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DISTRIBUTION PATTERNS AND DIVERSITY OF PERIPHYTON COMMUNITY IN THE GLACIER FED STREAM BALKHILA AT TILFARA FROM GARHWAL HIMALAYA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Author MT designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors CBK, AKD and ST managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The present study aims to assess the distribution patterns, density, diversity and ecology of periphyton community in the Balkhila stream which is a glacier fed tributary of the Alaknanda river in Chamoli district of Uttarakhand. Periphyton are the algal communities attached to various submerged objects and contribute as food for zoobenthos and nektonic communities as well as a primary producer in an aquatic ecosystem. Population structure of the stream was represented by total 16 periphytic genera belonging to 3 classes viz., Bacillariophyceae (*Cymbella, Navicula, Fragilaria, Nitzschia, Amphora, Diatoma, Synedra, Tabellaria, Cocconeis* and *Meridion*), Chlorophyceae (*Chlorella, Ulothrix, Zygnema Oedogonium* and *Spirogyra*) and Myxophyceae (*Phormidium*). Bacillariophyceae emerged as dominating periphyton class throughout the year. Shannon- Wiener diversity Index and Margalef Index depicted that winter months were more conducive for the growth of periphyton. The multivariate SIMPLER test was performed to show the dissimilarity of periphyton. The multivariate cluster analysis among seasons was also performed. To study the abundance and distribution of periphytic communities in relation to various abiotic factors on seasonal basis, the multivariate canonical correspondence analysis (CCA) was performed.

Keywords: Periphyton; balkhila; stream; glacier fed; CCA.

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1. INTRODUCTION

Periphyton is one of the crucial component among all benthic biota in an aquatic ecosystem as it not only provides food for benthic and nektonic communities, but also gives life to the ecosystem by giving oxygen after photosynthesis. Periphytic communities are self regulatory having its own cycle of abundance and plays important role in trophic structure and function [1]. Periphytic studies have been carried out worldwide due to their important role in aquatic ecosystems [2]. The taxonomic diversity of periphyton in rivers reflects the characteristics of geographical location and landscape of the region [3]. Biggs [4], described that in fast flowing rivers, periphytic communities of oligotrophic habitats as a primary producers plays crucial role in food web due to transformation of energy. According to Cummins et al. [5], the geology and climate are two important factors which influence the various characteristics of river basin and thereby the type and density of vegetation of the region.

Periphyton are also well studied as water quality indicators [6,7,8,9]. Some of the forms are good water quality indicators while others grow enormously in deteriorating water quality. Segura et al. [10], while working on the epilithic diatoms in Upper Lerma river in Mexico illustrated that *Amphora pediculus* and *Eolimna tantula* are the indicators of clean water and *Nitzschia palea* and *Gomphonema parvullum* are the pollution indicator species. Sczepocka and Szulc [11], described *Cocconeis placentula* and *Planothedium rostratum* as highly sensitive species to contamination in Pilica river in Poland. According to Rai et al. [12], benthic algae plays an important role and have great potential in biomonitoring the water quality due to their cosmopolitan nature, easy availability, short life span and very sensitive to various environmental and human perturbations. Various ecological factors in an aquatic environment viz. water temperature, light availability, grazing and other physical disturbances are responsible for enhancing or limiting the algal growth, distribution and can be studied through different experimental approaches and setups [13]. Studies on the effect of various abiotic factors on the population structure, distribution and abundance of different benthic communities in the Himalayan rivers have been carried out by Kumar and Nautiyal [14], Sagir and Dobriyal [15] and Tariq et al. [16].

In Uttarakhand, work on periphyton has been carried out by some researchers. The extensive work on periphyton has been carried out in Eastern Nayar [17,18,19], Western Nayar [15,20], Alaknanda river system [21], Ganga river system [22], Laster Gad stream [23], Khankra [24] and Mal Gad [25].

