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Ecological Perspective on the Density and Diversity of Periphytons from Ragda Gad Stream from Garhwal Himalaya, India

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Abstract The present study deals with the study of Physico-chemical characteristics and the periphytic algal community of the Ragda Gad stream in district Pauri Garhwal, state Uttarakhand, India. The coordinates of this spring-fed stream are 30° 11'15" N and 78°46'22" E. During the investigation it was found that the periphytic algal community of Ragda Gad stream mainly comprised 25 taxa belonging to 3 major class namely Bacillariophyceae (*Cymbella sp.*, *Synedra sp.*, *Fragilaria sp.*, *Gomphonema sp.*, *Navicula sp.*, *Tabellaria sp.*, *Achnanthes sp.*, *Bacillaria sp.*, *Diatoma sp.*, *Amphora sp.*, and *Nitzchia sp.*, etc), Chlorophyceae (*Cladophora sp.*, *Oedogonium sp.*, *Spirogyra sp.*, *Microspora sp.*, *Volvox sp.*, *Zygenema*, *Ulothrix sp.*, *Closterium sp.*, *Cosmarium sp. and Geminela sp,)* and Cyanophyceae (*Nostoc sp.*, *Anabaena sp.*, *Rivularia sp. and Phormidium sp.*). The dominance of Chlorophyceae in the stream indicates the healthy condition of the stream ecosystem. It is having crystal clear water and is free from pollution. Further, as a result of less anthropogenic pressure, the quality of water is rather superior.

Keywords: *Periphyton, spring-fed stream, ecology, Garhwal Himalaya*

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1. Introduction

The relationship between diversity and productivity is a fundamental idea in the ecological investigations [1]. Establishment of a concrete connection either empirically or theoretically for both producers and consumers [2] depends on several factors like the spatial scale of observation [3,4], distribution [5], and community assemblage history [6]. Thus, the diverse nature of ecosystems and organisms considered [7] may result in the differences in the observed patterns. Periphyton are the significant component of an aquatic ecosystem consisting mainly of algae, bacteria, protozoa, and fungi that grow on rock substratum. They serve as a chief food resource for higher tropical level organisms in a local and downstream ecosystem. The growth of periphyton is limited by light or nutrient or both and is influenced by temperature. Periphyton community is extremely reactive to the degradation of aquatic ecosystem quality. Broadly, climate, geology and human activity dictates their morphology and hydrology. Different periphyton growth forms can also accomplish diverse functional roles in benthic communities [8]. The Periphytons have gained much importance in the spring-fed streams, being stable, as compared to moving plankton. Hence there is an immense need to organize information on the diversity of habitat, biotic diversity and structure of major biotic communities in natural or near-natural conditions and their distribution in the spring-fed Ragda Gad Stream. Periphyton is a chief food for nibbling fishes (eg. *Schizothorax richardsonii*, *S. plagiostomus* , and *Tor chilinoides*).

Many reports on the Periphyton community, geological, and limnological aspects of the springs of the Himalayas in India and abroad are available [9,10,11,12]. Still, a comprehensive study of stream biodiversity and physico-chemical stability of the springs of Garhwal Himalayas is trivial. Considering these facts the present study on the periphyton community of streams of Garhwal Himalayas has been undertaken. Thus, the present investigation will help enhance the knowledge about this natural food of fishes , and in understanding the production potential of water bodies and thereby maintaining the eco-friendly environment.

2. Materials and Methods

2.1. Study Area

Ragda Gad is an important spring-fed stream originating from the Kinaas mountain place (Latitude 30°11′15″N, Longitude 78°46′22″E) in the city Pauri, District Pauri Garhwal (Garhwal Himalaya) as shown in Figure 1. The sample material was collected from January 2019 to

December 2020. It had a moderate gradient, bushy tree, shrubs and herbaceous streamside vegetation with an open canopy. The study stream in this region was bounded by cultivated catchments. Land use practices dominant in the Ragda gad stream are forest and agriculture. Streams flowing through these agricultural areas tend to have higher nutrients concentrations than streams through forested areas. The sampling site was located at 'Asnole Sara'. This sampling site is located in the semi Rhithron-Potamon Zone. The bottom texture at the study area was dominated by gravel, pebbles, sand and leaf litter.

