of stream Balkhila at Siron during 2018-2019*

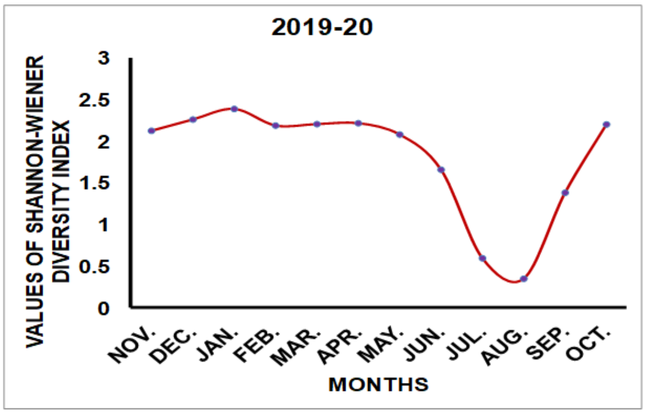

Fig. 3. *Shannon-Wiener diversity index values of stream Balkhila at Siron during 2019-20*

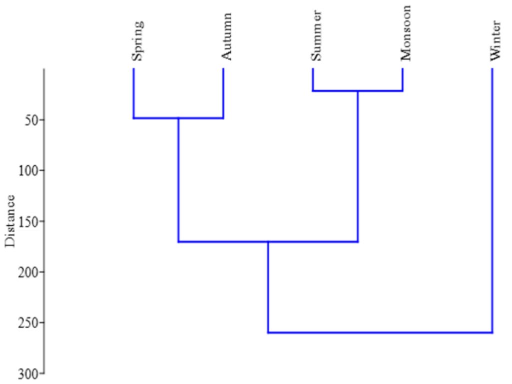

Fig. 4. *Cluster analysis showing the similarity of periphyton among different seasons in the Balkhila stream at Siron during the year 2018-20 (Average values)*

ed 49.8%, 24.06%, 15.18% and 10.97% of the variance with eigenvalues of 0.068, 0.032, 0.020 and 0.015, respectively. The winter season was associated with the genera *Fragilaria, Ulothrix, Chlorella, Meridion, Amphora, Cocconeis, Zygnema and Phormidium* and was governed by the factors dissolved oxygen, total hardness and total alkalinity. This is because in winter, environmental characteristics such as high DO contents, a good amount of algal carpets in the stream, complete solar penetration and high alkalinity supported the growth of these periphytic species. The autumn and monsoon seasons were associated with *Navicula*, *Diatoma* and *Tabellaria* which are more tolerant species. The spring season was associated with *Synedra* and *Cymbella* and governed by water temperature. The monsoon season was strongly associated with current velocity and turbidity. During the second year of study 2019-2020, axes 1, 2, 3 and 4 represented 43.87%, 26.43%, 19.9% and 9.79% of the variance with eigenvalues of 0.051, 0.031, 0.023 and 0.011, respectively. The winter season was associated with *Fragilaria, Amphora, Spirogyra, Zygnema, Phormidium, Diatoma and Cocconeis* and governed by dissolved oxygen, total hardness, pH and total alkalinity. The autumn, spring and summer seasons were associated with *Oedogonium, Chlorella* and *Synedra* and governed by water temperature. The monsoon season was loosely associated with *Cymbella* and *Tabellaria*. The monsoon season was strongly associated with current velocity and turbidity. During both years of the study, it was found that the maximum periphytic genera were associated with the winter season because of the stable environment with no disturbances due to natural or anthropogenic interferences, whereas the least diversity occurred in

