J. Mountain Res. P-ISSN: 0974-3030, E-ISSN: 2582-5011 DOI:https://doi.org/10.51220/jmr.v18i1.30
Vol. 18(1), (2023), 281-293

Ecology, Diversity And Community Structure Of Periphyton In The Datpul Gad Stream A Spring Fed Tributary Of River Nayar From Uttarakhand, India

Ghulam Mustfa[1*] • Ishtiyaq Ahmed[1] • Mohd Tariq[1] • A.K. Dobriyal[1]

[1]*Department of Zoology, HNB Garhwal University (A Central University), BGR Campus Pauri Garhwal-246001, Uttarakhand, India*
[*]Corresponding Author Email: ghulammustafa2053@gmail.com

Received: 10.12.2022; Revised: 05.06.2022; Accepted: 07.06 2023

Abstract: The paper focuses on the ecology, diversity, and community structure of periphyton in the Datpul Gad stream during the period of 2019-2020. The stream is a significant spring-fed tributary of the River Nayar, situated in the Agroda village of Pauri district, Uttarakhnad state. Several physico-chemical parameters were examined from October 2019 to September 2020 to assess the periphyton growth conditions. These parameters included water temperature, current velocity, dissolved oxygen, pH, total alkalinity, and total hardness. The results indicated that all these physico-chemical parameters were favorable for periphyton growth during the winter season. The periphyton community in the stream comprised 12 genera, including Diatoma, Navicula, Cymbella, Fragillaria, Synedra, Gomphonema, Nitzschia, and Tabellaria from the Bacillariophyceae, Ulothrix, Stigeoclonium, and Spirogyra from the Chlorophyceae and Phormidium from the Myxophyceae. The density of periphyton was found to be highest during the winter season and lowest during the monsoon season. To assess the diversity of the periphyton community, the Shannon-Wiener diversity index and Margalef index were calculated. The researchers employed multivariate cluster analysis and the Simper test to determine the similarity and average dissimilarity of periphyton composition among different seasons. Canonical correspondence analysis (CCA) was performed to investigate the influence of abiotic factors on periphyton abundance. Additionally, multivariate Principal Component Analysis (PCA) was conducted to depict the abundance of periphyton during different seasons.Overall, the study provides insights into the periphyton community dynamics, diversity, and response to abiotic factors in the Datpul Gad stream throughout the 2019-2020 period.

Key words: CCA • PCA • Diversity • Abundance • Abiotic factors

Introduction

Periphyton is the crucial component of aquatic ecosystem and it is found attached to various submerged objects found in water viz. stones, pebbles, wood etc. Being an important part of aquatic food chain, it also provides shelter and food to benthic macroinvertebrates (Dobriyal et al 2011, Bahuguna and Negi 2018). In hill streams the periphyton forms an important algal component of the ecological setup as plankton are minimum in their density due to fast flowing nature of water (Kumar et.al. 2006). There are several physico-chemical parameters which influence the periphyton distribution and density and can have huge impact on aquatic mites (Bahuguna et al 2020, Negi et al 2021), macrozoobenthos (Dobriyal et.al 1992, Bahuguna and Dobriyal 2018, Mamgain et al 2021) and fish diversity (Bahuguna, 2020, 2021) and checklist of benthic macroinvertebrate (Koshal et at 2017). Optimal levels of all the physico-chemicals factors are crucial for the proper sustainment of aquatic life and any abrupt change in these can have negative consequences. In aquatic ecosystems, the periphyton development are greatly influenced by various physico-chemical and biological factors such as light availability (Warren et al 2017), current velocity of water (Townsend et al 2012), various nutrient concentrations (Myrstener et al 2018),

grazing by consumers (Jones and Sayer 2003, Garcia et al 2015), temperature (DeNicola 1996, Baluni et al 2017, 2018; Baluni 2020), substrate type (Murdock and Dodds 2007), competition (Stevenson et al 1991). In benthic food webs, the periphyton even acts as a basal resource for invertebrates as well as vertebrates consumers (Muñoz et al 2001).

Periphytic organisms also act as excellent source of pollution indicator because of their sensitive nature to slight changes in aquatic bodies. For the biomonitoring of aquatic pollution, periphyton have been widely used by several researchers (Leland & Carter 1985, Newman et al 1985; Cosgrovea et al 2004).

In India, hydrobiological studies has been carried out by several researchers ((Singh et al 1982; Dobriyal 1985, Dobriyal and Singh 1989, Dobriyal and Kotnala 1993, Dobriyal and Kotnala 2005, Sagir and Dobriyal 2020 and Baluni et al 2021, Tariq et al 2020a, b, 2021, 2022a).

The present hypothesis was proposed to explore the periphytic distribution and community structure and their relationship with various physico-chemical parameters in the Datpul Gad stream of Uttarakhand.

