

Composition ofPeriphytic Algae of River Jhelum in SrinagarKashmir, India

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Abstract

The study was conducted to address the importance of the periphytic community for the river system, the knowledge of their diversity, as well as their composition, may contribute to a better understanding of the status of the river also.Sampling was done on monthly basis from June to November 2018, from four different sites (approx. 35 km stretch) of river Jhelum in Srinagar, to observe periphytic algal distribution and diversity.Keeping in view the authenticated and extensive publications, freshwater habitats contribute to aquatic biodiversity and give a comprehension of sensitivity in response to anthropogenic changes. River Jhelum holds a lot of importance in supporting the livelihoods of people and hosts a significant biological diversity. A total of 45 speciesbelonging to 4 major classes were recorded i.e., *Bacillariophyceae*(19), *Chlorophyceae*(16), *Cyanophyceae*(8) and *Euglenophyceae*(2).The most common periphytic species encountered across all 4 sites included *Cladophora sp.*, *Cosmarium sp.*, *Cymbella sp.*,*Cyclotella sp.*, *Didymosphenia sp.*, *Gyrosigma sp.*,*Navicula sp.*,*Nitzschia sp.*, *Nostoc sp.*, *Synedra sp.*and *Ulothrix sp.Bacillariophyceae*dominated both in diversity as well as thedensity at each site, followed by *Chlorophyceae*and then *Cyanophyceae* whereas *Euglenophyceae* contributed only 2 species with very low population. Amongst the study sites, the values of the Shannon -Weiner Diversity Index were highest at Site III (3.8) and lowest (3.1) at Site II while as highest (73.46) and lowest (48.97). Sorensen's Similiaritycoefficients were found between Site I and Site II and Site II and Site IV. The data represent that the *Bacillariophyceae*was the most dominant class in terms of density, abundance as well as diversity. The result suggests that richest diversity of periphyton at station III was due to the enrichment of water from upstream to downstream.Hopefully, the baseline data generated from the present paper contribute to filling the knowledge gaps of composition of periphytic algae of river Jhelum in Srinagar Kashmir, India.

Keywords: Algae, Bacillariophyceae,Chlorophyceae, Cyanophyceae, Euglenophyceae, River Jhelum

1. Introduction

Rivers are the main source of water supply for humans as well as for biological ecosystems besides socio-economic and other services. In Kashmir Valley, river Jhelum is considered as a lifeline for a huge population as it is the main drinking water resource and sustenance of agriculture, industrial, irrigation to hydropower generation(Mir andGani, 2019; Bhat*et al*., 2020; Khanday*et al*., 2021). Unfortunately, the alarming increase in anthropogenic activities (Mir and Jeelani, 2015), expanding population (Showqi*et al*., 2016), intensive use of pesticides (Rashid and Ramshoo, 2013) has led to the worsening of these fragile ecosystems(Ramshoo*et al*., 2015) and inappropriate vanishing of bio-species growing in these ecosystems. River Jhelum has been studied in terms of water quality (Rather *et al*., 2016; Mehmood*et al*., 2017; Mir and Gani, 2019), benthos (Engblom and Lingdell, 1999), fish fauna (Yousuf*et al.*, 2006), sediment (Mir *et al.,* 2013), etc. But very little information is available for the periphyton community of river Jhelum, which provides an enormous surface for periphytic growth. The periphytic algal community is a fundamental part of the river ecosystem. The Periphyton in streams and rivers are considered as the very essential component by being among the dominant primary producers (Finlay *et al*., 2002) and constituting an important source of autochthonous organic matter (Wetzel and Likens, 2000).Periphyticalgae contribute largely to the biodiversity of these ecosystemsdue to their high species richness(Werumm, 2001).Periphyton assemblages can be spatially complex and temporally variable depending on a wide range of environmental and biological factors (Biggs and Kilroy, 2000), including light (Rosemond, 1993;Kiffney and Bull, 2000), nutrients (Cascallar*et al*., 2003), temperature (Weckstroem and Korhola, 2001), current velocity, carbonates, moisture gradient, physical disturbance,substrate type(Werumm, 2001), competition (Stevenson *et al.,* 2006) and invertebrate grazing(Doi*et al*.,2008).Alkalinity, dissolved oxygen, and biological oxygen demand have been reported to be of primary influence in diatom dynamics (Lai *et al*., 2019).Physical turbulencesuch as floods, droughts, and gravel removal can periodically scour periphyton from the river bed (Siva and John, 2002). In addition, the frequency, type, magnitude, timing, and season of the disturbances can have substantial effects on the biomass and structure of these communities(Komulaynen, 2002), although the algal community recovers fairly rapidly within 2 to 4 weeks. And it is only because of its distinctiveness and swift turnover, thatthese communities provide both food and shelter for the benthic fauna of the aquatic system (Finlay *et al*., 2002).

