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Phytoplankton diversity and water ecology of River Nun, Garhwal Himalaya, Uttarakhand

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ABSTRACT

The present study evaluates the phytoplankton diversity along with physico-chemical characteristics in Nun River during a time period of October 2023 to March 2024. A total of 38 genera of phytoplankton belonging to 7 classes, 21 orders and 26 families were recorded. Phytoplankton in the river are represented by seven major classes, Bacillariophyceae (07), Chlorophyceae (16), Cyanophyceae (10), Trebouxiophyceae (2), Tubulinea (01) Ulvophyceae (01) and Chrysophyceae (01). The phytoplankton density was reported to be abundant at site 1 in January dominated by two classes Bacillariophyceae and Chlorophyceae ranged between 42 Unit1^{-1}-262 Unit1^{-1} and 34 Unit1^{-1} -296 Unit1^{-1} respectively. Results showed the evenness index was varied between 0.88 to 0.98 this indicated that particular genus of the phytoplankton community is not evenly distributed in all sites and on the basis of Shannon weiner index value we accomplished that the water quality from Nun River can be accounted as moderately polluted to clean.

Key words: *Phytoplankton, Nun River, Physicochemical parameters, Garhwal Himalya*

Introduction

Water maintains the ecological balance between different living creature groups and their surroundings (Kumar *et al.,* 2024). The organization, abundance, fertility, and physiological environment of aquatic life are all reflected in the physico-chemical parameters of water resources. The world's biodiversity is remarkably supported by these strained systems (Tockner, 2021). A numerous of phytoplankton species which have been found in aquatic system over the past two centuries that are the building blocks of aquatic ecosystems. These varied and many creatures are essential to freshwater and marine habitats because they drive global biogeochemical cycles, nutrient cycling, and primary production.

Phytoplankton have an important role in maintaining aquatic food webs, influencing climatic patterns, and assisting in the creation of oxygen on Earth, despite their modest size (Dang, 2020). A phytoplankton is a class of micro algae & include the species from all the different divisions, Rodophyta and Phaeophyta (Pal and Choudhury, 2014). Diatoms, dinoflagellates, cyanobacteria (blue-green algae), coccolithophores, and other unicellular algae are among the many species that make up phytoplankton (Anderson *et al.,* 2021). Every group displays distinct physical and physiological traits tailored to their particular ecological niches. Because of their diversity, phytoplankton may be found thriving in a variety of aquatic environments, including freshwater habitats, tropical seas, and polar oceans (Morim *et al.,* 2023). The ability of phytoplankton in response to environment stimuli is the important determinant is a competitive success of specific taxonomic groups. In a balance environment, phytoplankton provide food for a wide scale of aquatic animal including macroinvertebrates, shrimps, crabs and fish. When extra nutrients are available, phytoplankton may increase in size out of control & formation harmful algal bloom (HABs) (Fernández-González *et al.,* 2022).

An imperative bio-indicator for evaluating the river's water quality is plankton. Although some species of phytoplankton may be hazardous to humans and other organisms due to its poisonous compounds discharge into the water, they are nonetheless valuable initial producers and the building block of the food chain in aquatic web (Ariyadej *et al.,* 2004). Since phytoplankton is very sensitive to environmental changes, any alteration to their habitat may have an impact on the tolerance, quantity, variety, and dominance of the planktonic communities within it. Accordingly, plankton population monitoring can be a trustworthy method for determining the level of contamination in waterways (Edwards *et al.,* 2016; Fernández-González *et al.,* 2022). Phytoplankton in particular was utilized as a water quality indicator. The most significant biological phenomena in nature, phytoplankton, is a crucial part of the riverine ecosystem and affects the primary production of the system, supporting the full range of life. It is the water pollution bio-indicators. As stated by Escaravage and Prins (2002), Gupta *et al.* (2013) biotic and abiotic variables influence its emergence, disappearance, density, and distribution pattern.

Numerous studies on phytoplankton have been conducted in various freshwater environments (Calijuri *et al.,* 2002; Angadi and Shiddamallayya, 2005; Singh *et al.,* 2017; Jain *et al.,* 2018; Ravinder *et al.,* 2018; Kumar *et al.,* 2020; Chamard *et al.,* 2024). Numerous qualitative monitoring and reports on both lotic and lentic aquatic environments, particularly in the Himalayan Garhwal area, are available. In the Himalayan streams, which are globally significant for biological production in connection to biodiversity, such ecological studies have just been started (Guleri *et al.,* 2021). Therefore, the present study aimed to investigate the Nun River's phytoplankton diversity, water quality as well as to study the association among physico-chemical parameters and phytoplankton density of the river.