Materials and Methods

Study Area

The present study was carried out at Datpul Gad stream which is an important tributary of River Nayar in Agroda village of Pauri district and is 18km from the main market of Pauri district of Uttarakhand state. The site is represented by riparian vegetation of coniferous forest and some mixed vegetation and some human settlement is also found along the side of the stream. The Datpul Gad stream is important source of water to the local population of the region. (Fig. 1).

Fig. 1: Map showing study area of Datpul Gad.

Analysis of Physico-chemical Parameters

All the physico-chemical parameters i.e., dissolved oxygen (DO), current velocity of water (CV), pH, total hardness (TH), total alkalinity (TA), Turbidity were analyzed as per standard methods suggested by Welch (1948),

APHA (2012). Surface temperature of the water was analyses by using the centigrade thermometer. The current velocity of the water was analyzed with the help of float method, in this method a light weight float which attached to a rope of known length is allowed to flow with the current of water and time is noted down when it is released and finally velocity is measured in (m/sec.). A portable digital pH meter was used record the pH of the stream by directly dipping it into the water on the spot. Dissolved oxygen content of the water was determined by modified Winkler's method. Total hardness and total alkalinity was calculated as per standard methods suggested by Welch (1948). A digital turbidity meter was used to analyze the turbidity of water sample nephlometeric turbidity units (NTU). Sampling of periphyton was done simultaneously with physico-chemical parameters.

Periphyton Sampling and analysis

Periphyton was collected from 1 inch square of various submerged objects in water especially from stones and pebbles. The 1-inch square was measured with the help of scale having inch division. The collected sample was then preserved in 4% formalin and then carried to the departmental laboratory of zoology department at BGR Campus Pauri for further analysis. The counting of periphyton was done by following formula:

$$n = (a \times 1000) \times b$$

Where: n = number of units of Periphyton in selected area, a = average number of periphyton in a cubic millimeter capacity. b = Concentration prepared in ml.

The qualitative analysis of periphyton was made with the help of micro processing imaging system (MIPS), stranded keys (Prescott, 1939a, b; Ward and Whipple, 1992) and the keys available online.

Statistical Analysis

The various statistical methods and multivariate analysis was done with help of Microsoft excel and Past 4.0 software.

Results and discussion

The seasonal variation in the physico-chemical parameters of Datpul Gad stream during the year Oct. 2019 to Sep. 2020 is presented in the table 1. The water temperature of the stream was maximum (21.50±0.71) in monsoon season whereas, minimum (10.0±1.0) water temperature of the stream was recorded in winter. Similar finding of low water temperature during winter and high during summer and monsoon season was reported by Kumar and Nautiyal (2019) in the Bhagira-thi River, Tariq et al., (2022b) in the Balkhila stream. The current velocity (m/sec.) of water was found maximum (0.64±0.06) in monsoon season and minimum (0.40±0.06) in winter. The high current velocity during monsoon season was also reported by Bisht et al., (2019) in the Pinder River, Tariq et al., (2021, 2022b) in the Balkhila stream. The pH of the stream was recorded maximum (7.88±0.16) in winter whereas, least (7.32±0.15) in monsoon season. The pH is high during winter season due to algal growth (Dobriyal and Singh, 1988; Bahuguna and Dobriyal, 2018). The dissolved oxygen content of the water was calculated high (10.53±0.52) in winter and low (9.05±0.07) in monsoon season which corroborates the finding of Matta et al., (2020), Tariq et al., (2022b). The total alkalinity of stream was found maximum (63.33±8.02) in winter season and minimum (42.0±0.00) in monsoon season. The total hardness of the stream Datpul Gad stream was found high (68.83±4.75) during winter and low (53.0±1.41) in monsoon season.

Table 1: Seasonal variations in the physico-chemical parameters of Datpul Gad stream during the year Oct. 2019 to Sep. 2020

SEASONS	WT (°C)	CV (m/sec.)	pH	DO (mg/l)	TA (mg/l)	TH (mg/l)
AUTUMN	15±1.41	0.43±0.03	7.76±0.11	10.05±0.02	62.50±2.12	65.25±0.35
WINTER	10.00±1.00	0.40±0.06	7.88±0.16	10.53±0.52	63.33±8.02	68.83±4.75
SPRING	13.50±2.12	0.52±0.01	7.55±0.07	9.80±0.14	49.00±1.41	59.00±1.41
SUMMER	21.00±4.24	0.50±0.00	7.40±0.14	9.30±0.14	45.50±0.71	57.00±1.41
MONSOON	21.50±0.71	0.64±0.06	7.32±0.15	9.05±0.07	42.00±0.00	53.00±1.41