Excessive periphyton growth can occur in rivers as a result of human disturbances, high water temperatures, and excess nutrient productionand through releases from wastewater treatment facilities and domestic processes, etc. (Wargo and Holt, 2004).As a result of these responses,these algal communities have been used as biotic indicators of ecological conditions and changes in conditions in response to human and natural disturbance (Denicola*et al.*, 2004).Therefore, the characterization of the periphytoncommunity is a very important tool for the verification of environmental conditions and the water quality of an aquatic ecosystem (Komulaynen, 2002). There are studies, which have

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usedperiphytonto monitor chronic metal pollution in rivers since periphytic organisms can accumulate metals from ambient water and sediments in their biomass (Morin *et al.*, 2008). Therefore studying the periphyton diversity in river ecosystem becomes increasingly important and is attracting the attention of scientists and ecologists all over the world.It is in this context that we specifically aimed to addressthe importance of the periphytic communityfor the river system, the knowledge of their diversity, as well as their composition, may contribute to a better understandingof the status of theriver also. Furthermore, the present study will be a baseline data for further research.

2. Materials and Methods

Studyarea

The river Jhelum originates from the major spring at Verinag (Vyeth) in the Anantnag district towards the south-eastern part of the Kashmir valley located in western Himalaya. From Verinag, the river traverses through the heart of the Kashmir valley and enters the Wular Lake origin to the outlet. It is a perennial, snow-fed river that forms a lifeline ofthe valley and holds a greater significance. The study area lies between the geographical coordinates of 33°58′45.4”–34°07′47.1” latitude and 74°54′16.5”–74°43′11.0” longitude.

Sampling sites

The present work focuses on the middle stretch of the Jhelum river from Marwal in Kakapora (Pulwama District) toTengpora,in the Srinagar District (Fig. 1). In this study, the sampling stations were selected from upstream to downstream.A total of four study sites were selected along a course of a 35 km stretch of the river. Site I (Marwal) was characterized by rural settlements on the banks thus receiving domestic wastes, agricultural land and dense trees of different species especially of *Populus*and *Salix*. Site II (Aramwari) was characterized by sparse human population and little commercial activities along both its banks. Site III (Qamarwari) was with both the commercial activities and residential settlements along both banks, releasing wastes into the river without treatment. Site IV (Tengpora)was having almost the same feature as site I.

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Fig. 1. Geographic location of the Study area and Sampling sites

Climate and vegetation

The climate in the area ranges from sub-Mediterranean to generally temperate, with a wide range of precipitation and dryness. On temperate range minimum-maximum in winter and summer is marked by four seasons, viz., winter (December–February), spring (March–May), summer (June–August) and autumn (September–November) (Husain, 2001).July is the warmest month of the year, with temperature rising to an average of 20°C, while January is the coldest, with temperatures as low as -6°C. (http://www.imd.gov.in/pages/main.php).

Methods

Samples from each site were collected once in a month from June to November 2018, by scrapping 5 cm^2 surface areas of boulders, wood and sacks using blade and brushes. It was washed into a tray and then transferred into a vial of suitable volume (Biggs and Kilroy, 2000).Samples were preserved with 1ml Lugol's iodine and three drops of 4% formalin (APHA, 2010).The samples were then raised to a constant volume of 25ml (APHA, 2010). The samples were immediatelytransferred to the laboratory for analysis following APHA, 2010.Identification was carried out with the help of standard keys (Prescott, 1939; Cox, 1996; Edmondson, 1992; Biggs and Kilroy, 2000; Krammer and Lange-Bertalot, 2000; Reichardt, 2004; Zelazna-Wieczorek, 2011; APHA, 2010). Density was calculated using Sedgwick- Rafter cell (50 mm length, 20 mm width and 1mm deep) with total surface area 1000 mm^2. Shannon- Wiener Indexwas used to calculate the species diversity (Shannon, 1963).The species similarity between various sites was calculated by Sorensen Similarity Coefficient (Sorensen, 1984).

3. Results and Discussion

A total of 45 periphytic algae species belonging to 4 classes:Bacillariophyceae (diatoms), Chlorophyceae (green algae), Cyanophyceae (blue-green algae) and Euglenophyceae (flagellates) were found during the study period.The dominant class was Bacillariophyceaecontributing 19 species (constituting 50% of the total periphytic algae community composition) followed by Chlorophyceae 16 species which made 35% of community composition, Cyanophyceae 8 species (12%) andEuglenophyceae 2 species (3%)(Table1). The dominant species was*Navicula* species.Among all the sites, site III recorded maximum number of species (30) followed by site I and IV (28) and site II (21). The common species found at all the sites were:*Cymbella*,*Cyclotella*,*Didymosphenia*,*Gyrosigma*,*Navicula*,*Nitzschia*,*Synedra*, *Cladophora*,*Cosmarium*,*Ulothrix* and *Nostoc*.Along with wide divergence in dominance from all the stations, the similarity indices showed that all the stations were rather similar, but station I and station II were found to be showing highest similarity with each other (Table 2). The Shannon Weiner Index was highest for site III and IV (3.6 each), followed by Site I (3.3) and Site II (3.1) (Fig.8).