Material and Methods

Study area

The present study was employed at the Nun River, located in Dehradun, Uttarakhand, India, is a vital water body that originates in the Himalayan foothills and serves as a tributary to the Tons River. Its geographical area lies between 30.379544° latitude and 77.987773° longitude and the catchment area includes forests, agricultural lands, and urban settlements, acting as a drainage basin for runoff and receiving inputs from rainfall, snowmelt, and groundwater(Das *et al.,* 2023). The river's flow regime experiences seasonal variations, with peak flows during the monsoon season and reduced discharge in the dry season. Despite its modest size, the Nun River supports a di-verse array of aquatic and riparian ecosystems, providing habitat for various plant and animal species. The three study sites S1, S2 and S3 of Nun River were selected for phytoplankton diversity exploration and physico-chemical analysis (Figure 1).

Fig. 1. The study area showing three different sites S1, S2 and S3.

Data collection and analysis

The conventional procedures described in Trivedy and Goel (1984), Welch (1952), and APHA (2005) were followed while studying physicochemical characteristics. The monthly sampling was performed for both physicochemical parameters and phytoplankton during months of October 2023 to March 2024. Samples of phytoplankton have been collected by passing a phytoplankton net through 100 liters of water, and they were then preserved in 4% formalin. In the laboratory, further investigation was conducted. Using the keys provided by Ward and Whipple (1959), Needham and Needham (1962), Sarode and Kamat (1984), phytoplankton were identified up to the lowest detectable taxonomic unit, primarily genus. The number of phytoplankton per ml of water sample was quantified using the Sedgwick-Rafter Cell Counter (Welch 1952).

Several ecological indices, such as the the species richness index (Margalef, 1957), Shannon-Weiner species diversity index (Shannon and Wiener, 1963), and the evenness index (Pielou, 1969), were applied to the monthly data on phytoplankton density.

Results and Discussion

Physico-chemical parameters

The monthly fluctuation of physicochemical parameters reported at three study sites S1, S2 and S3 (Figure 2, 3, 4). The Average water temperature of nun River found minimum 16°C in the month of December and maximum 25 °C in March. The average air temperature showed variation from 16°C in December to 26.67 °C in March. Similar ranges of water and air temperature have been recorded by in Gautam Kund and Renuka Lake (Singh *et al.*, 2018; Singh *et al.*, 2022). The dissolved oxygen was reported minimum 9.61 mg/l in March and maximum 11.73 mg/l in December. The solubility of oxygen increases at colder temperatures, which could account for the somewhat greater value of dissolved oxygen observed during the winter (Sabata and Nayar, 1995). The free CO2 varied from 3.60 mg/l in December to 6.00 mg/l in February. This indicates that the higher temperature stimulates the respiratory activities and processing of organic matter, resulting high production of CO2 (Khan *et al.*, 2013). Alkalinity showed fluctuation from 15.33 mg/l (October, January) to 33.33 mg/l (March). The water pH value ranges between 7.27 and 8.15 during the study period. The similar pH value range reported by Malik and Rathi (2022) from Garhwal Himalaya in Tehri reservoir. WHO (2011) states that while 6.5 to 8.5 is suggested for drinking water, there is no health-based recommendation range for pH value.

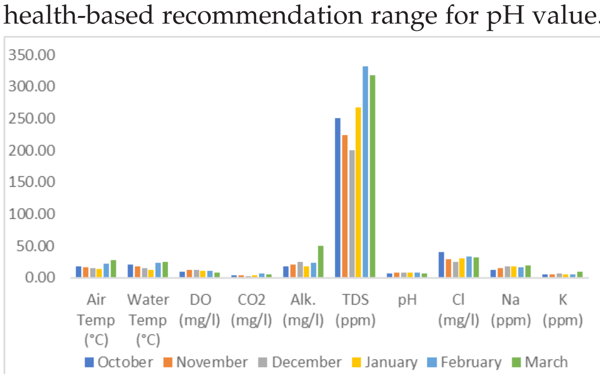

Fig. 2. Monthly fluctuation of physicochemical parameters of Nun river at Site S1 during the study period (October 2023-March 2024).