2.2. Collection, Preservation, and Identification of Periphyton Samples

The physico-Chemical analysis was conducted as per standard Method recommended by APHA [13]. Stones of different sizes were picked up from the bottom of the stream and a known area (1cm^2) was marked on the stone. The periphyton was scrapped from the marked area (1cm^2) with the help of scalpel and brushes and mixed with a small amount of water and then stored into the labeled container. Periphyton sample was preserved in 1ml Lugol's iodine and three drops of 4% formalin. In the laboratory, the periphyton was further concentrated in 100ml. The counting was done with the help of Sedgwick-Rafter counting slide using the following formula:

$$n = (a \; x \; 1000) \; x \; b$$

Where
n = number of units of Periphyton / cm^2.
a = average number of periphyton in a cubic millimeter capacity.
b = Concentration prepared in ml.

Photo micrographic images of phytoplankton were analyzed with the help of Stereo Zoom Trinocular Microscope with Tucsan camera attachment. The identification of the sample was carried with the help of taxonomical works of Prescott [14,15], Desikachary [16], Ward and Whipple [17].

3. Results and Discussion

Monitoring of water quality (Physico-chemical parameter) is extremely significant for knowledge of biodiversity in spring-fed hill streams. Water quality is influenced by climate, geological, hydrological and anthropogenic factors [18]. The typical physicochemical parameters of Ragda Gad (spring-fed) are presented in Figure 2 to 7. Water temperature is a vital factor that controls aquatic life in a spring-fed water stream [19]. Water temperature was observed to be minimum (12.7 ± 1.50°C) in February whereas maximum (21.3±1.14°C) in September. The average water velocity continually changed throughout the year with the lowest value (0.18 ±0.09 ms^{-1}) in December whereas the highest value (0.40 ±0.05 ms^{-1}) in July. Agarwal *et. al.*, [20] observed that the highest faunal density in winter and lowest in monsoon season may be due to water temperature, turbidity, and water velocity. Average turbidity was estimated to be minimum (11.4±2.05 NTU) in February and maximum (90±5.50 NTU) in July. Similar observations were noticed in the Chandrabhaga River from Garhwal Himalaya [21].

D.O. is a critical environmental factor that decides the ecological health of a stream and protects aquatic life. Average dissolved oxygen was recorded highest (11.9± 0.72 mgl^{-1}) in February and lowest (8.1± 0.30mg l^{-1}) in October. The maximum value of D.O. in the winter season and minimum level in monsoon were also noticed in Haraz River in Iran [22]. The average minimum pH was noticed in August (7.4 ± 0.20) and maximum the month of November (8.3 ± 0.50). Alkaline water promotes high primary productivity [23]. The water of the Ragda Gad stream was alkaline throughout the study period. The average total Alkalinity was observed to be minimum (20.5± 1.30 mg l^{-1}) in February and maximum (34 ±5.10 mgl^{-1}) in November. Natural water is usually alkaline due to the presence of carbonates in sufficient quantities [24].

The monthly variation in the mean density of periphyton recorded from the Ragda Gad stream is presented in Table 1. The population density of Bacillariophyceae varied from a low of 3.13±00.22 ind./cm^2 in August to a high of 140.09±09.30 ind./cm^2 in January. The highest mean population density of Chlorophyceae was observed as 70.5±04.23 ind./cm^2 in October and minimum density as 3.0±00.64ind./cm^2 in June. The population density of Myxophyceae reached its highest peak (84.9±04.52 ind./cm^2) in February while the lowest (20.54±5.07 ind./cm^2) in September. The overall mean density of the periphyton was found to be the maximum number in January (230.48±8.11 units cm^{-2}) and minimum in August (3.13±0.22 Units cm^{-2}). In the present work, the annual percentage composition of periphytic flora of Ragda Gad revealed that major contribution was made by Bacillariophyceae (54%) follow by Chlorophyceae (36%) and Myxophyceae (10%) (Figure 8).