Table1. Abundance of species of Periphyton at 4 study sites

CLASS	**Site I**	**Site II**	**Site III**	**Site IV**	**Overall**
Bacillariophyceae	14	10	14	13	19
Chlorophyceae	7	5	11	8	16
Cyanophyceae	5	5	4	4	8
Euglenophyceae	2	1	1	2	2
Total	28	21	30	28	45

Bacillariophyceae

Bacillariophyceae dominated at all the sites during the current study. At site I, a total of 14 species were found with*Navicula* sp. most dominating (MD 32 ind/cm^2) and *Diatoma* sp. (MD 6 ind/cm^2)was least abundant (Fig. 2a). At site II, a total of 10 species were found. Among them *Cymbella* sp.wasmost dominant (MD 33 ind/cm^2), whereas *Tabellaria* sp.(MD 7.5 ind/cm$^{2)}$was found to be least abundant (Fig. 2b). Atsite III,a total of 14 species were found where *Cymbella* sp. dominated (MD 56 ind/cm^2), whereas *Cyclotella* sp. was least abundant (MD 15 ind/cm^2) (Fig. 2c).At site IV, a total of 13 species were found where the *Navicula*sp. was the most abundant(MD 58.2 ind/cm^2) and *Nitzschia* sp. (MD 9.5 ind/cm^2) was least abundant (Fig. 2d).The common species between the sites include *Amphipleura*, *Cymbella*, *Diatoma*, *Cyclotella*, *Amphora*, *Eutonia*, *Fragilaria*, *Frustulia*, *Gyrosigma*, *Navicula*and *Didymosphenia*. Whereas *Amphora*, *Achnanthes*and *Pinularia*were found exclusively at site I.

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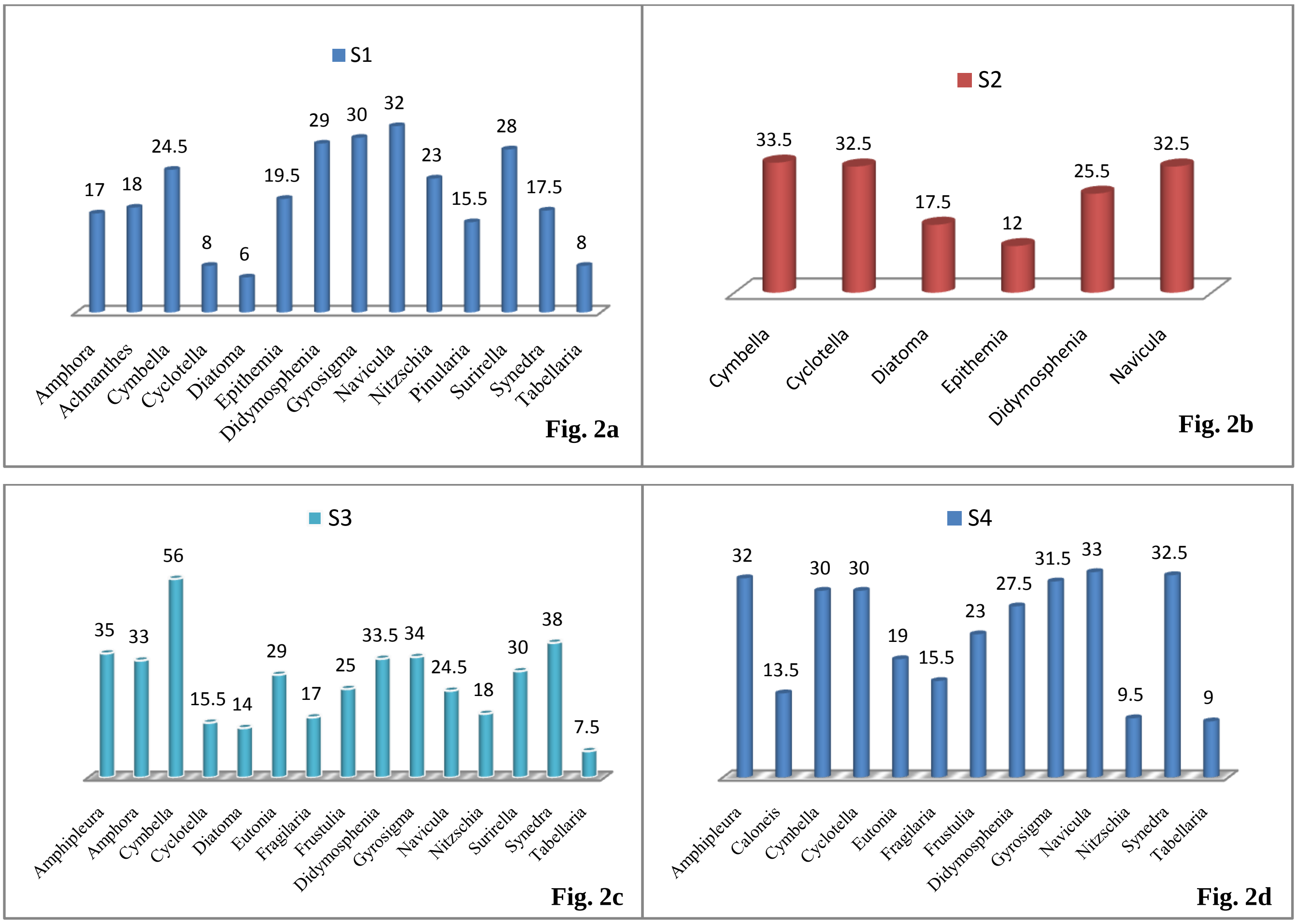


Fig. 2.(a-d) Trends in Mean density (MD, ind/cm^2) of Bacillariophyceae at 4 sites