During the study, the pH value of the Nun River was found to be within the WHO-approved range. The average TDS value found lowest 207 ppm in November and highest 300.33 ppm in March. Likewise, the Chloride, sodium and potassium values were ranged between 27.08 (December) -37.70 mg/l (October), 12.64 ppm (October)- 19.84 ppm (March) and 5.02 ppm (October)-7.77 ppm (March), respectively. The phytoplanktonic communities are showing influence due to physicochemical parameters and also determine their prosperity, appearance and seasonal variations (Ganai *et al.*, 2010; Manickam *et al.*, 2012).

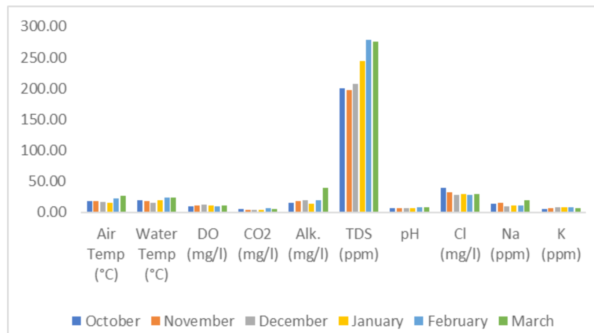

Fig. 3. Monthly fluctuation of physicochemical parameters of Nun river at Site S2 during the study period (October 2023-March 2024).

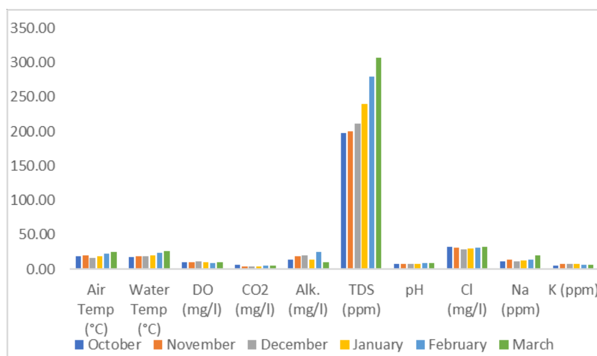

Fig. 4. Monthly fluctuation of physicochemical parameters of Nun river at Site S3 during the study period (October 2023-March 2024).

Phytoplankton diversity

A total of 38 genera of phytoplankton were reported from three study sites of Nun River during the October 2023 to March 2024, belonging to 7 classes, 21 orders and 26 families (Table 1). The density of phytoplankton ranged from 2.00 Unit1^{-1} at site S1 to 138.00 Unit1^{-1} at S3 during January (Figure 5). The density of class Bacillariophyceae found minimum

42 Unit1^{-1} at site 2 in November and maximum 262 Unit1^{-1} at site 1 in January. Bacillariophyceae was also reported maximum by Ishaq *et al.* (2013) in the month of January. *Navicula, Fragilaria, Epithemia, Fragilaria*, and *Synedra* were dominantly found species from Bacillariophyceae at all three sites followed by *Compylodiscus* and *Tabellaria*. Class Chlorophyceae was found having minimum density 34 Unit1^{-1} at site 3 in October and maximum density 296 Unit1^{-1}at sites 1 in January. In this class, *Scenedesmus, Mougeotia, Spirogyra, Closterium, Gonatozygon,* and *Penium* were dominating individuals followed by *Volvox*, *Sorastrum, Chaetophora, Netrium*, and *Genicularia*. The class Chlorophyceae and Bacillariophyceae were also found with high density in Song River, Alaknanda River and Bhagirathi River (Singh *et al.,* 2017; Jain *et al.,* 2018; Bantwan, 2018) Likewise, the density of Chrysophyceae was minimum 0 at mostly sites and maximum 20 Unit1^{-1} at site 3 in December and dominating by *Dinobryon*. The class Cyanophyceae was reported having minimum density 20 Unit1^{-1} at

Table 1. Checklist and Site-wise occurrence of phytoplankton of Nun River during the study period (October 2023-March 2024).