Table 1. Monthly variations in the density of periphytic algae from the Ragda Gad stream

Months	Chlorophyceae (Blue green algae)	Bacillariophyceae (Diatoms)	Myxophyceae (Green algae)	Total numbers of periphyton units/cm^2.
January	10.19±00.82	140.09±09.30	80.2±10.11	230.48±8.11
February	8.92±00.65	110.05±07.20	84.9±04.52	203.87±5.23
March	6.5±00.57	101.72±07.94	72.5±06.24	180.72±4.17
April	5.4±00.54	80.35±08.40	62.23±03.62	147.98±4.06
May	3.02±00.31	73.5±06.20	55.47±05.20	131.99±3.06
June	3.0±00.64	70.7±05.80	44.64±07.48	118.34±4.05
July	Nil	Nil	Nil	Nil
August	Nil	3.13±00.22	Nil	3.13±00.22
September	2.5±00.28	43.6±06.43	20.54±5.07	66.64±4.04
October	70.5±04.23	62.21±05.20	51.87±05.10	184.58±5.4
November	24.10±03.4	85.32±08.10	79.34±07.22	188.76±5.70
December	9.8±03.21	119.23±29.20	81.8±06.54	210.83±10.87

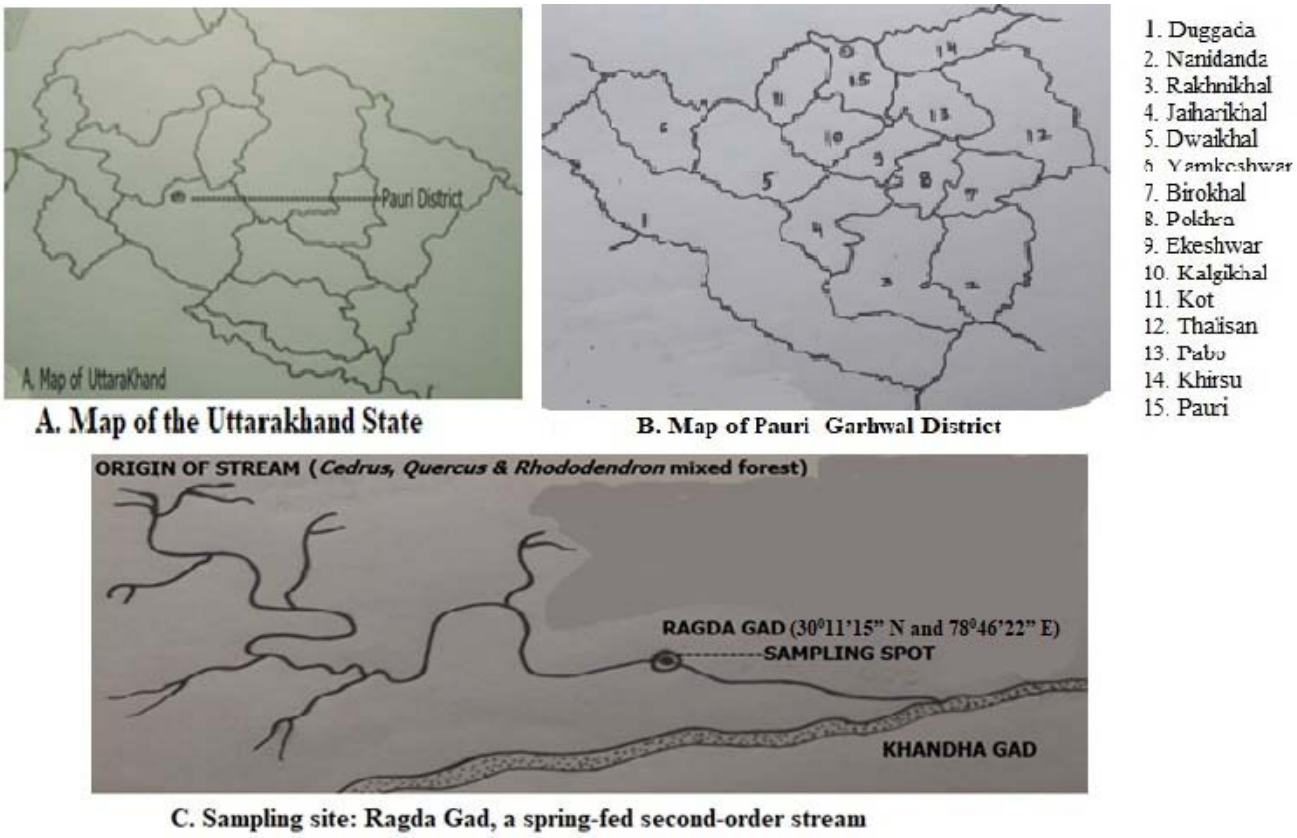

Figure 1. Map of the Study Area

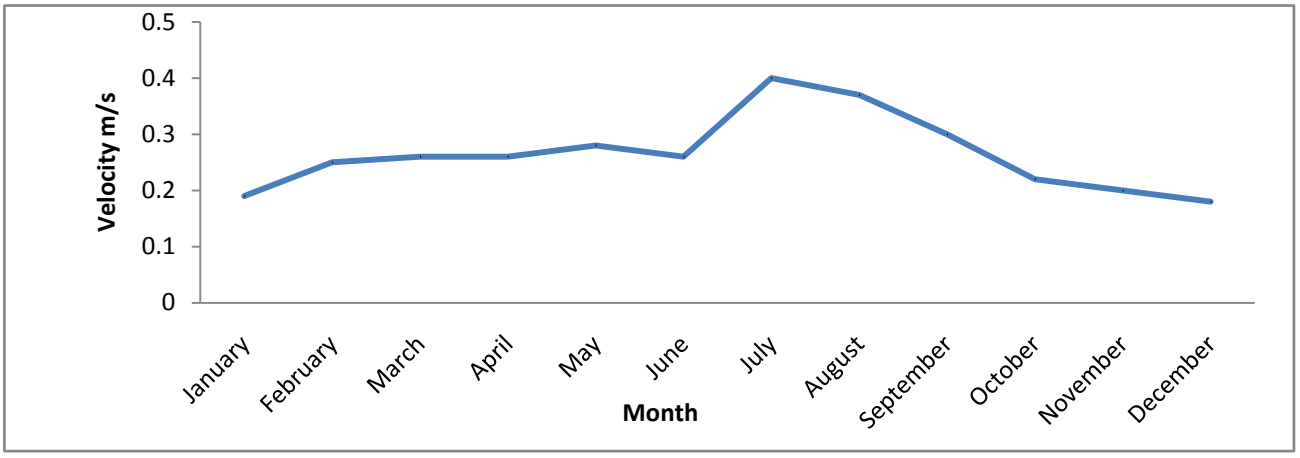

Figure 2. Monthly variation in the average velocity of the Ragda Gad stream

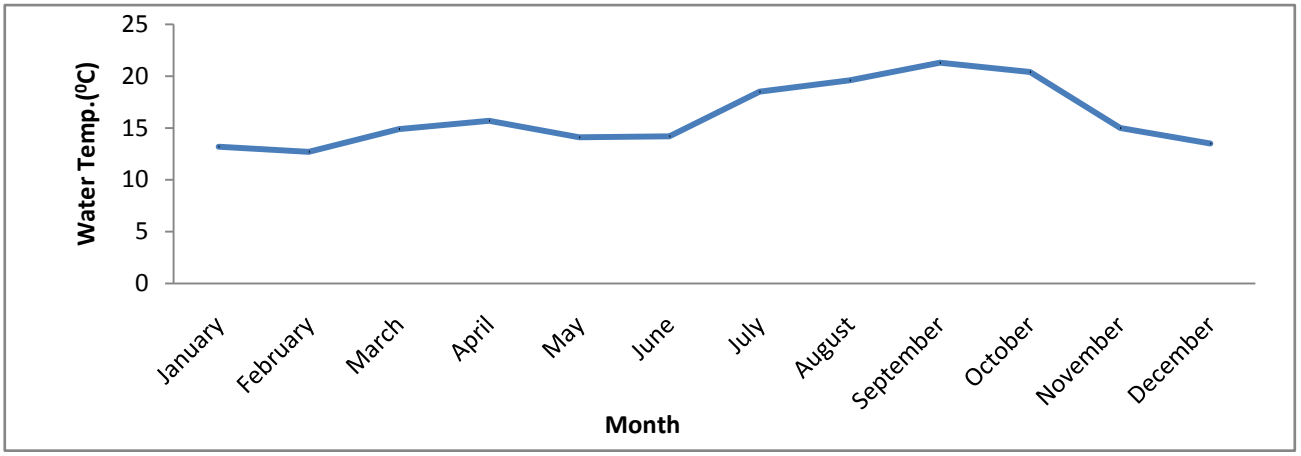

Figure 3. Monthly variation in the average water temperature of the Ragda Gad stream