Chlorophyceae

A total of 7 species were found at site I, where *Zygnema* sp. was dominating (MD 8.5 ind/cm^2) (Fig.3a). At site II total 5 species were found with *Cosmarium* sp. (MD 27.5 ind/cm^2) most abundant and *Chlorella* sp. (MD 11 ind/cm^2) least abundant (Fig.3b).Site III was foundto be most diverse, represented 11 species, where*Cosmarium* sp.(MD 34.5 ind/cm^2) was the most abundant and *Hydrodictyon* sp.(MD 6 ind/cm^2) least abundant (Fig. 3c). At Site IV a total of 8 species were found in which *Cosmarium* sp. (MD 31.5 ind/cm$^{2)}$ was most abundant and *Oedogonium*sp. (MD 14 ind/cm$^{2)}$ least abundant (Fig.3d).Common species at all the sites found include:*Cladophora*, *Cosmarium*, *Geminella*, *Oedogonium*, *Sphaerocystis*, *Zygnema*and*Ulothrix*. Whereas *Chlorella* was found only at site II, *Desmidium*, *Geminella*, *Hydrodictyon*, *Oedogonium*, *Sphaerocystis*and *Straustrum* were found only at site III and *Volvox* was only present at site IV.

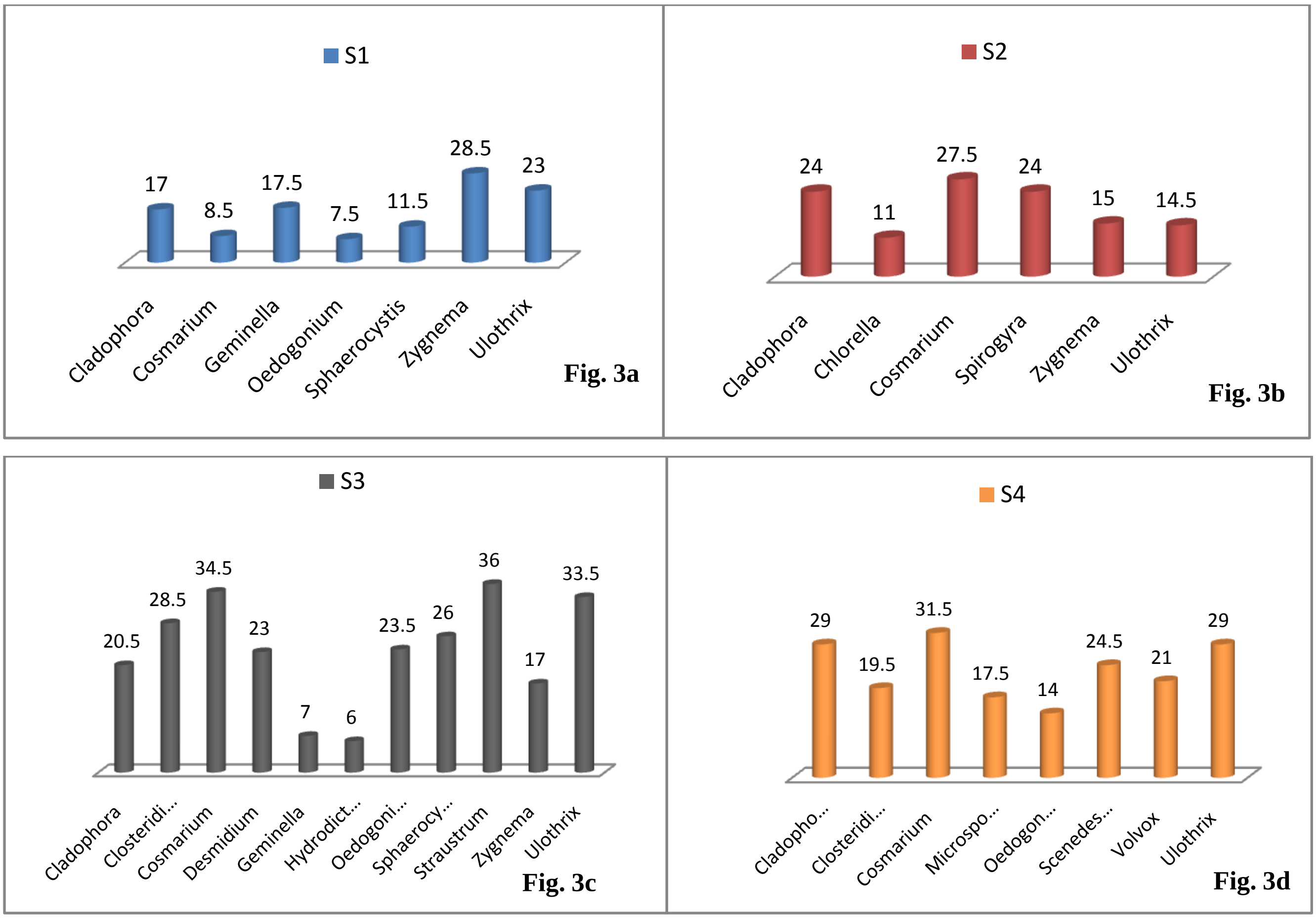
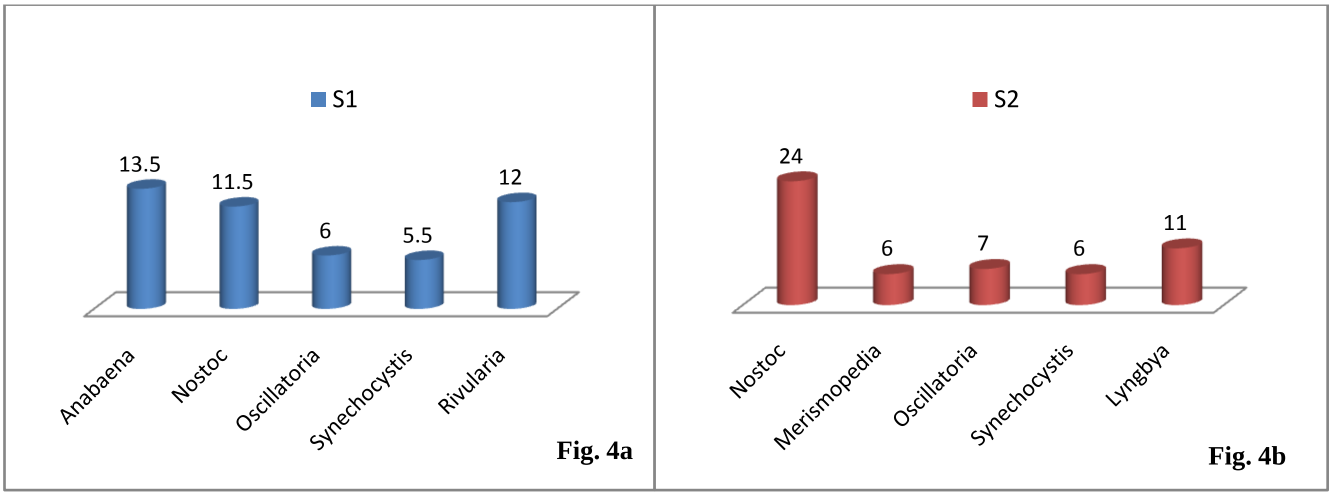