The seasonal variation in the periphyton density of Datpul Gad stream during the year Oct. 2019 to Sep. 2020 is presented in Table 2. The stream Datpul Gad was represented by 12 periphytic genera belonging to 3 classes viz. Bacillariophyceae (*Diatoma, Navicula, Cymbella, Fragillaria, Synedra, Gomphonema, Nitzschia* and *Tabellaria*), Chlorophyceae (*Ulothrix, Stigeoclonium* and *Spirogyra*) and Myxophyceae (*Phormidium*). The maximum (2046.3±105.9) (Units.10^3.inch^{-2}) density of the periphyton was found in winter season and minimum (332.7±226.0) in monsoon. The class bacillariophyceae was found most diverse and dominant than chlorophyceae and myxophyceae in the stream Datpul Gad which corroborates the finding of Daimari (2003), Liang and Li (2008), Singh and Das (2009), Baluni et al 2017, 2018 and Baluni (2020). The Sorenson similarity Index of periphyton of Datpul Gad stream during the year Oct. 2019 to Sep. 2020 is presented in the table 3.

Table 2: Seasonal variations in the periphyton density of Datpul Gad stream during the year Oct. 2019 to Sep. 2020 (Units. 10^3. Inch^{-2})

Periphyton Class	Genus	Autumn	Winter	Spring	Summer	Monsoon
Bacillariophyceae	*Diatoma*	477±222.0	751.3±107.4	381±100.4	217±77.8	110.0±54.4
	Navicula	34±48.1	604.7±76.2	562±56.6	297±12.7	120.7±22.0
	Cymbella	52±14.1	182.0±143.4	190±90.5	60±39.6	67.3±104.7
	Fragillaria	53±75.0	166.7±33.2	184±62.2	24±17.0	16.0±27.7
	Synedra	8±11.3	0±0.0	151±86.3	0±0.0	18.7±32.3
	Gomphonema	50±11.3	109.0±48.4	58±62.2	0±0.0	0±0.0
	Nitzschia	52±53.7	27.3±33.0	120±33.3	13±4.2	0±0.0
	Tabellaria	17±24.0	94.0±26.2	0±0.0	5±7.1	0±0.0
Total		**743±213.5**	**1935.0±131.2**	**1646±492.1**	**616±158.4**	**332.7±226.0**
Chlorophyceae	*Ulothrix*	0±0.0	44.0±38.3	91±58.0	0±0.0	0±0.0
	Stigeoclonium	0±0.0	7.3±12.7	0±0.0	0±0.0	0±0.0
	Spirogyra	0±0.0	30.0±17.3	0±0.0	0±0.0	0±0.0
Total		**0±0.0**	**81.3±62.2**	**91±58.0**	**0±0.0**	0±0.0
Myxophyceae	*Phormidium*	81±55.2	30.0±27.5	6±8.5	0±0.0	0±0.0
Total		**81±55.2**	**30.0±27.5**	**6±8.5**	**0±0.0**	0±0.0
Grand total		**824±158.4**	**2046.3±105.9**	**1743±541.6**	**616±158.4**	**332.7±226**

Table 3: Sorenson similarity Index of periphyton of Datpul Gad stream during the year Oct. 2019 to Sep. 2020.

	N	D	J	F	M	A	M	J	J	A	S
O	0.714	0.5	0.75	0.706	0.667	0.75	0.615	0.5	0.4	0.222	0.5
N		0.625	0.875	0.824	0.8	0.875	0.769	0.833	0.6	0.444	0.667
D			0.778	0.842	0.706	0.667	0.667	0.571	0.5	0.364	0.571
J				0.947	0.706	0.778	0.8	0.714	0.5	0.364	0.571
F					0.778	0.842	0.75	0.667	0.462	0.333	0.533
M						0.941	0.714	0.769	0.545	0.4	0.769
A							0.667	0.714	0.5	0.364	0.714
M								0.909	0.667	0.5	0.727
J									0.75	0.571	0.8
J										0.8	0.75
A											0.571
S											

The maximum similarity of periphyton genera was found in winter months whereas, the months of the monsoon season differ greatly. The index values was high (0.947) during winter in the month of February and minimum (0.222) in monsoon in the month of August. Similar results were found by Dobriyal et al (2011) in Nayar River of the Garhwal Himalaya. The average dissimilarity in the periphyton density of Datpul Gad stream during the year Oct. 2019 to Sep. 2020 is presented in the table 4. The simpler test indicates that overall average dissimilarity in the periphyton during different season was found to be 51.64%. This is due to the variation in the physico-chemical parameters during different seasons. Simpler test was also performed by Tariq et al (2022b) to show the dissimilarity of periphyton. The cluster analysis plot showing similarity of periphyton during different seasons of Datpul Gad during the year Oct. 2019 to Sep. 2020 is presented in the figure 2. The dendrogram thus formed suggested that summer and monsoon were similar groups joined by autumn which were later joined by other similar groups of winter and spring season. The values of Shannon-Wiener diversity index and Margalef index of periphyton of Datpul Gad stream during the year Oct. 2019 to Sep. 2020 id presented in the Figure 3 and 4. The Shannon-Wiener index value was high (1.91) in the month of march and low (0.633) in the month of August whereas, the value of Margalef index was high (1.17) in the month of February and low (0.20) in the month of August.