The present study is carried out to explore the diversity and dynamics of periphytic communities of glacier fed stream Balkhila from Garhwal Himalaya and to portray accurately the relationship among various physico-chemical factors with benthic population. A survey of review literature indicated that no work has been conducted on the ecology and biodiversity of high altitude glacier-fed streams in the upper reaches where there is least anthropogenic interference. Present study is a part of this project in which an attempt has been made to study the ecology and biodiversity of the Balkhila stream from Chamoli Garhwal Himalaya and to portray accurately the effect of various physico-chemical factors on their growth and diversity. As we know that periphytic population is sensitive to water quality, we can compare our study with other organically enriched streams.

2. MATERIALS AND METHODS

2.1 Study Area

The Balkhila river is a high altitude glacier fed tributary of Alaknanda river in Chamoli Garhwal, Uttarakhand. The Tilfara spot of the Balkhila stream was sampled for a period of two years from November 2018 to October 2020. The Tilfara spot is situated an altitude of 932 masl within a latitiude of 30^0 23' 17" N and longitude 79^0 19' 15" E . The spot is represented by some mixed riparian vegetation on both the side (Fig. 1).

2.2 Water quality analysis (Physico-chemical parameters)

All the physico-chemical parameters (Water temperature, water current velocity, dissolved oxygen, pH, turbidity, total alkalinity and total hardness) were analyzed on monthly basis from 2018-20. Surface water temperature of the stream was analyzed by using thermometer having centigrade division. The current velocity of water was estimated on the spot by float method, in this method a light weight plastic float tied on a rope and allowed to flow with water up to known distance and velocity was calculated accordingly ($m.sec^{-1}$). An electronic portable pH meter was used for on the spot pH determination. The estimation parameters like DO (dissolved oxygen), TA (total alkalinity) and TH (total hardness) were assessed by the standard methods [26]. The turbidity of water was analyzed in the laboratory using Nephelometer.

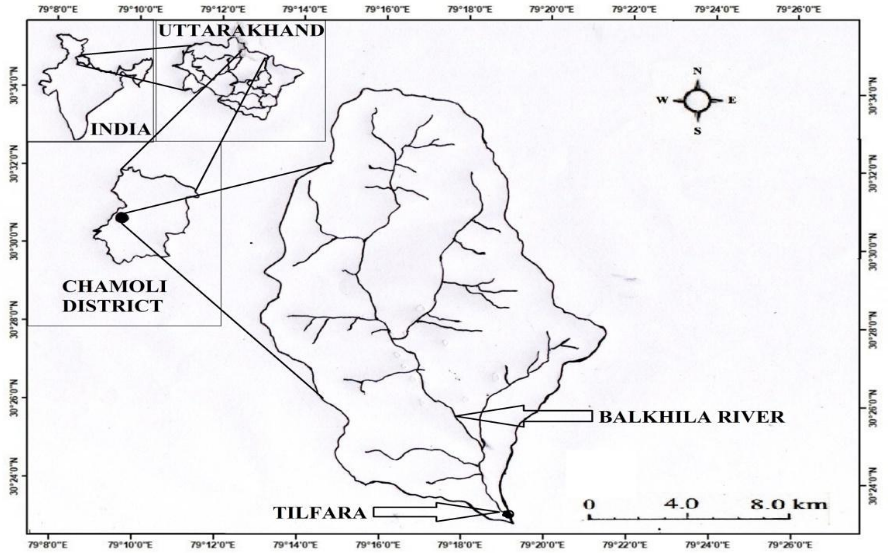

Fig. 1. Map showing study site in the Balkhila stream, Chamoli Uttarakhand

2.3 Periphyton Sampling

Two to three replicate samples of periphyton were collected with the help of scrapper from 1 cm^2 area from stones or other submerged objects depending upon their density and preserved in 4% formalin. The 1 cm^2 area was measured with help of scale. The collected samples were then carried to the laboratory and were analysed with the help Sedgwick-Rafter counting chamber by using the following formula:

$$n = a \times 1000 \times c$$

(Where n = Number of periphyton per cm^2 area, a = average number of periphyton in one chamber and c = total amount of preservative i.e. 50ml). Qualitative analysis of periphyton was done with the help of different keys and monographs using cladistic analysis [26,27]. The key morphometric parameters as per cladistic analyses were body organization, shape of chloroplasts, cell wall characters, system and symmetry of raphe, etc. In case of diatom identification, dilute HCl was also used for clarity whenever required.

