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Assessment of Seasonal Variations in Physico-Chemical Characteristics and Algal Diversity in the Lingti Stream of Kangra District, Himachal Pradesh, India

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KEYWORDS

Analysis, Diversity, Distribution, Index, Physico-chemical, Principal Component Analysis (PCA), Seasonal variations.

ABSTRACT:

The present study evaluates seasonal variations in the physico-chemical parameters and algal diversity of the Lingti Stream, Kangra District, Himachal Pradesh, India. Diversity indices across pre-monsoon, post-monsoon, and winter seasons revealed relatively stable algal diversity, with taxa having 21 species consistently and only minor variations in individual abundance (ranging from 827 to 885 individuals). The stability of diversity is high, as shown through the results recorded by Simpson's Index between 0.908 and 0.8794 and Shannon's Index between 2.429 and 2.636. According to the Evenness and Equitability indices, the distribution patterns in the community structure are balanced, with the maximum values occurring during the winter season. Analysis of variance showed a total variation of the data as explained by two components of principal axis of Principal Component Analysis (PCA) as PC1 with 89.136 and PC2 with 10.864. The dominant patterns in the data revealed themselves through PC1, where winter results aligned strongly together. The main environmental parameters influencing PC1 were alkalinity, total hardness, and magnesium ion concentration, whereas calcium ions and total dissolved solids (TDS) had the greatest influence on PC2. The values of temperature and pH had limited effects on the composition of both components. The hydrological patterns that change with the seasons, as well as critical water chemistry variables, have a significant impact on the growth of the algal population in the Lingti stream.

Introduction:

Water is the most essential component for all living beings on our planet because almost all species depend upon it for survival and cannot thrive without it. Water quality and terrestrial ecology are the main determinants of the diversity of aquatic organisms [1]. Since algae are the major producers of freshwater ecosystems and they keep the environment balanced by providing energy to the food chain and managing the diversity of algae in the flora, which can help to conserve freshwater resources. Additionally, it keeps ecosystems healthy and Water's overall quality constant [2, 3]. The primary significance of algae in the aquatic ecosystem can be attributed to their biotic nature as minute aquatic algae that are pigmented with chlorophyll and proliferate through photosynthesis [4]. Physico-chemical characteristics determine the quality of water. The physico-chemical properties of water are also affected by human interference in either a direct or an indirect way by the release of organic and inorganic contents into the water. Thus, these human interventions alter the natural water quality, which is known as "water pollution" [5]. A few climate and environmental factors might be to blame for such a type of pollution. A good indicator of human-made pollution is the fluctuation of life in aquatic biological complexes [6, 7]. Physico-chemical characteristics of water vary from season to season. In India, various locations experience climate changes throughout the course of a single year [3, 8]. The Lingti Stream near Kangra District in Himachal Pradesh, India, serves as a fundamental freshwater source that sustains human activities and nature-based ecosystems [8]. Water chemistry and biological diversity of this water resource experience strong effects from natural seasonal changes between precipitation amounts, temperatures and land management practices [9]. Algal communities inside biological populations serve as crucial bioindicators that reveal environmental disturbances by changing their species richness, population numbers, and cooperative species patterns [8]. The ecological condition of the stream requires continuous monitoring of seasonal changes observed in temperature, pH, dissolved oxygen levels, total hardness, nutrient concentrations, and ionic measurements, as well as algal diversity patterns[10]. This study conducted a thorough evaluation spanning pre-monsoon, post-monsoon, and winter seasons to evaluate water quality parameter changes and algal variety trends in Lingti Stream. The vital elements that affected periodic alterations were determined through Principal Component Analysis (PCA), multivariate research techniques. The finding of research delivers insights that can help to suggest sustainable management methods and conservation efforts for Himalayan freshwater ecosystems.

Study area:

Himachal Pradesh, situated in the northernmost part of India, is characterized by its mountainous terrain. Its geographical coordinates are approximately 32° 5' 3.1416" North latitude and 77° 34' 16.2012" East longitude. Kangra district, situated within Himachal Pradesh, occupies a region between 31˚ 21′ to 32˚ 59′ N latitude and 75˚ 47′ 55″ to 77˚ 45′ E longitude. This district is positioned along the southern slope of the Himalayas and experiences varying elevations due to the presence of the Shivalik Mountains, Dhauladhar Range, and the Himalayas themselves, stretching from the northwest to the southeast.

Lingti Stream: It is situated between latitude 32.16118° North and longitude 76.406934° East. Right Bank tributary of the Neugal Khad.

Material and Method:

Algal samples were collected in the three different seasons from May 2023 to July 2024 from the said stream. Algal and water samples were collected for research purposes. The samples were kept in 4% formaldehyde. Weak iodine solution, methyl blue, 1% neutral red crystal, and iron hematoxylin stain were utilized to distinguish between blue and green algae. The gelatinous sheath was stained using chloro-zinc iodide, iron-hematoxylin (1%), and iodine solution. Samples were washed with distilled water and centrifuged twice at 3000 r/min. The specimens were examined under a light microscope (Leica DM 100) using temporary objective slides containing 0.10 ml of fresh and preserved water. Micrographs were taken with a Nikon D-3300 camera at 100X, 400X, and 1000X magnification. The algae were mostly investigated in a live state. Identification criteria included exterior appearance, color, morphology, size, cellular structure, pigmentation, and reproductive features. Taxa were classified into orders, families, and genera, with diagnostic keys developed for each species. The identification of taxa was made by the following standard manuals [11], [12],[13], [14], [15], [16].