Table 4: average dissimilarity in the periphyton density of Datpul Gad stream during the year Oct. 2019 to Sep. 2020.

Taxon	Av. dissim	Contrib. %	Cumulative %	Abundance Autumn	Abundance Winter	Abundance Spring	Abundance Summer	Abundance Monsoon
Diatoma	15.12	29.27	29.27	477	751	381	217	110
Navicula	15.03	29.11	58.38	34	605	562	297	121
Fragillaria	4.215	8.162	66.54	53	167	184	24	16
Cymbella	3.359	6.505	73.05	52	182	190	60	67.3
Synedra	2.685	5.199	78.25	8	0	151	0	18.7
Nitzschia	2.653	5.138	83.38	52	27.3	120	13	0
Gomphonema	2.544	4.926	88.31	50	109	58	0	0
Phormidium	2.089	4.045	92.36	81	30	6	0	0
Ulothrix	1.806	3.498	95.85	0	44	91	0	0
Tabellaria	1.616	3.13	98.98	17	94	0	5	0
Spirogyra	0.4225	0.8181	99.8	0	30	0	0	0
Stigeoclonium	0.1028	0.1991	100	0	7.3	0	0	0
Overall average dissimilarity	**51.64%**							

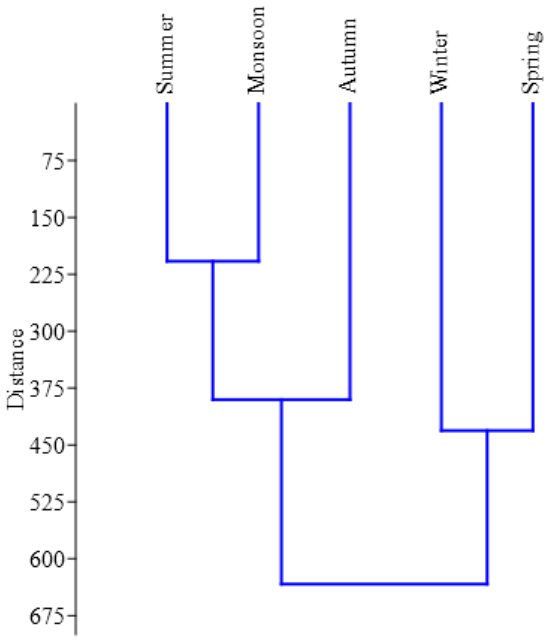


Fig. 2: Cluster analysis (CA) plot showing similarity of periphyton during different seasons of Datpul Gad stream during the year Oct. 2019 to Sep. 2020.

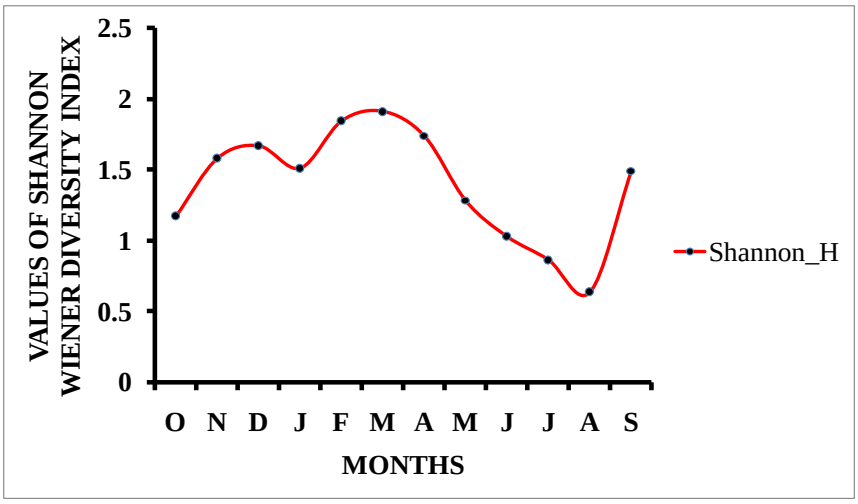


Fig. 3: Values of Shannon-Wiener diversity Index of periphyton of Datpul Gad stream during the year Oct. 2019 to Sep. 2020.