2.4 Use of Statistical Tools

For the statistical analysis of data computer software such as Microsoft excel 2007 and Past 3 were used. The diversity Indices such as Shannon Wiener diversity Index and Margelef Index was calculated by using Past 3 software. The Past 3 Software was also used to perform the multivariate tests such as SIMPLER test, cluster analysis and canonical correspondence analysis (CCA).

3. RESULTS AND DISCUSSION

The average monthly variations in the physico-chemical factors of the Balkhila stream during the two years of study from November 2018 to October 2020 is presented in the Table 1. The average maximum (19.0 ^{0}C) water temperature of the stream was found in the month of June and minimum (10.75 ^{0}C) water temperature was found to be in the month of January. In general the glacial streams are represented by very low water temperature due to emergence of melt water from the glacier snout [28]. Fureder [29], also observed that in kryal streams temperature reaches to only few degrees Celsius due to their proximity to glaciers. The temperature of stream was higher because the study area is located far from the glacier snout. The current velocity of water was peak (1.7 m/sec.) in July and least (0.59 m/sec.) was reported in the month of January which corroborates the finding of Bisht et al. [30], in the Pinder river. The pH of the stream was found to be high (8.30) in January and low (7.25) in July. Singh et al. [31], have found that the high pH in winter season was due to the growth of periphyton and low in monsoon months due to acidic nature of rain water. The dissolved oxygen of the stream estimated maximum (13.15 mg.l^{-1}) in January and minimum (9.0 mg. l^{-1}) was found in the month of June. The high DO during winter months was also reported by Lencioni and Spitale [32], in the glacier fed stream at Italian Alps. The total alkalinity of the stream was peak (63.50 mg. l^{-1}) in January and least (32.20 mg.l^{-1}) was estimated in the month of June. The total hardness of the stream was recorded maximum (76 mg. l^{-1}) in December and minimum (55 mg. l^{-1}) in May. The turbidity of the stream was found to be maximum (69 NTU) in the month of August and minimum (6.5) in the month of January. Uehlinger et al. [33], suggested that the glacier fed streams are characterised by high turbidity as compared to the non glacial streams. They reported average annual turbidity of 125±128 NTU in glacier fed streams which was maximum during monsoon between June and mid September. Glacial melt water greatly influenced the physico-chemical factors (turbidity, water temperature and sediment transport) of the stream, [28,34,35]. Similar fluctuation in turbidity was reported in many Himalayan rivers [36,37,38].

The periphyton diversity of the Balkhila stream consisted of 16 genera belonging to 3 classes viz. Bacillariophyceae with 10 genera (*Cymbella, Navicula, Fragilaria, Nitzschia, Amphora, Diatoma, Synedra, Tabellaria, Cocconeis and Meridion*), Chlorophyceae with 5 genera (*Chlorella, Ulothrix, Zygnema, Oedogonium* and *Spirogyra*) and Myxophyceae with single genus (*Phormidium*). The average monthly density of periphyton communites of the Balkhila stream during the two years of study from November 2018 to October 2020 is mentioned in the Table 2. The periphyton density of the stream (Individuals/cm^2) was found to be maximum (251.7±21.2 x 10^3) in January whereas, the density was minimum (10±7.1 x 10^3) in July. The glacier-fed streams generally harbour low biodiversity due to cold water, turbulence and high current velocity but it has some specific species which are rarely available in moderately warm waters [39]. In Balkhila stream the Bacillariophyceae was the most diverse class than Chlorophyceae and Myxophyceae. The density of periphton was maximum during winter (which is due to low temperature, high dissolved oxygen, low current velocity and low turbidity) and minimum during monsoon. Nautiyal et al. [22], found the same trend of season specific variations of periphytic population in various tributaries of river Ganga and Kumar [40], in the glacier fed river Goriganga at Pithoragarh. The class Bacillariophyceae was dominant in the stream which corroborates the finding of Baluni et al. [24] and Bahuguna et al. [25].