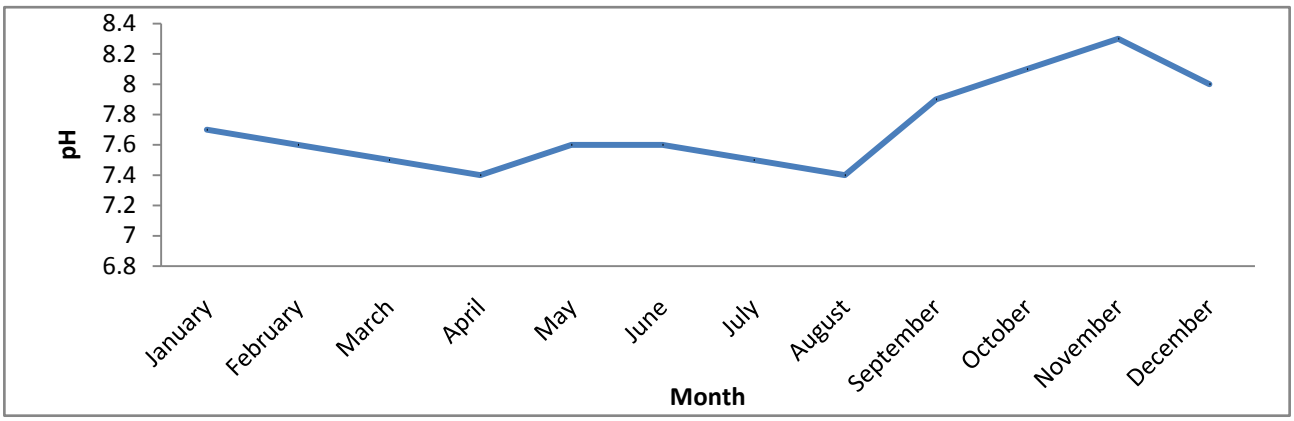

Figure 4. Monthly variation in the average pH of the Ragda Gad stream

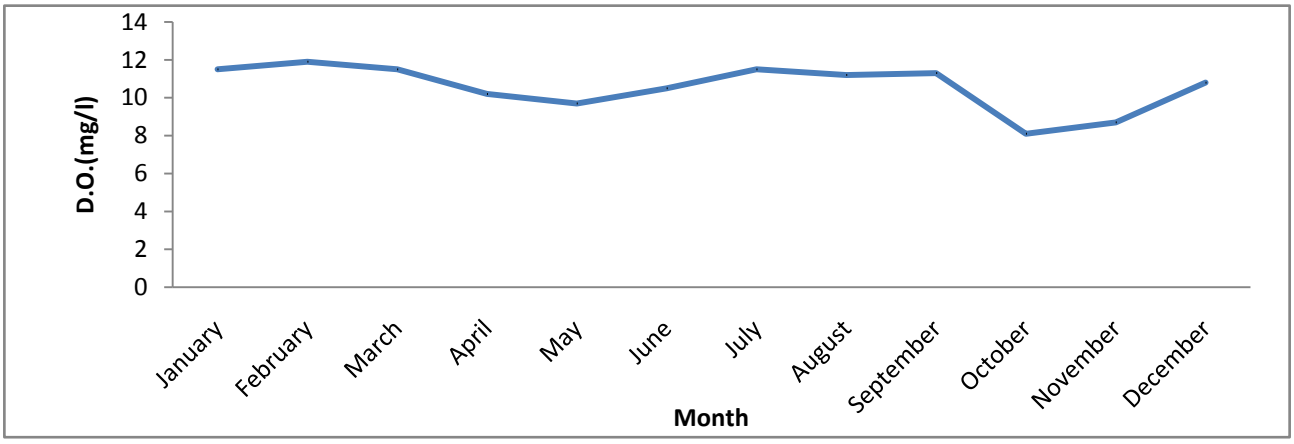

Figure 5. Monthly variation in the average D.O. of Ragda Gad stream

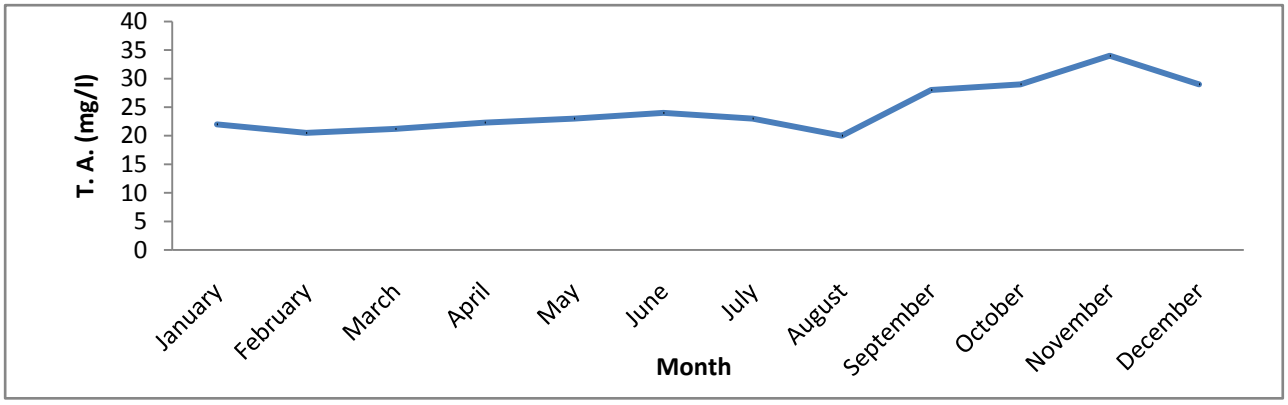

Figure 6. Monthly variation in the average T.A. of the Ragda Gad stream

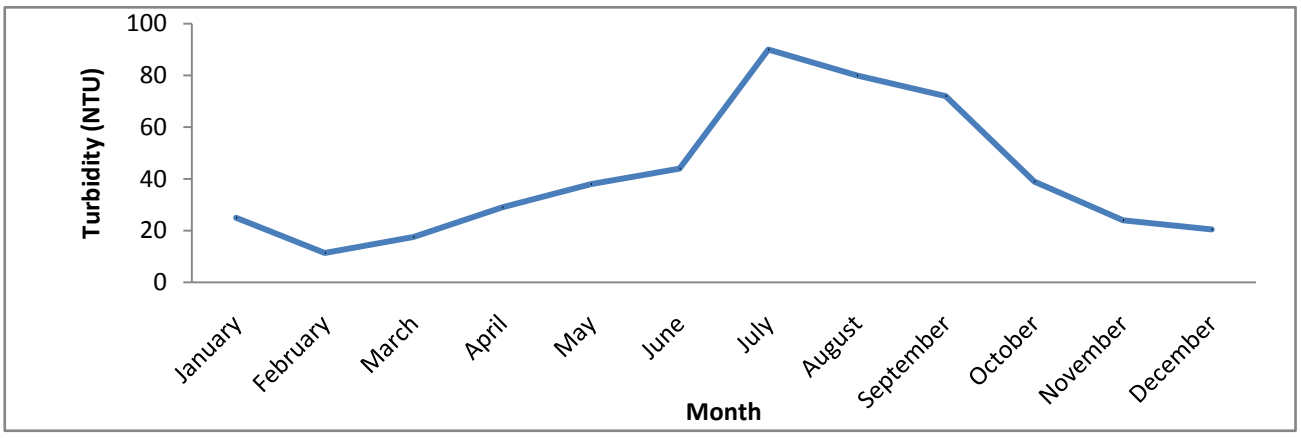

Figure 7. Monthly variation in the average turbidity of the Ragda Gad stream

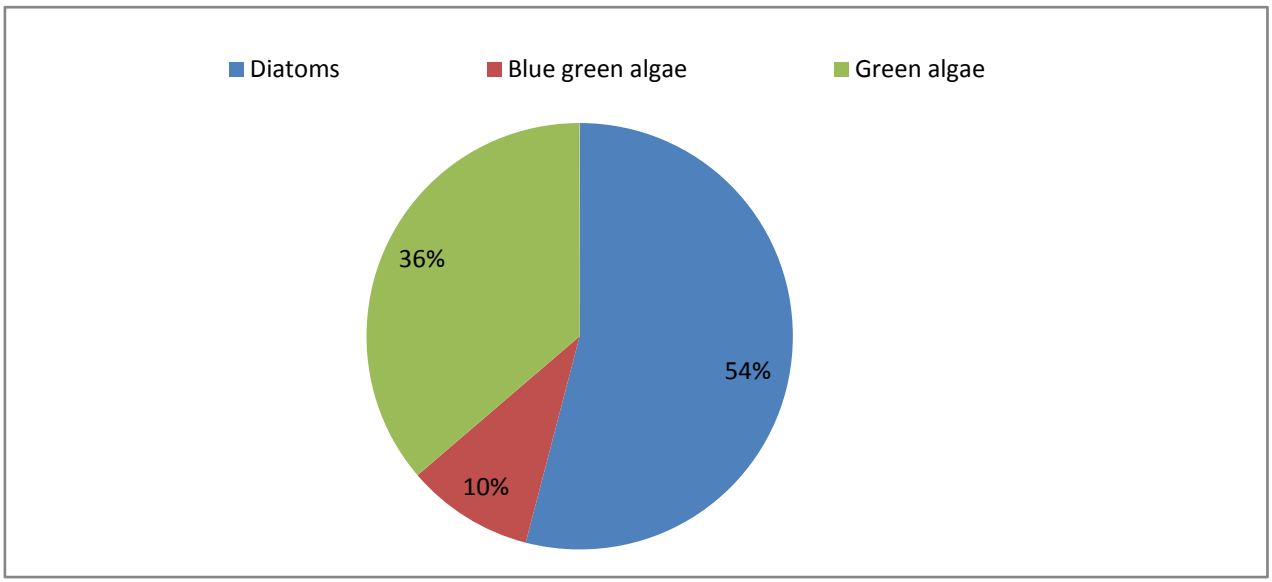

Figure 8. Percentage distribution of periphyton in the Ragda Gad stream

The substrates like leaves, gravel, wood, and the macrophytes were found to be supporting more diversity in comparison to structurally simple substrates, such as sand and bedrock [25]. This can be a good explanation for the high abundance and diversity of periphyton at the sampling stream Ragda Gad, which has high macrophyte growth. The highest number of periphytic concentration was noticed in January (230.48±8.11 units cm^{-2}) which was attributed to diatoms (140.09±9.30 units cm^{-2}), green algae (80.2±8.11 