The canonical correspondence analysis (CCA) plot showing the effect of Physico-chemical parameters on periphyton during different seasons of Datpul Gad stream during the year Oct. 2019 to Sep. 2020 is presented in the figure 5. The axis 1,2,3 and 4 represents 56.64%, 29.73%, 10.55% and 3.083% of the variance with an eigenvalues of 0.156, 0.082, 0.0291, 0.008.the winter and autumn season was represented by genera *Diatoma*, *Tabellaria*, *Spirogyra*, *Stigeoclonium*, *Gomphonema* and *Phormidium* and governed by factors total alkalinity, total hardness, pH and dissolved oxygen. The spring season was associated with genera *Nitzschia*, *Synedra*, *Ulothrix* and *Fragillaria.* The monsoon and summer season was represented by *Cymbella* and *Navicula* and governed by water temperature and current velocity. The CCA was also performed by Kumar and Nautiyal (2019), Sagir and Dobriyal (2020), and Tariq et al (2022b) to study the relationship between different abiotic factors benthic communities in an aquatic ecosystem.

Fig. 4: Values of Margalef Index of periphyton of Datpul Gad stream during the year Oct. 2019 to Sep. 2020.

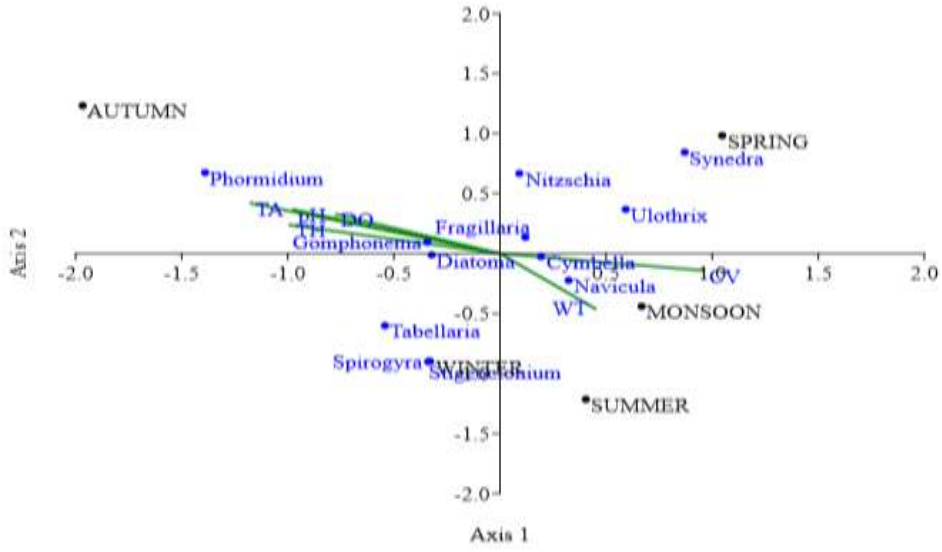
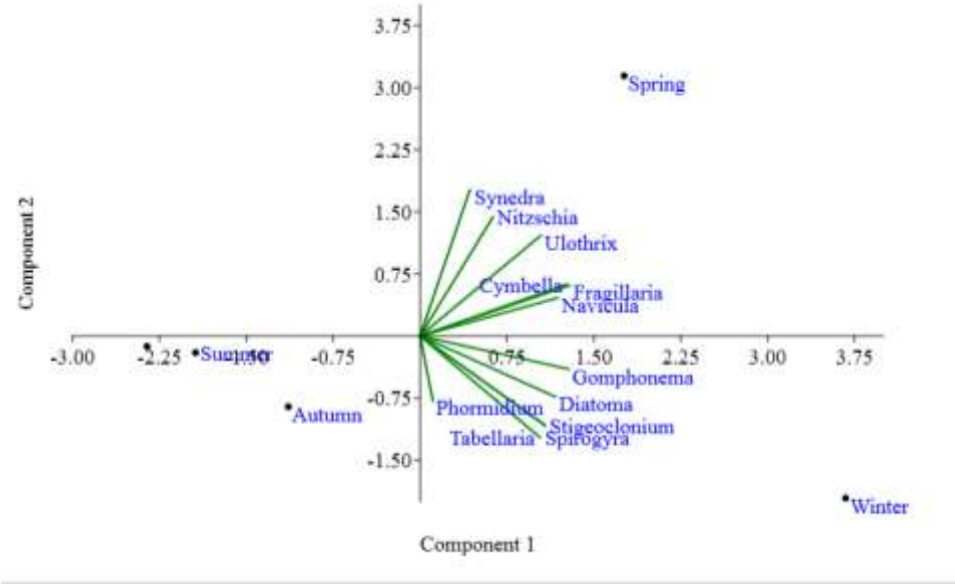
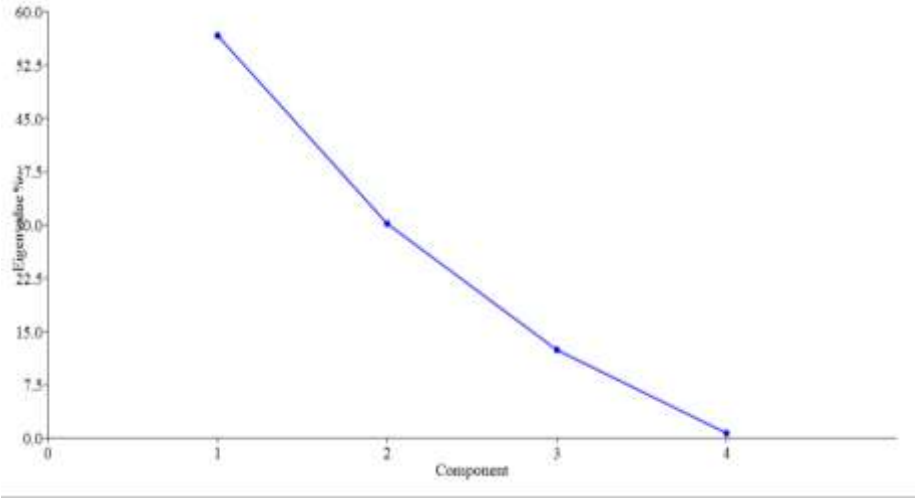