Table 1. Average Monthly variations in the physico-chemical parameters of the Balkhila stream during two years of study (November 2018 to October 2020)

Months	WT (^{0}C)	CV (m.sec^{-1})	pH	DO (mg.l^{-1})	TA (mg.l^{-1})	TH (mg.l$^{-1)}$	T (NTU)
Nov.	13.10	0.84	7.95	12.80	45.40	71	25.5
Dec.	11.80	0.68	8.20	12.80	51.20	76	7.0
Jan.	10.75	0.59	8.30	13.15	63.50	75	6.5
Feb.	13.75	0.60	8.15	11.05	48.90	70	6.5
Mar.	14.60	0.63	7.85	10.75	46.10	59	13.0
Apr.	16.25	0.76	7.75	10.20	39.10	57	15.0
May	17.20	0.98	7.85	9.25	38.90	55	19.0
Jun.	19.00	1.26	7.40	9.00	32.20	57	33.0
Jul.	18.25	1.70	7.25	9.05	33.10	61	37.0
Aug.	16.35	1.68	7.55	9.05	33.50	63	69.0
Sep.	15.30	1.61	7.85	9.15	33.60	62	66.5
Oct.	13.80	0.97	7.70	12.20	42.20	67	36.0

WT = Water temperature, CV = Current velocity, DO = Dissolved oxygen, TA = Total alkalinity, TH = Total hardness, , T = Turbidity

Table 2. Average density of periphyton of the Balkhila stream during two years of study November 2018 to October 2020 (units x 10^3. cm^{-2})

Months	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total periphyton
NOV.	130±11.7	7.5±5.9	2.5±1.1	140±18.8
DEC.	192.5±24.7	9.2±5.9	2.5±1.1	204.2±17.7
JAN.	238.3±21.2	13.3±0.0	nil	251.7±21.2
FEB.	186.7±4.7	9.2±1.2	nil	195.8±3.5
MAR.	121.7±11.8	2.5±1.1	nil	124.2±12.9
APR.	93.8±11.2	2.1±0.6	nil	95.8±10.6
MAY.	39.2±3.5	1.7±0.0	nil	40.8±3.5
JUN.	28.4±11.8	1.7±0.0	nil	30±11.7
JUL.	10±7.1	nil	nil	10±7.1
AUG.	10.9±1.2	nil	nil	10.9±1.2
SEP.	28.4±2.3	1.7±0.0	nil	30±2.4
OCT.	83.4±18.9	3.4±4.7	0.9±1.2	87.5±13.0

The average dissimilarity of periphyton of the stream Balkhila at Tilfara between two years of study 2018-20 is presented in the Table 3. The overall average dissimilarity of periphytic communities was found to be 11.41% between first and second year of study.

The Shannon-Wiener and Margalef diversity Index values of the Balkhila stream during the two years of study from November 2018 to October 2020 is given in Table 4. The Shannon-Wiener diversity Index values were found high (2.334 and 2.261) in the month of December and January and low (0.5269 and 0.641) in the month of July during the first and second year of study. The Margalef Index values were found high (2.679 and 2.616) in the month of December and low (0.3789 and 0.417) in the month of July and August during the first and second year of study. According to Kocatas [41], the range of this index is from 0-5, but generally it ranges between 1.5 - 3.5. Index values above 3 shows established stable ecosystem and below 1 indicates for habitat degradation and pollution.

The Regression plot of various physico-chemical parameters with periphyton abundance of the Balkhila stream during the two years of study from November 2018 to October 2020 is given in Fig. 2 to 7. The stream's water temperature (R^2= 0.7792, r= -0.883) and current velocity (R^2= 07229, r = -0.85) represented inverse relation with periphyton abundance whereas, pH (R^2= 0.7793, r= 0.883), dissolved oxygen (R^2= 0.7484, r= 0.865), total alkalinity (R^2= 0.9248, r= 0.962) and total hardness (R^2= 0.6193, r= 0.787) of the stream represented positive relation with periphyton abundance. The response of the periphytic communities varied differently to the river flow and the sampling of the substrate type [42].