Fig. 3.(a-d) Trends in Mean density (MD, ind/cm^2) of Chlorophyceaeat 4 sites

Cyanophyceae

Site I was dominated by *Anabaena* sp. (MD 13.5 ind/cm^2), followed by*Nostoc* (MD 11.5) and *Synechocystis* sp. was least abundant with a mean monthly density of 5.5 ind/cm^2(Fig.4a).AtSite II*Nostoc* sp. was the most abundant (MD 24 ind/cm^2) and *Merismopedia sp.* was least abundant(MD 6 ind/cm^2)(Fig.4b). *Rivularia* sp. dominated the site III (MD 28.5 ind/cm^2) with*Spirulina* sp.least abundant (4 ind/$cm^{2)}$(Fig.4c).At site IV*Anabaena* sp. was abundantly found (MD 30 ind/cm^2) (Fig.4d).The common species include *Anabaena*,*Nostoc*, *Oscillatoria*and*Synechocystis*,whereas *Lyngbya sp.*was found only at site II (MD 11).



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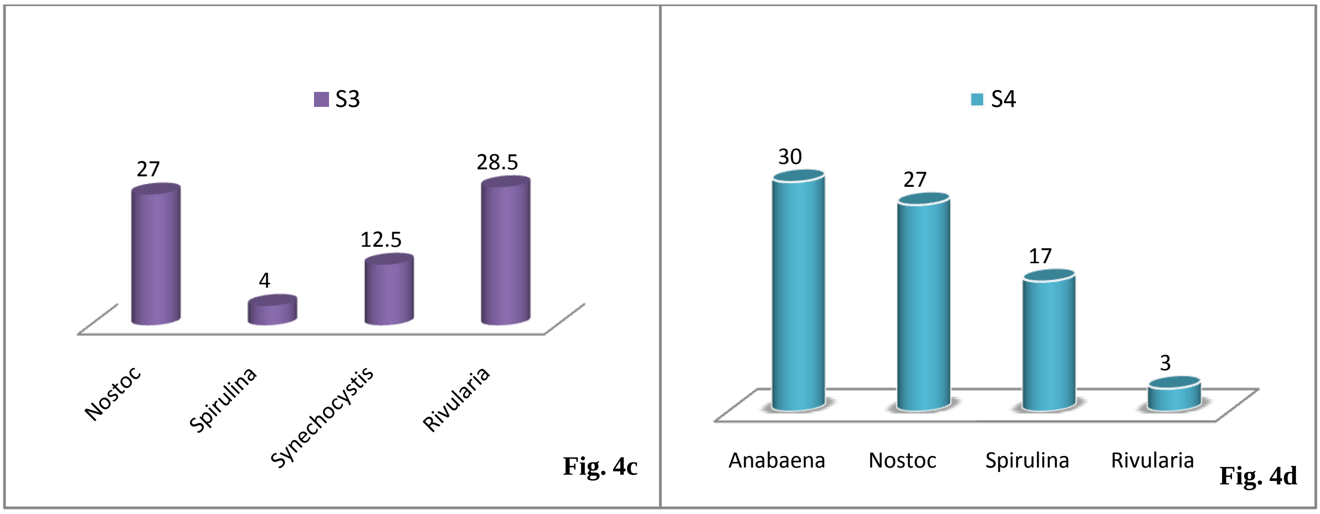

Fig. 4.(a-d) Trends in Mean density (MD, ind/cm^2) of Cyanophyceae at 4 sites

Euglenophyceae

At Site I and Site IV each, two species *Euglena sp.* and *Chlamydomonas* sp. were found (Fig.5a), but only one species (*Euglena* sp.) was found at site II and III each(Fig.5b).