units cm^{-2}) and blue-green algae (10.19±0.82 units cm^{-2}). The lowest number of periphyton was observed in July (3.13±0.22 units cm^{-2}) which was dominated by the diatoms (3.13±0.22 units cm^{-2}) but green algae and blue-green algae were completely absent due to heavy monsoon period. In July, the density of periphytic algae was observed to be absent and low density was noticed in August month. It may be because of the heavy monsoon period that causes a higher disturbance. Burial and washout by heavy rainfall are a major cause of periphytic algal loss [26]. In the present study, the density of periphyton was found to be decreasing from February to August. This may be due interaction of various physico-chemical parameters with periphyton. Flow permanence, water chemistry, and temperature are important hydrological factors determining species distribution and community composition of periphyton [27]. Cantonati [28] also suggested that among various environmental factors, pH and conductivity are the most important factors influencing diatom assemblages.

Algae attached in the fast-flowing water should be firmly anchored to hard surfaces. Algal growth on a natural substrate like pebbles, stones, leaves, and sand, etc. represent the natural flora. In the present study of Ragda Gad streams, the submerged macrophytes were not recorded. The Periphyton study was carried out only from submerged stones and pebbles. Periphytic algae in our study exhibited a good diversity in terms of species numbers. A total of 25 taxa of periphytic algae were noticed in the Ragda Gad stream during the period of investigation (Table 2). The distribution of lithophytic algae showed three major species groups Bacillariophyceae, Chlorophyceae, and Cyanophyceae (Table 2). The order of dominance was Bacillariophyceae (11) > Chlorophyceae (10) > Cyanophyceae (04). Bacillariophyceae was the most dominant followed by Chlorophyceae and Cyanophyceae which is generally the trend found in the lotic system [29]. Similar observations among periphytic flora in several streams are reported previously also [30].

Table 2. List of periphyton recorded from the Ragda Gad stream.