Table 3. Average dissimilarity of periphyton of the stream Balkhila between two years of study (November 2018 to October 2020)

Taxon	Av. dissim	Contrib. %	Cumulative %	Abundance 2018-19	Abundance 2019-20
Diatoma	3.926	34.41	34.41	83.4	179
Nitzschia	1.576	13.81	48.22	123	84.9
Fragilaria	1.093	9.58	57.8	48.3	75
Synedra	0.8843	7.75	65.55	172	150
Cocconeis	0.61	5.346	70.9	113	98.4
Spirogyra	0.5813	5.095	76	0	14.2
Chlorella	0.4749	4.162	80.16	26.8	15.2
Tabellaria	0.4421	3.875	84.03	105	116
Cymbella	0.4135	3.624	87.66	267	277
Navicula	0.3439	3.014	90.67	195	187
Oedogonium	0.2784	2.44	93.11	3.3	10.1
Zygnema	0.2702	2.368	95.48	3.4	10
Ulothrix	0.2088	1.83	97.31	13.4	8.3
Meridion	0.1392	1.22	98.53	10	13.4
Amphora	0.09825	0.8611	99.39	13.5	15.9
Phormidium	0.0696	0.61	100	5	6.7
Overall average dissimilarity	11.41				

Table 4. Shannon-Wiener and Margalef diversity Index values of the Balkhila stream during the two years of study (November 2018 to October 2020)

	2018-19		2019-20	
	Shannon-Wiener Index	**Margalef Index**	**Shannon-Wiener Index**	**Margalef Index**
NOV.	2.097	2.294	2.3	2.994
DEC.	2.334 P	2.679 P	2.214	2.616 P
JAN.	2.235	2.205	2.261 P	2.335
FEB.	2.012	1.896	2.099	2.099
MAR.	2.026	1.915	2.011	1.852
APR.	1.944	1.954	2.067	2.257
MAY.	1.94	2.25	1.889	2.184
JUN.	1.848	2.038	1.63	1.688
JUL.	0.5269 F	0.3789 F	0.641 F	0.7213
AUG.	1.248	1.443	0.6826	0.417 F
SEP.	1.698	2.203	1.31	1.176
OCT.	1.751	1.761	1.886	2.797

P= PEAK, F= FALL

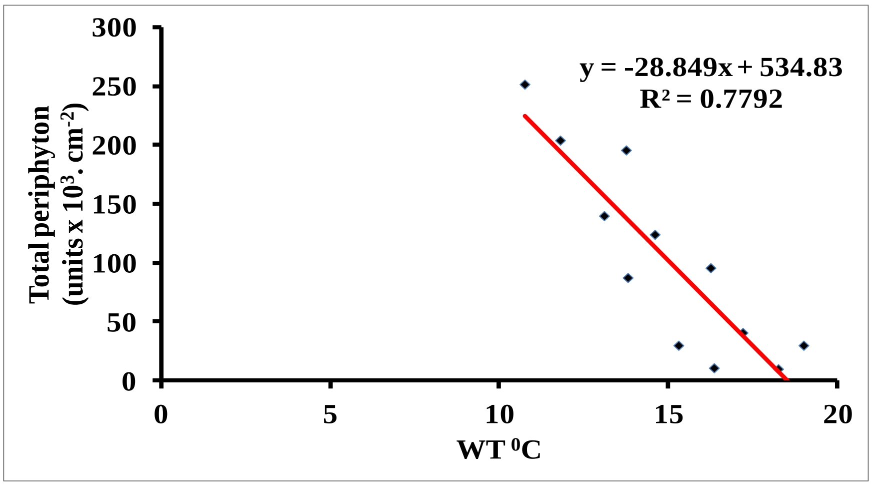

Fig. 2. Regression plot of WT (water temperature) with periphyton abundance of the Balkhila stream during two years of study from November 2018 to October 2020