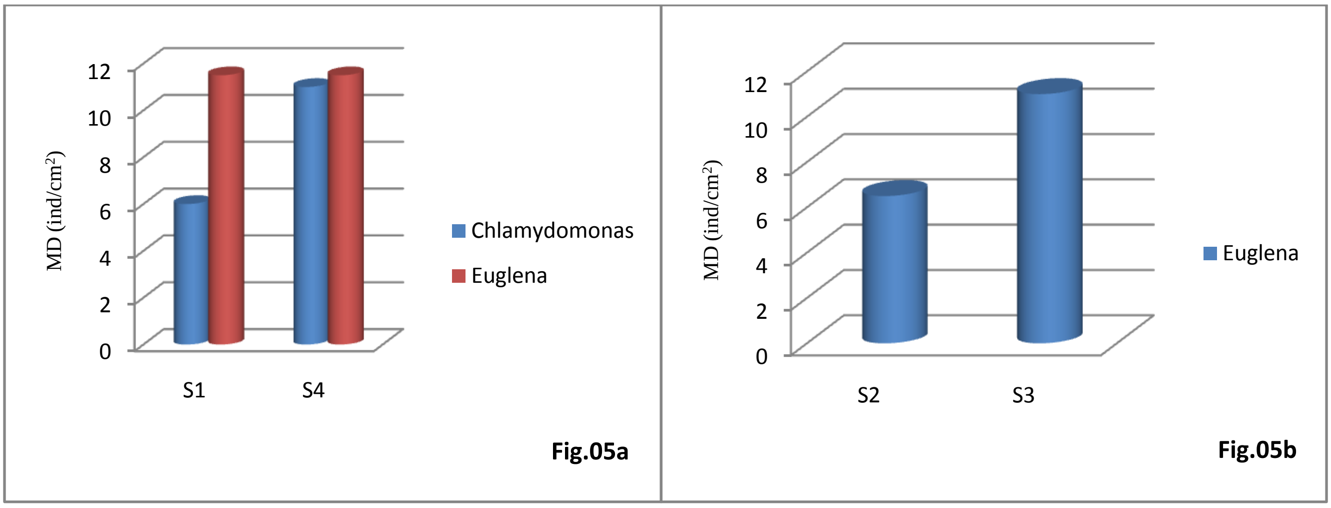

Fig. 5.(a-b) Trends in Mean density (MD, ind/cm^2) ofEuglenophyceaeat 4 sites

Relative density (Percentage composition)

The relative dominance of different groups showed that Bacillariophyceae was the dominant at all study sites, composed of 19 species (RD 50%), followed by Chlorophyceae (RD 35%) which was composed of 16 species and was most dominant at site III, Cyanophyceae consisted of 8 species(RD 12%) and Euglenophyceae with only 2 species(Fig.6).

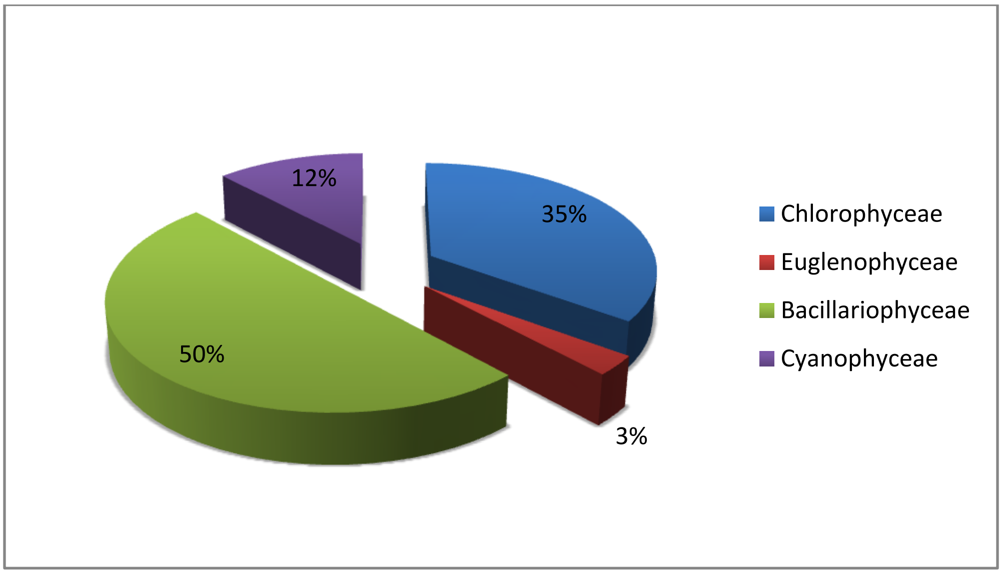

Fig. 6. Overall Relative Density (RD) of periphytic algaeat different study sites

Monthly variation in diversity

On the Monthly basis the diversity of the periphyton was found to increase from June to October, from which it again decreased towards the November. The maximum diversity was found in the month of October and the lowest was found in June (Fig. 7).