Fig. 5: Canonical correspondence analysis (CCA) plot showing the effect of physico-chemical parameters on periphyton during different seasons of Datpul Gad stream during the year Oct. 2019 to Sep. 2020.

The principal component analysis (PCA) plot showing the abundance of periphyton during different seasons of Datpul Gad during the year Oct. 2019 to Sep. 2020 is presented in the figure 6. The PC1, 2, 3 and 4 represents 56.6%, 30.2%, 12.42% and 0.70% of the variance with an eigenvalues of 6.80, 3.6, 1.49 and 0.084. The winter season represented by genera *Gomphonema, Diatoma, Spirogyra, Tabellaria, Phormidium* and *Stigeoclonium*. The spring season was associated with genera *Synedra, Nitzschia, Ulothrix, Cymbella, Navicula* and *Fragillaraia.* The most of the genera were dominant in winter and spring season whereas, all genera of periphyton were least in autumn, summer and monsoon season. From the above discussion it has been concluded that the Datpul Gad represents maximum density of periphyton in winter because all the ecological parameters were in optimum level but on the onset of monsoon season the density of periphyton decreases due to perturbed ecological conditions.



(A)



(B)

Fig. 6: (A) Principal Component analysis (PCA) plot showing abundance of periphyton during different seasons of Datpul Gad stream during the year Oct. 2019 to Sep. 2020.
(B) Scree plot of PCA showing eigenvalues of components.

References

APHA (2012) Standard methods for examination of water and wastewater. 22nd Edn., APHA, AWWA, WPCF, Washington DC, USA.

Bahugun P and Negi S (2018) Distribution pattern of benthic macroinvertebrate community in the spring fed stream of Garhwal Himalaya, India. *J. Mountain. Res.* 13: 51-58.

Bahuguna P (2021) Distribution pattern of Ichthyofauna diversity in different habitats in the first-, secondand third order streams of Randi Gad from Garhwal Himalaya, *India. Natl. Acad. Sci. Lett.* 2021. https://doi.org/10.1007/s40009-020-01032-9.

Bahuguna P (2020) Fish diversity in different habitats in the 1st, 2nd and 3rd order streams of Kyunja Gad from Garhwal Himalaya, India. *Uttar Pradesh Journal of Zoology*. 41(3): 24-29.

Bahuguna P and Dobriyal AK (2018) First report on the occurrence of some benthic macroinvertebrates in the spring-fed streams of Garhwal Himalaya, India. *International Journal of Research and Analytical Research and Analytical Reviews (IJRAR)*, 5(4), 437-443.

Bahuguna P, Rana KK, Rayal R and Khanduri NC (2020) Density and diversity of aquatic mites in a glacierfed river Mandakani from Garhwal Central Himalaya, India. *Uttar Pradesh Journal of Zoology*. 41(10): 1-8.

Baluni P (2020) Ecological perspective on the density and diversity of periphytons from Ragda Gad stream from Garhwal Himalaya, India. *Applied Ecology and Environmental Science*. 8(5): 192-198.

Baluni P, Kumar K and Joshi HK (2018) Ecology, Distribution Pattern, Density and Diversity of Periphyton in Khankra Spring Fed Stream of Garhwal Himalaya, India. *J. Mountain Res*. 12: 73- 79.

Baluni P, Kumar R, Chamoli KP and Joshi HK (2017) Studies on the periphyton density, diversity and physico-chemical parameters of Laster Gad stream in district Rudraprayag from India. *J. Mountain Res*. 12: 73-79.

Baluni P, Rajan, Rayal R and Bahuguna P (2021) Observation on ecology and diversity of periphyton community in the Mal gad stream from Garhwal Region, India. *Uttar Pradesh J. Zool*. 42: 17, Page 84-94.

Bisht KL, Dobriyal AK and Singh HR (2019) A note on the ecosystem health of a glacier fed river Pinder from Chamoli Garhwal, Uttarakhnad. *J. Mountain. Res*.,4(2), 9-17.