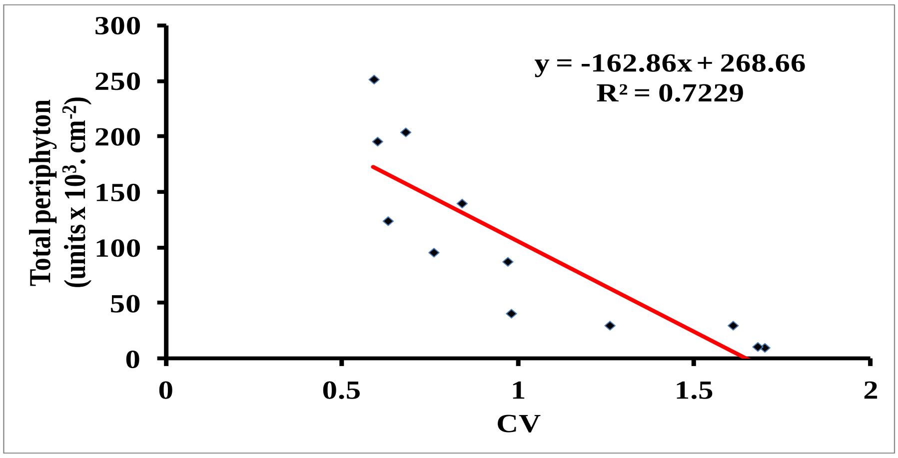

Fig. 3. Regression plot of CV (current velocity) with periphyton abundance of the Balkhila stream during two years of study from November 2018 to October 2020

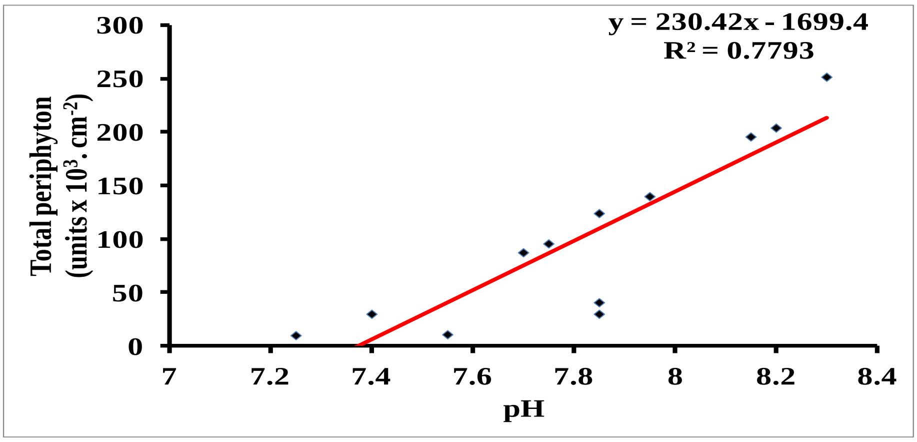

Fig. 4. Regression plot of pH with periphyton abundance of the Balkhila stream during two years of study from November 2018 to October 2020

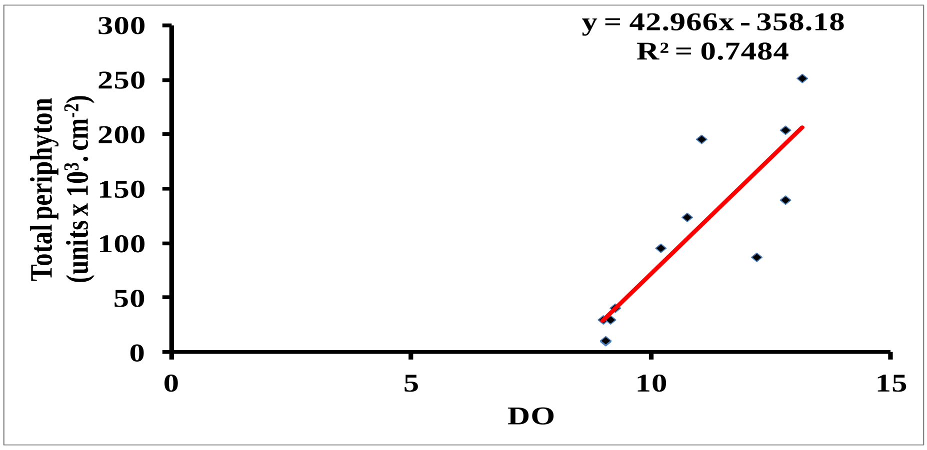

Fig. 5. Regression plot of DO (dissolved oxygen) with periphyton abundance of the Balkhila stream during two years of study from November 2018 to October 2020