S.No	Periphyton	Genus
A	Bacillariophyceae	
	1	*Cymbella sp.*
	2	*Synedra sp.*
	3	*Fragilaria sp.*
	4	*Gomphonema sp*
	5	*Navicula sp.*
	6	*Tabellaria sp*
	7	*Achnanthes sp.*
	8	*Diatoma sp.*
	9	*Bacillaria sp.*
	10	*Nitzchia sp.*
	11	*Amphora sp.*
B	Chlorophyceae	
	1	*Cladophora sp.*
	2	*Oedogonium sp.*
	3	*Spirogyra sp.,*
	4	*Microspora sp*
	5	*Volvox sp.*
	6	*Zygenema sp.*
	7	*Ulothrix sp.*
	8	*Closterium sp.*
	9	*Cosmarium sp.*
	10	*Geminela sp.*
C	Cyanophyceae	
	1	*Nostoc sp.*
	2	*Anabaena sp.*
	3	*Rivularia sp.*
	4	*Phormidium sp.*

Bacillariophyceae was noted as a major algal class both qualitatively and quantitatively from the Ragda Gad stream. The presence of a good concentration of SiO_2 in water bodies that possibly facilitate in the frustules formation [31] and its ability to thrive well in cold water could be responsible for this [32]. The diatoms mainly consisted of species of *Cymbella sp., Synedra sp., Fragilaria sp., Gomphonema sp., Navicula sp., Tabellaria sp., Achnanthes sp., Bacillaria sp., Diatoma sp., Amphora sp., Nitzchia sp.* etc. *Navicula sp., Bacillaria sp., Synedra sp.* and *Cymbella sp.* was observed to be the most dominant species amongst Bacillariophyceae.

Chlorophyceae was mainly represented by *Microspora sp., Volvox sp., Zygenema sp., Cladophora sp., Oedogonium sp., Spirogyra sp., Cosmarium sp., Closterium sp., Geminela sp.* and *Ulothrix sp., Oedogonium sp., Spirogyra sp., Cladophora sp.* and *Ulothrix sp.* was identified to be the most dominant species at sampling sites. Blue greens were recorded as the third but least dominant group represented by 4 taxa. Species of *Nostoc sp., Phormidium sp., Anabaena sp.* and *Rivularia sp.* was observed in good number.

Springs are unique in their characteristics *viz*; specific aquatic micro-ecosystems; the contact zone of the above-ground and underground of hydrosphere and habitation of infrequent and relict species of aquatic organisms [33]. Studies on seven springs of Kashmir showed a total of 50 taxa of periphytic algal community, of which 33 belonged to Bacillariophyceae, nine to Chlorophyceae, five to Cyanophyceae, two to Chrysophyceae and one to Euglenophyceae [10]. Temperature is recognized as a major role player for periphyton species distribution in spring water [34]. Water temperature has a positive influence on periphyton physiological activities such as growth and cell division. A maximum abundance of periphyton was observed during the winter season (December to February) in the Ragda Gad springs, which may be due to increased growth efficiency of periphyton during this period in addition to favorable physico-chemical attributes. It is suggested that the blanketing bottom effect of suspended bottom material adversely affected the rate of photosynthesis by upsetting the velocity and turbidity of the stream [9,35].

4. Conclusion

The aquatic ecosystem must be able to self-maintain or regulate and requires a robust community structure and sufficient integrity (Kay, 1991 [36]). Periphyton communities respond not only to a natural change in the stream but may also present variations as consequences of human intervention affecting the water body, either directly or through activities carried out in the immediate catchment on whole. The springs are an excellent indicator of the ecological state of groundwater and atmospheric precipitation in contrast to other water bodies and watercourses (lakes, rivers, streams, etc). The springs are much more stable in terms of hydrological and chemical conditions and are less exposed to occasional fluctuations. Water quality plays an important role in determining the periphyton community composition in a locality, Periphyton species composition and growth are a useful indicator of nutrient enrichment.

In the present work, the percentage annual composition of periphytic flora of Ragda Gad revealed that major contribution was made by Bacillariophyceae (54%) follow by Chlorophyceae (36%) and Myxophyceae (10%). A total of 25 taxa of periphytic algae belonging to Bacillariophyceae (11), Chlorophyceae (10) and Cyanophyceae (04) were observed in Ragda Gad stream during the period of examination. Periphyton communities respond not only to a natural change in the stream but may also present variations as consequences of human intervention affecting the water body, either directly or through activities carried out in the immediate catchment on whole [11]. The dominance of Chlorophyceae in the stream indicates the healthy condition of the stream ecosystem. It is having crystal clear water and is free from pollution. Further, as a result of less anthropogenic pressure, the quality of water is rather superior.

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