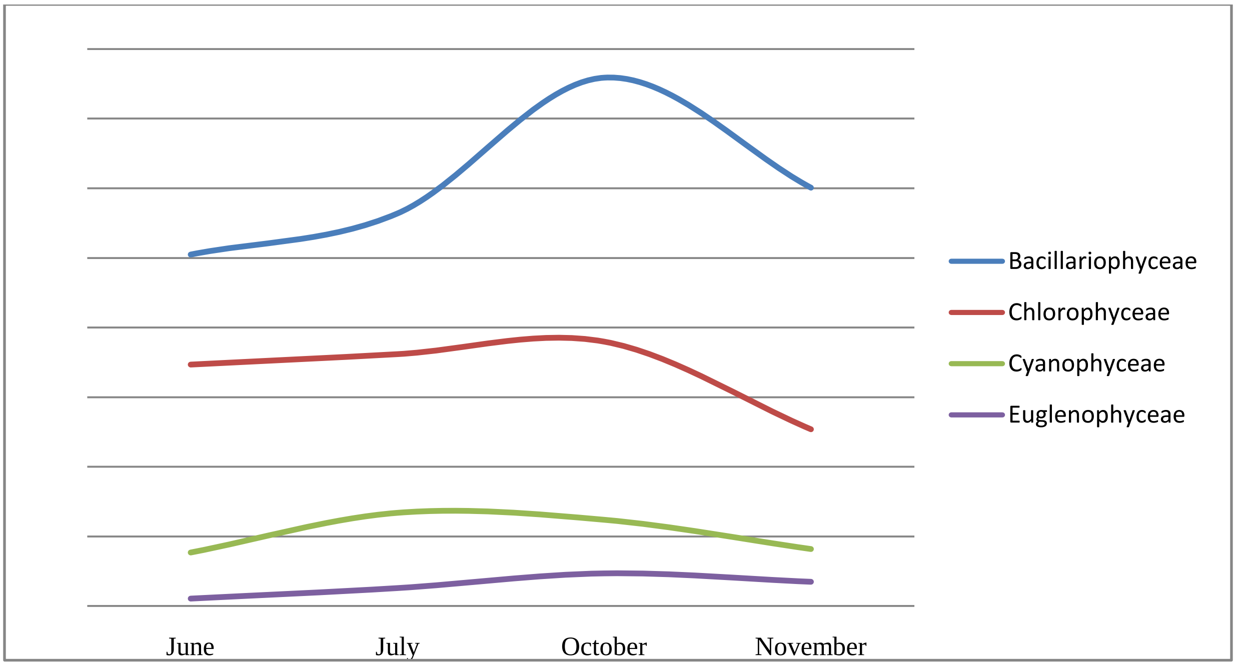

Fig. 7. Monthly variation in Periphytic diversity

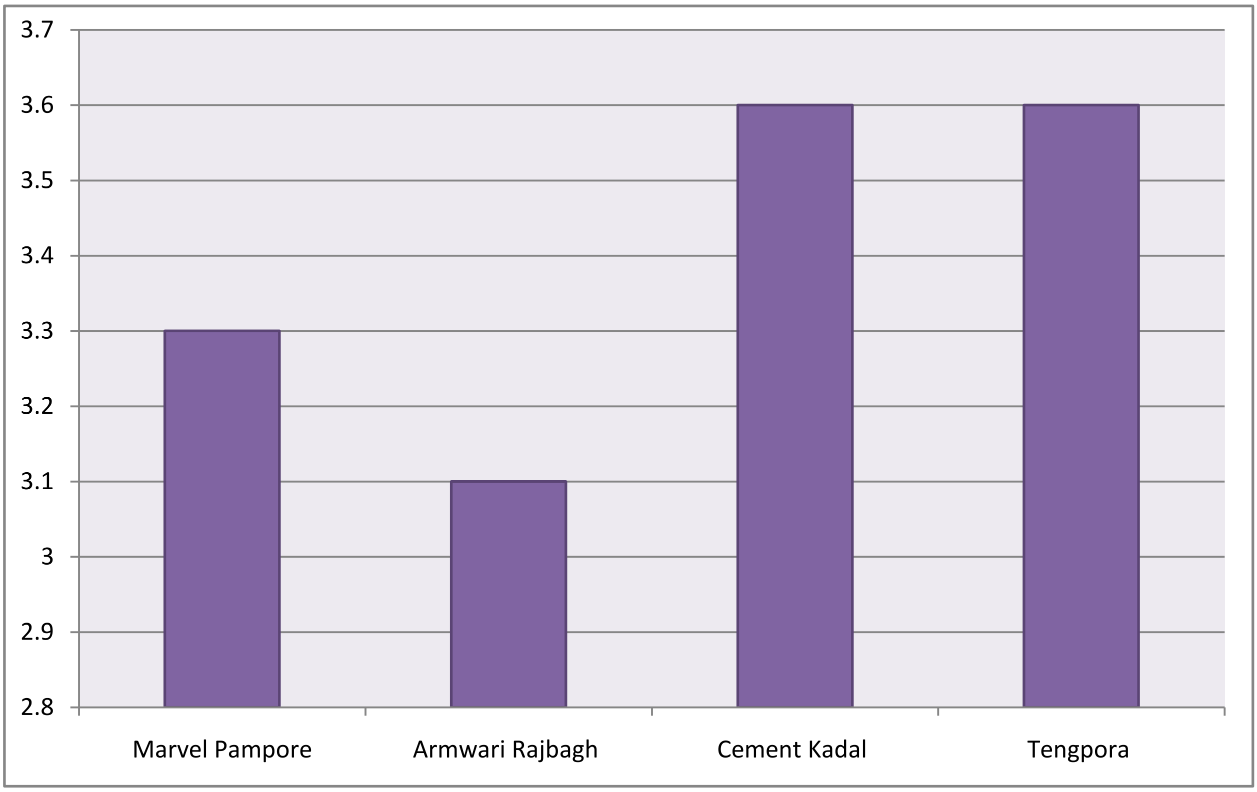

Fig. 8. Shannon-Wiener index of Periphytic algae at different study sites

Table2. Sorensen's Similarity coefficient between different sites

SITES	**S I**	**SII**	**SIII**	**SIV**
S I		0.73	0.65	0.57
S II			0.5	0.48
S III				0.72
S IV				

Discussion

The density and diversity of periphytic algal communities were studied at each site. Periphytic algal communities were found to be limited to few classes including Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae.The analysis of data showed that the Bacillariophyceae dominated periphytic algae composition. The dominance of Bacillariophyceaelike in the current study has been found as a general trend in most of lotic systems (Hynes, 1979) and springs worldwide (Demir and Kirkagac, 2005; Menegalija and Kosi, 2008; Angeli*et al.*, 2010; Smol and Stoermer, 2010).Our results are consistent with many studies done on periphyton in valley (Rashid and Pandit, 2008; Bhat*et* *al*.,2011).Diatom assemblage composition was dominated by *Navicula*sp. The dominance of Bacillariophyceae may be attributed to the presence of silicon dioxide in water bodies which probably helps in the frustules formation (Wetzel and Likens,2000; Sabater, 2000) and its ability to thrive well in the cold water (Rashid and Pandit, 2005; Sarwar, 1999; Bhat*et al*., 2010). Chlorophyceae followed by Cyanophyceae and Euglenophyceae were also important contributors. *Cymbella*sp. and *Navicula*sp. dominance seems to be favoured by low temperature and high light penetration (Lone *et al*., 2013). The dominance pattern of the Bacillariophyceae was beaten at site III by the Chlorophyceae. In addition to this dominance pattern, site III was found to be the most diverse as compared to other sites. This exceptional high diversity and the dominance of the Chlorophyceae at the site III could be attributed to the discharge of sewage and other solid wastes directly into the river (Winter, 1998; Hill *et al*., 2010). Other factors such as light, physical disturbance, nutrient concentrations and substrate suitability are also important factors influencing biomass accrual and productivity (Rosemond, 1993; Kim and Richardson, 2000).The abundance of Chlorophyceae at the site also reflects its high nutrient status (Allan, 2004; GreenWood and Rosemond, 2005). The dominance of Chlorophyceae also reflects the acidic nature of water. It has been found that green algae have an affinity forlow pH conditions (Lai *et al.*, 2019).In case of Cyanophyceae, there is an increasing trend in their growth with higher water temperature, lower alkalinity, conductivity and hardness (Baba *et al*., 2011), thus present at all the 4 sites.