Cosgrovea JDW, Morrison P and Hillman K (2004) Periphyton indicate effects of wastewater discharge in the near-coastal zone, Perth, Western Australia. Estuarine, Coastal and Shelf *Science*. 61(2): 331–338. DOI: 10.1016/j.ecss.2004.05.008

Daimari P (2003) *Ecology and fishery potential of some selected rivers in Arunachal Pradesh.* Ph.D. thesis, Gauhati University. 165p.

DeNicola DM (1996) Periphyton responses to temperature at different ecological levels. In: Stevensosn, R.J., Bothwell, M.L. and Lowe, R.I. (Eds.) *Algal ecology freshwater Benthic Ecosystem*, Academic Press: New York: 149-181.

Dobriyal AK and Kotnala CB (1993) Primary productivity of periphyton in the river Eastern Nayar at Satpuli, Pauri Garhwal. *Bioved*. 4: 267- 268.

Dobriyal AK (1985) Ecology of limno-fauna in small streams and their importance to the village life in Garhwal Himalaya. *Uttar Pradesh J. Zool.* 5:139- 144.

Dobriyal AK and Kotnala CB (2005) Primary productivity of the spring-fed river Nayar (Garhwal Himalaya, Uttaranchal). *Biological Diversity in Freshwater Environments* (Ed.) Nautiyal P, Bhatt JP, Gusain OP and Dobriyal A.K. Transmedia, Srinagar Garhwal.: 96-107.

Dobriyal AK and Singh HR (1988) Ecological basis for the ichthyofaunal variation in two hill strteams of Garhwal Himalaya. In: M. Mohan Joseph (Ed.) *The First Indian Fisheries Forum Proceedings*, Asian

Fishery Society, Indian Branch. Page 313-317.

Dobriyal AK and Singh HR (1989) Observations on temporal trends of phytoplankton diversity in the river Nayar of Garhwal Himalaya. *J. Freshwater Biol*. 1: 1-6.

Dobriyal AK, Balodi VP, Joshi HK, Bahuguna P and Kumar N (2011) Seasonal cyclicity of Macrozoobenthos correlated with detrimental abiotic factors in the Eastern Nayar of Garhwal Himalaya, Uttarakhand. In: *Himalayan Aquatic Biodiversity Conservation and new tools in Biotechnology* (Eds. J P Bhatt, Madhu Thapliyal and Ashish Thapliyal). Transmedia Publication Srinagar Garhwal: 94-103.

Dobriyal, A.K., Kumar, N., Kotnala, C.B., Bahuguna, A.K. and Singh, H.R. 1991. Preliminary observations on seasonal trends in macrozoobenthic diversity in the river Nayar of Garhwal Himalaya. In: Sehgal, K. L. (Ed.): *Recent researches in Coldwater Fisheries.* Today and Tommorrow Printers and Publishers, New Delhi Pp. 119-127.

Garcia EA, Townsend SA and Douglas MM (2015) Context Dependency of Top-Down and Bottom-Up Effects in a Northern Australian Tropical River. *Freshw. Sci*. 34, 679–690. doi:10.1086/681106

Jones JI and Sayer CD (2003) Does the Fish-Invertebrate-Periphyton Cascade Precipitate Plant Loss in Shallow Lakes? *Ecology*. 84, 2155–2167. doi:10.1890/ 02-0422

Kumar S and Nautiyal P (2019) Community Features of Benthic Macroinvertebrates and Bioassessment of the Stretch of Bhagirathi River Impacted by Maneri Bhali Stage I Hydroelectric Project. *International Journal of Ecology and Environmental Sciences*, 45 (3), 311-315.

Koshal Kumar, Jitendra Singh Rana, Anita Rawat Rana and Kotnala, CB (2017) Checklist of Benthic Macroinvertebrate Communities of Stream Rawasan In Garhwal Region (Central Himalaya), Uttarakhand (India). J Mountain Res 12: 91-95. ISSN-0974-3030

Kumar, K., Rautale, K.K.,.Bisht, K.L., Joshi, V.D., Rautela, A.S. and Dobriyal, A.K.(2006) Ecological studies on the biodiversity of river Khoh in the foot-hills of Garhwal Himalaya: Part I. Phytoplankton analysis. *Journal of Nature Conservators* 18(1): 71-80

Leland HV and Carter JL (1985) Effects of copper on production of periphyton, nitrogen fixation and processing of leaf litter in a Sierra Nevada, California stream. *Freshwater Biology* 15(2): 155–173. DOI: 10.1111/j.1365- 2427.1985.tb00189.x

Ling X and Li X (2008) Responses of phytoplankton and periphyton to environmental varitations in Urbanizing Tidal river. *J. of Bioinformatics and biomedical Engineering, Shanghai* 2873-2877.