CLASS	Order	Family	GENUS	S1	S2	S3
Baccillariophyceae	Naviculales	Naviculaceae	*Navicula*	++++	++++	+++
	Fragilariales	Fragilariaceae	*Fragilaria*	++++	+++	+++
	Centrales	Epithemiaceae	*Epithemia*	++++	+++	+++
	Surirellales	Surirellaceae	*Compylodiscus*	++	++	++
	Bacillariales	Fragilariaceae	*Fragilaria*	++++	+++	+++
			Tabellaria	++	+	++
			Synedra	++++	++++	++++
Chlorophyceae	Chlamydomonadales	Volvocaceae	*volvox*	++	++	+
	Sphaeropleales	Hydrodictyaceae	*Sorastrum*	++	++	++
		Scendesmaceae	*chaetophora*	++	+	++
	Oedogoniales	Oedogoniaceae	*Bulbochaete*	+	+	+
	Chlorocooccales	Scenedesmaceae	*Scenedesmus*	+++	+++	++
	Zygematales	Zygnemataceae	*Mougeotia*	+++	+++	++++
			spirogyra	++++	++++	++++
		Oocystaceae	*Closterium*	+++	++	++++
		Mesotaeniaceae	*Spirotaenia*	+	++	+
			Netrium	++	+	++
			Genicularia	++	++	++
			Gonatozygon	+++	+++	+++
		Desmidiaceae	*Docidium*	+	+	+
			Penium	+++	+++	+++
			cosmarium	+++	++	++
	Ulotrichales	Microsporaceae	*Microspora*	+++	++	++
Chrysophyceae	Chromulinales	Dinobryaceae	*Dinobryon*	+	-	++
Cyanophyceae	Nostacales	Nostocaceae	*Aphanizomenon*	-	-	++
	Hormogonales	Oscillatoriaceae	*Phormidium*	++++	++++	++++
			Oscillatoria	++	++	++++
		Nostaceae	*Nostoc*	++++	++++	++++
			Anabanea	+	+	++
	Chroococcales	Chroococcaceae	*Calothrix*	+	+	+
	Chroococcales	Microcystaceae	*Microcystis*	++	++	++
	Synechococcales	Merismopediaeae	*Coelosphorium*	+	+	++
			Merismopedia	-	-	++
	Nostacales	Rivulariaceae	*Rivularia*	+++	+++	++++
Trebouxiophyceae	Incertae sedis	Botryococcaceae	*Crucigenia*	-	+	+
			Botryoccocus	+	-	+
Tubulinea	Arcellnida	Difflugiidae	*Difflugia*	+	-	+
Ulvophyceae	Cladophorales	Cladophoraceae	*Cladophora*	+	+	+

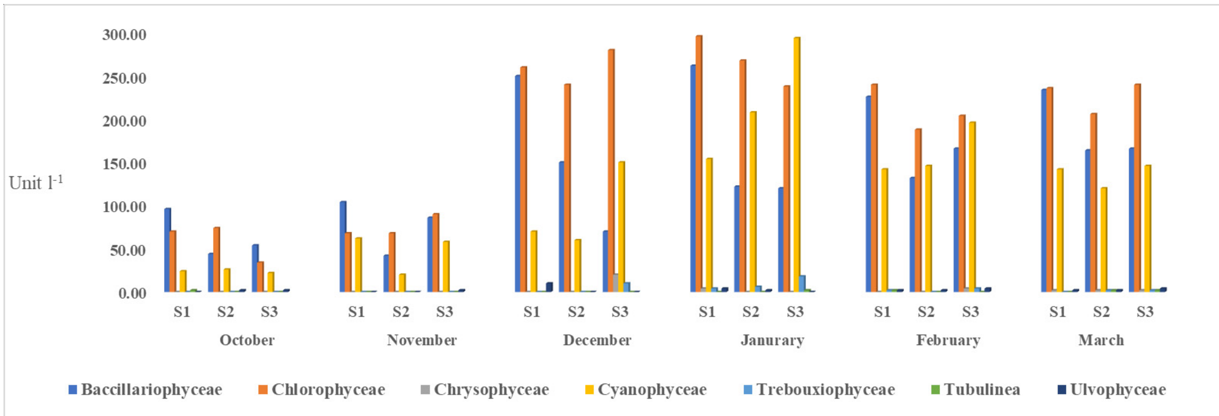

Fig. 5. Class-wise density fluctuation of Nun river during the study period (October 2023-March 2024) [Unit^{-1}].