On the monthly basis, maximum density of periphyton was obtained in the month of October at all the study sites. This could be attributed to the lukewarm water during this month. Similar results were obtained by Bhat and Yousuf (2002) and Bhat*et al*. (2010) who also opined that the intermediate temperature provides optimum conditions for the growth and reproduction. The low density of periphytic algae in July was attributed to high water discharges and its related shear stress that prevent algae to grow (Nikora*et al*., 1997; Lone *et al*., 2020). Biggs *et al*. (2000) have reported burial and washout by heavy flows to be the main cause of periphytic algae loss. The decrease in diversity and density towards winter were attributed to exceptionally lower water temperature (Badar and Pandit, 2006), which hinders the growth of periphyton. It is obvious from the results that the river Jhelum will become eutrophied if the pollutant and the sewage inputs continue. Therefore, the sewage should be treated properly before being drained into the river and proper management strategies should be adopted for the protection of the river.

4. Conclusion

The analysis showed that the composition of communities, richness and distributional pattern of periphytic algae in the river Jhelum is structured by the discharge, dissolved oxygen, sediment, nutrient status and other environmental factors. The dominant species was *Navicula* sp. The richest diversity of periphyton at station III was to high nutrient enrichment of water. In addition to detailed studies in future, we recommend that the waste water should be treated before releasing into the river. This study provides baseline information for environmentalists and researchers for studying stream periphyton and can be used for the subsequent water quality surveys.

Conflict of Interest

No potential conflict of interest was reported by the author(s).

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Authors Contribution

This work was carried out in collaboration among all authors. All the authors approved final draft of the manuscript for submission.

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