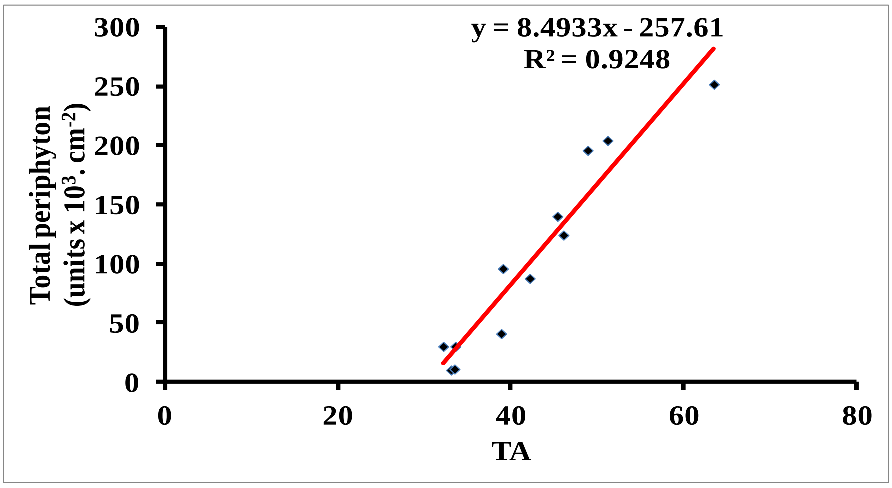

Fig. 6. Regression plot of TA (total alkalinity) with periphyton abundance of the Balkhila stream during two years of study from November 2018 to October 2020

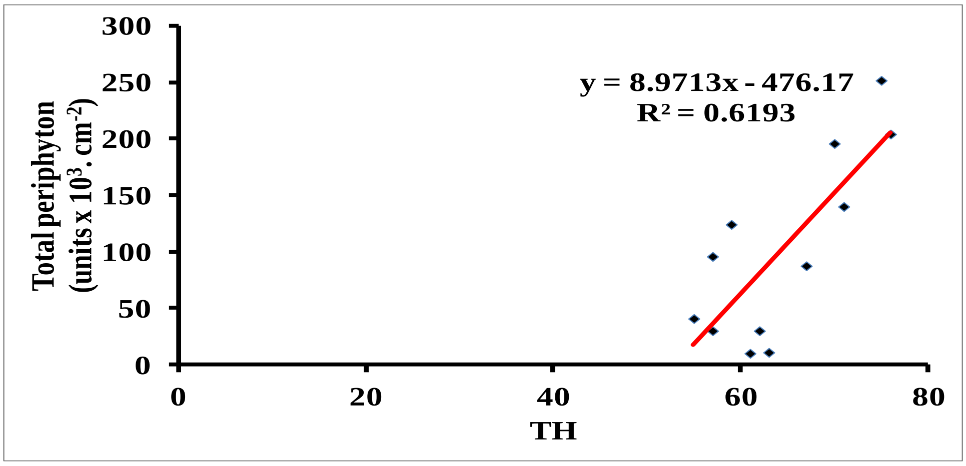

Fig. 7. Regression plot of TH (total hardness) with periphyton abundance of the Balkhila stream during two years of study from November 2018 to October 2020

The multivariate cluster analysis of periphyton communities of the Balkhila stream during the two years of study from November 2018 to October 2020 is mentioned in Fig. 8. The cladistic diagram represented that spring season showed close similarity with autumn season. The other similar group of summer and monsoon season joined the former group. Later these similar kinds of groups joined the winter season.