Mamgain D, Bahuguna P, Dobriyal AK and Rayal R (2021) Macrozoobenthos of Basti dammar stream in Rudrprayag District Garhwal Uttarakhand: Diversity and habitat analysis. J. Mountain Res. 16(1): 235-246.

Matta G, Kumar A and Nayak A et al. (2020) Water qual-ity and plantonic composition of river Henwal (India) using comprehensive pollution index as biotic-indices. *Trans Indian Natl.Acad. Eng.* 5, 541-553.

Muñoz I, Real M, Guasch H, Navarro E and Sabater S (2001) Effects of Atrazine on Periphyton under Grazing Pressure. *Aquat. Toxicol.* 55, 239–249. doi:10.1016/s0166-445x(01)00179-5.

Murdock JN and Dodds WK (2007) Linking benthic algal biomasss to stream substratum topography. *Journal of Phycology* 43: 449-460.

Myrstener M, Rocher-Ros G, Burrows RM, Bergstrom A K, Giesler R., Sponseller RA, et al (2018) Persistent nitrogen limitation of stream biofilm communities along climate gradients in the Arctic. *Glob. Change Biol.* 24 (8), 3680–3691. doi:10.1111/gcb.14117.

Negi S, Bahuguna P and Dobriyal AK (2021) Drifting behaviour: of aquatic mites and regulating ecological parameters in Khankragad stream, a spring fed tributary of Alaknanda river, Rudraprayag Garhwal, Uttarakhand, India. *J. Mountain Res.* 16(1): 61-75.

Newman MC, Alberts JJ and Greenhut VA (1985) Geochemical factors complicating the use of aufwuchs to monitor b10 accumulation of arsenic, cadmium, chromium, copper, zinc. *Water Research.* 19(9): 1157–1165. DOI: 10.1016/0043-1354(85)90352-5

Prescott GW (1939a) *How to know the freshwater Algae*. Brown Co. publishers: 450.

Prescott GW (1939b) Some relationship of phytoplankton to limnology and aquatic biology. *Publ. Amer. Asso. Adv. Sci.:* 10: 65-78. Service New Delhi.

Sagir M and Dobriyal AK (2020) Structural and function diversity periphyton community from the Western Nayar river of Garhwal Himalaya. Uttar Pradesh Journal of Zoology, 41(1), 15-29.

Singh DN and Das AK (2009) Diversity of periphyton in a Peninsular river. *J Inland Fish. Soc. India.* 41(1): 69-72.

Singh HR, Badola SP and Dobriyal AK (1982) Ecology of the river Nayar of Garhwal Himalaya. *Uttar Pradesh J. Zool.* 2: 72-76.

Stevenson RJ, Peterson CG, Kirschtel DB, King CC and Tuchman NC (1991) Density-dependent growth ecological strategies and effect of nutrients and shading on benthic diatom succession in stream. *Journal of Phycology*, 27: 59-69.

Tariq M, Kotnala CB and Dobriyal AK (2022a) Current status of Ichthyo-faunal diversity of glacier fed stream Balkhila from Garhwal Himalaya. *J.Mountain Res.*,17(1):9-16.

Tariq M, Kotnala CB and Dobriyal AK and Tabassum S (2022b) Population structure and diversity of the periphyton community in the glacier fed stream Balkhila at Siron from Garhwal *Himalaya Journal Of Applied And Natural Sciences*, 14(1):163-171.

Tariq M, Kotnala CB and Dobriyal AK (2020b). Diversity and population structure of macroinvertebrates in the glacier fed stream Balkhila at Tilfara from Garhwal Himalaya. *J.Mountain Res*. Vol. 15:81-89.

Tariq M, Kotnala CB, and Dobriyal AK (2020a) Dynamics and diversity of macrozoobenthos in the glacier fed stream Balkhila at Siron in Chamoli Garhwal. *Uttar Pradesh Journal of Zoology*, 41(1):80-91.

Tariq M, Kotnala CB, Dobriyal AK and Tabassum S (2021) Distribution pattrerns and diversity of periphyton community in the glacier fed stream Balkhila at Tilfara from Garhwal Himalaya. *Uttar Pradesh Journal of Zoology*, 42(24): 879-889.

Townsend SA, Garcia EA, and Douglas MM (2012) The Response of Benthic Algal Biomass to Nutrient Addition over a Range of Current Speeds in an Oligotrophic River. *Freshw. Sci.* 31, 1233–1243. doi:10.1899/11-163.1.

Ward HB and Whipple GC (1992) *Freshwater Biology*. New York; John Wiley and Sons.

Warren DR, Collins SM, Purvis EM, Kaylor MJ, and Bechtold HA (2017) Spatial Variability in Light Yields Colimitation of Primary Production by Both Light and Nutrients in a Forested Stream Ecosystem. *Ecosystems* 20(1), 198–210. doi:10.1007/s10021-016-0024-9.

Welch PS (1948) *Limnological method*s. McGraw Hill, New York.