site 2 in November and 294 Unit1^{-1} at site 3 in January as dominated by *Phormidium*, *Oscillatoria*, *Microcystis* and *Nostoc*. The presence of *Oscillatoria* represents occurrence of pollution at the study site 3 as observed by Gadag *et al.*, (2005) and Ganai *et al.*, (2014). The density of Trebouxiophyceae found with minimum density 2 Unit1^{-1} in February and March; and maximum 18 Unit1^{-1} at site 3 in January having *Crucigenia* and *Botryoccocus*. The class Tubulinea dominated by *Difflugia*, found with 0 density at mostly sites and maximum 2 Unit1^{-1} (January, February, March). Moreover, the density of Ulvophyceae was minimum 2 Unit1^{-1} at mostly sites and maximum 20 Unit1^{-1} at site 1 in December, dominated by *Cladophora.*

In Nun River, the percentage fluctuation of different classes was analyzed from three study sites. At study site 1 Bacillariophyceae had largely contributed with 39.46% followed by Chlorophyceae with 39.39%, Cyanophyceae with 20%, Ulvophyceae, Chrysophyceae, Trebouxiophyceae, and Tubulinea with very lowest value (Figure 6). At study site 2, the contribution of Chlorophyceae was highest with 45.43%, followed by Bacillariophyceae with 28.46%, Cyanophyceae with 25.24%, Chrysophyceae, Tubulinea, Trebouxiophyceae and Ulvophyceae with lowest value (Figure 7). At site 3, Chlorophyceae reported with largest contribution (40.37%) followed by Cyanophyceae (32.19), Baccillariophyceae (24.61), Trebouxiophyceae (1.26), Chrysophyceae (0.97), Ulvophyceae (0.45) and Tubulinea (0.15) (Figure 8). According to previous studies it was reported that several algae belonging to Bacillariophyceae, Chlorophyceae, and Cyanophyceae are indicators of water pollution thus it concluded that the river water is moderately polluted (Zargar and Ghosh, 2006; Naik *et al.*, 2010). The downstream increase in the relative density of Chlorophyceae in river Nun is in accordance with the assumption of Vannote *et al.* (1980), who assumed an increase in the density and diversity of green algae on moving downstream.

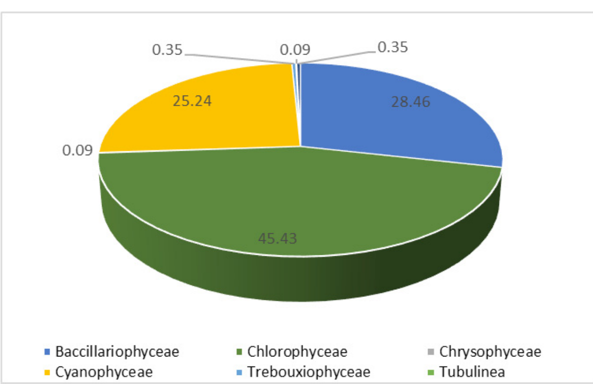

Fig. 6. Percentage fluctuation of phytoplankton of Nun River at site S1 during the study period (October 2023-March 2024).

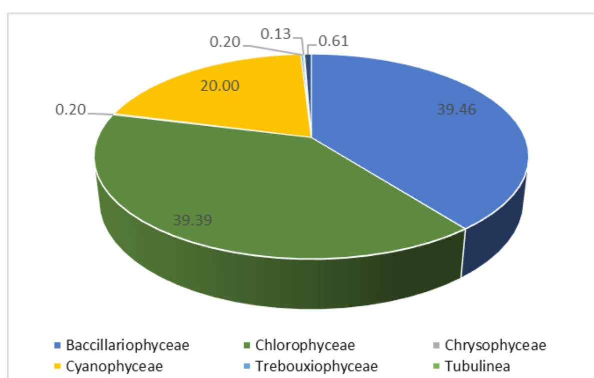

Fig. 7. Percentage fluctuation of phytoplankton of Nun River at site S2 during the study period (October 2023-March 2024).