The multivariate canonical correspondence analysis (CCA) showing the effect of physico-chemical factors on the periphyton abundance of the Balkhila stream during the two years of study from November 2018 to October 2020 is presented in the Fig. 9. The axis 1,2,3 and 4 represented 49.12%, 29.09%, 11.78% and 10.01% variance with an eigenvalues of 0.060, 0.035, 0.0144 and 0.0122. The winter and spring season was associated with *Fragilaria*, *Navicula*, *Tabellaria, Meridion*, *Synedra*, *Diatoma* and *Spirogyra.* The abiotic factors such as dissolved oxygen, pH, total hardness and total alkalinity were closely associated with winter season. The autumn season represented *Cymbella*, *Zygnema*, *Nitzschia* and *Phormidium.* The monsoon season was associated with *Chlorella, Cocconeis* and *Amphora* and governed by water temperature, current velocity and turbidity. Most of the genera was close to winters season and loosely associated with monsoon. Kumar and Nautiyal [14], computed CCA plot at three sites in the Bhagirathi river to portray accurately the relationship between various environmental variables and benthic biota. CCA was also performed by Tariq et al. [16,39] and Scott et al. [43], to determine the relationship between fauna and environmental data matrices which they found significant.

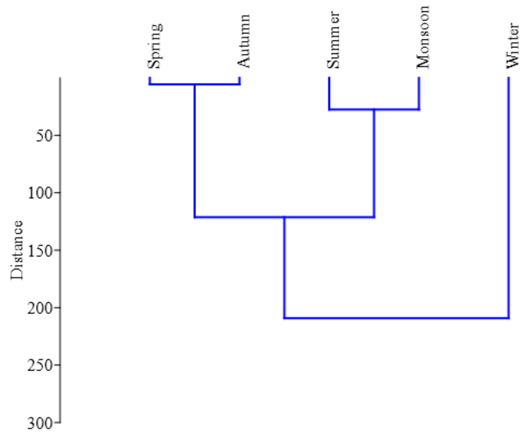

Fig. 8. Cluster analysis of periphyton communities in the Balkhila stream during the two years of study from November 2018 to October 2020. (Average values)

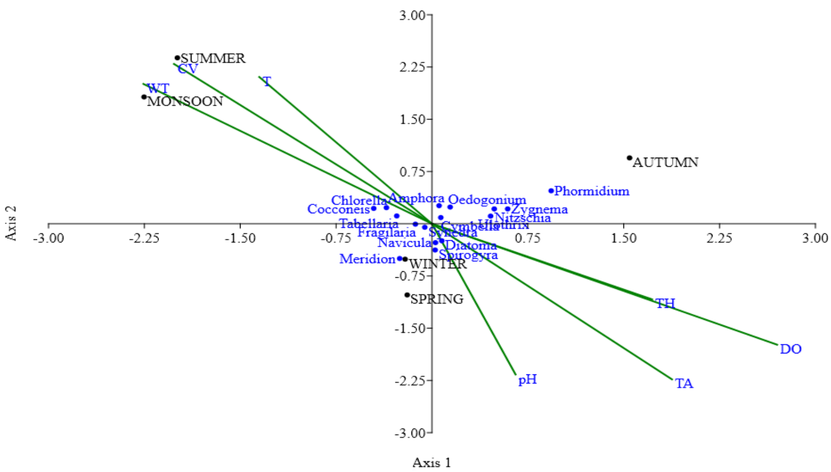

Fig. 9. Canonical correspondence analysis (CCA) of periphyton communities in the Balkhila stream during the two years of study from November 2018 to October 2020 (Average values)

4. CONCLUSION

From the above discussion it has been concluded that the maximum density and diversity of the periphyton community was found be in winter season and minimum in monsoon season . The high density and diversity during winter was due to optimum level of all the physico-chemical factors and during monsoon perturbed ecological setup resulted in low density and diversity of periphyton. It has been also concluded that the periphyton showed positive relation with pH, dissolved oxygen, total alkalinity and total hardness whereas, negative relation with water temperature, current velocity and turbidity. The stream Balkhila is located at higher altitude where there is least anthropogenic activities and provides excellent habitat for periphyton population to grow well during the stable ecological conditions. The results of our study can be compared with different aquatic bodies to check the pollution status. So, the ecological studies on this stream are very significant.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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