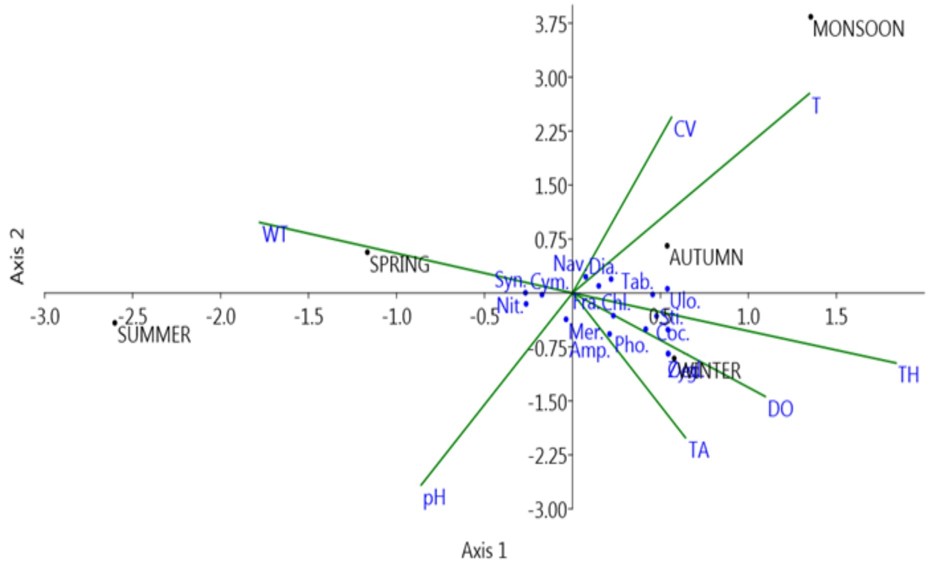

Fig. 5. *Canonical correspondence analysis (CCA) of periphyton among different seasons in the Balkhila stream at Siron during 2018-2019*

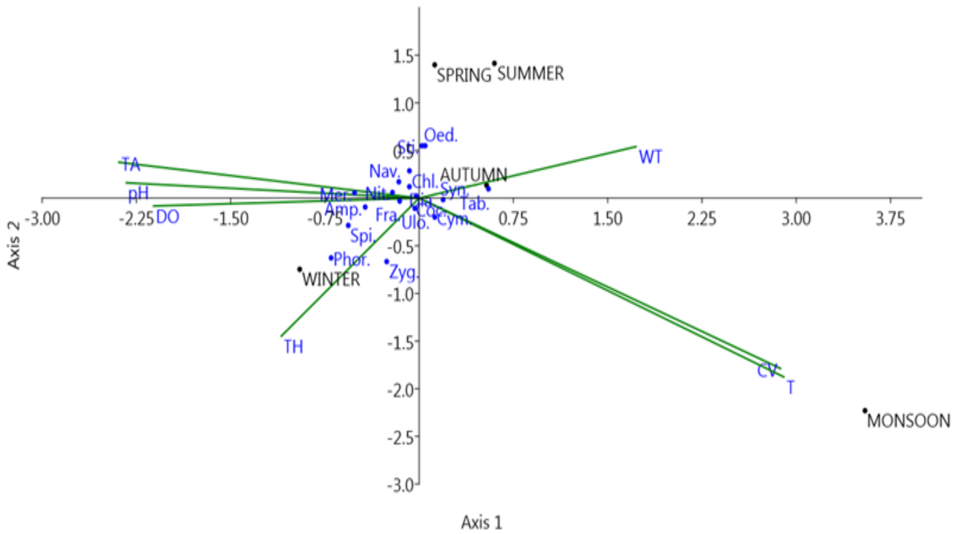

Fig. 6. Canonical correspondence analysis (CCA) of periphyton among different seasons in the Balkhila stream at Siron during 2019-20. *Acronyms: Cym.= Cymbella, Fra.= Fragilaria, Nit. = Nitzschia, Amp.= Amphora, Dia.= Diatoma, Syn. =Synedra, Tab.= Tabellaria, Coc.= Cocconeis, Mer.= Meridion, Chl.= Chlorella, Ulo.= Ulothrix, Zyg.= Zygnema, Oed.= Oedogonium, Sti.= Stigeoclonium, Spi= Spirogyra Pho.= Phormidium.*

the monsoon season due to the perturbed ecological setup (disturbances created due to the influx of soil, and pollutants and high velocity due to natural processes such as flash floods and soil erosion). The CCA was also performed by Kumar and Nautiyal (2019), Sagir and Dobriyal (2020), and Tariq *et al*. (2020) to study the lineage of physico-chemical parameters towards the different benthic communities in the Garhwal Himalayan Rivers. They found that the CCA plot clearly depicted the lineage of different physico-chemical parameters towards the benthic biota.

Conclusion

The present study concluded that stream Balkhila (Chamoli Garhwal, Uttarakhand) provides conducive habitats for periphytic communities. All the periphytic communities flourish well during the winter season (December, January and February). The maximum density and diversity of the periphyton were reported during the winter months because, during that period, all the abiotic factors (water temperature, dissolved oxygen, pH, current velocity, total alkalinity, total hardness and turbidity) were at an optimum level, which could promote the growth of periphytic communities, whereas, during monsoon season (July, August and September), environmental disturbances were responsible for the least growth of the same, and after the harsh environmental conditions (created due to the natural disruptive phenomenon), the stream showed quick recovery.

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Conflict of interest

The authors declare that they have no competing interests.

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