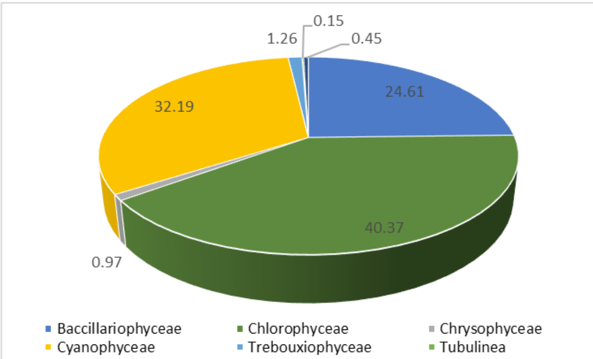

Fig. 8. Percentage fluctuation of phytoplankton of Nun River at site S1 during the study period (October 2023-March 2024

Ecological indices

In Nun River, the diversity index value of Shannon-Weiner was found minimum 3.54 in 4.45 November at site 3 whereas, the maximum diversity index value found 4.62 at site 2 in March. With the help of Shannon and Weiner index pollution status of any water resources can be determined. As stated by Wilham and Dorris (1968) the significant values range from 0 to 4 and also the values greater than 3 determinates clean water; values in the range of 1-3 determinate moderate pollution and values below 1 determinate heavily polluted. Thus, this index indicates the water quality of Nun River is clean as the values were reported between 3-4. According to (APHA, 2005) the Shannon Weiner Index reflects the change in community brought about by the environmental stress. The genus richness index of phytoplankton was recorded minimum 4.45 during December at site 1 while, recorded maximum 10.33 during December at site 3. The evenness index of Nun River was varied between 0.80 to 0.98 this indicated that particular genus of the phytoplankton community is not evenly distributed in all sites. On the basis of the above mention ecological indices the river water quality can be accounted as clean (Figure 9).

Conclusion

The current study's findings suggest that the Nun River contains a wide diversity of phytoplankton genera. Additionally, it was found that the variety of phytoplankton species composition and their seasonal distribution pattern in the Nun River are influenced by the combined effects of studied physico-chemical parameters. The current study also indicates that modifications to the physico-chemical properties of the river may result in both qualitative and quantitative modifications to the phytoplankton populations. Consequently, a clear picture of the monthly interaction between phytoplankton and environmental variables is provided by the study as a whole. The current study's data will make a substantial contribution to the evaluation of phytoplankton populations' state in connection to the physicochemical characteristics found in the Nun River. The study is crucial since it is the most comprehensive assessment of the reservoir's water quality that has been done too far and will serve as a basis for further investigations.

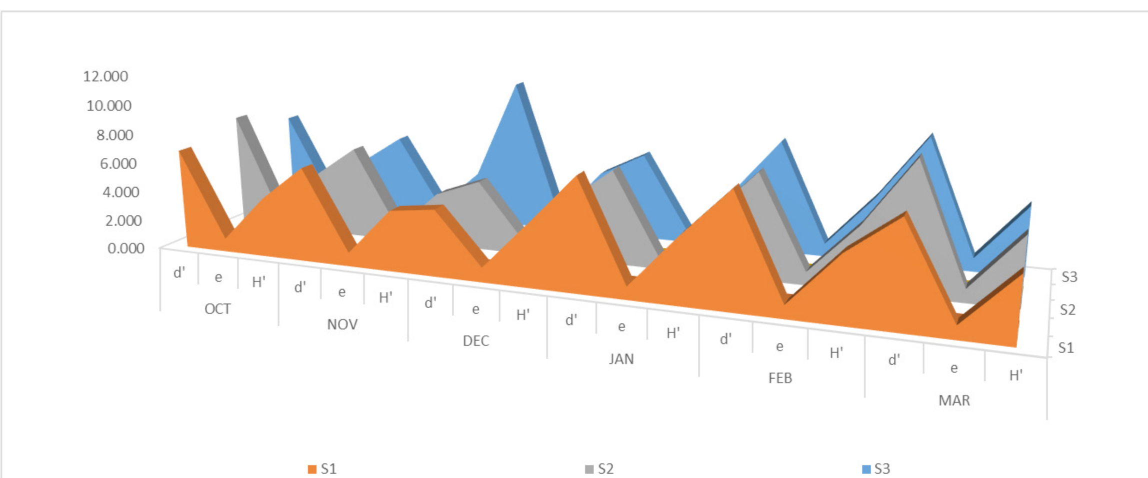

Fig. 9. Monthly fluctuation in diversity index of Nun river at site S1, S2 and S3 during the study period (October 2023-March 2024).

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Conflict of Interest

The authors clearly declare that they have no known conflict of interest and personal relationships that could have influence the data reported in this paper.

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