Statistical Analysis: The assessment of algal diversity in the selected streams was carried out using a range of quantitative diversity indices to capture different aspects of community structure. These included Taxa_S (species richness), Dominance_D (dominance index), Simpson_1-D (Simpson's diversity index), and Shannon_H (Shannon-Wiener diversity index), each providing insights into species composition, abundance, and distribution patterns. Statistical analyses were performed using diversity software, and PCA was applied to determine the principal components influencing seasonal variations.

Physical and chemical properties of water samples: The physical and chemical parameters of the water samples were determined using APHA-recommended standards. The parameters were analyzed according to Indian water testing guidelines. Temperature, EC, TDS, and pH of water samples were measured on site by using a Water Analysis conducted in the field [17]. Total alkalinity, Total Hardness, Magnesium, and Calcium were measured in the laboratory following [18, 19]American Public Health Association[20].

Result and Discussion:

The study of algal species across three seasons (Pre-monsoon, Post-monsoon, and Winter) shows significant variation in abundance and distribution patterns among different taxa. A total of 21 algal species have been identified in the present study (Table: 1). In Chlorophyceae, *Spirogyra rhizoides, Oedogonium pyriform, Cladophora glomerata*, and *Chlamydomonas*

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mucicola showed high abundance, especially during Winter. In Cyanophyceae, such as *Anabaena* species, *Aphanothece* species, *Calothrix* species and *Gomphosphaeria* species were moderately abundant, peaking in the Post-monsoon. Bacillariophyceae genera such as *Cocconeis, Cymbella, Fragilaria, Gomphonema,* and *Synedra* fluctuated with higher abundance either during pre-monsoon or post-monsoon, indicating a predilection for cooler, flowing waters [21]. In the present study, certain species were found to be abundant, such as *Spirogyra rhizoides*, which had the highest abundance during pre-monsoon (213), declined greatly during post-monsoon (68), and increased again in winter (114). This suggests that Pre-monsoon conditions (warmer, nutrient-enriched waters) are highly favorable for its growth. *Oedogonium pyriforme* and *Cladophora glomerata* also showed consistent increases toward winter, indicating their resilience and adaptability to colder temperatures. *Chlamydomonas mucicola* grew steadily, peaking in winter (123), indicating that lower temperatures and stable conditions favour unicellular green algae.

The diversity metrics of algal communities have been observed during the pre-monsoon, post-monsoon, and winter seasons, as shown in Table 2. Taxa_S denotes species richness (number of taxa), while Individuals represents the total number of algal cells or colonies counted. Dominance_D indicates the probability that two randomly selected individuals belong to the same species (lower values indicate higher diversity) [22]. Simpson_1-D is the inverse of dominance, reflecting overall species diversity [23, 24]. Shannon_H is the Shannon-Wiener diversity index, which explains the number and consistency of the species present. This data shows that post-monsoon and winter exhibit the most diversity and evenness, suggesting a more balanced algal community during these periods. Species richness (Taxa_S) remained constant across seasons, showing that all species were present year-round. However, their abundance varied. In the pre-monsoon season, the highest total individual (885) has been recorded. Diversity indices like Shannon_H and Simpson (1-D) were highest in post-monsoon (Shannon_H = 2.636; Simpson_1-D = 0.908), indicating greater biodiversity and a more even distribution of individuals among species during this season. Dominance_D was lowest in post-monsoon (0.09199), again supporting the idea that no single species entirely dominated the algal community. *Cladophora glomerata* consistently had high abundance across all seasons, peaking in Winter (156 individuals). *Oedogonium pyriforme* and *Chlamydomonas mucicola* were among the consistently dominant genera throughout the year. Some species, like *Hydrodictyon indicum* and *Calothrix braunii*, showed a slight decline during winter. Both abundance and diversity indices decreased slightly after the monsoon season, possibly due to increased runoff, dilution effects, or habitat disturbance caused by excessive rains.

Table 1: Seasonal Variation in the Abundance of Different Algal Species During Pre-monsoon, Post-monsoon, and Winter.

Sr.no	Name of Algal Species	Pre-monsoon	Post-monsoon	Winter
1.	*Anabaena utermoehlii* Geitler	18	13	10
2.	*Anabaena helicoidea* C. Bernard	16	18	8
3.	*Aphanothece castagnei* (Kutzing) Rabenhorst	2	4	2
4.	*Calothrix braunii* Bornet &Flahault	6	8	4
5.	*Calothrix javanica* De Wildeman	13	18	10
6.	*Chlamydomonas mucicola* Schmidle	94	100	123
7.	*Cladophora glomerata* var. *nana* Wang	123	125	156
8.	*Cocconeis placentula* var. *meridionalis* Brun	12	21	6
9.	*Cymbella tumida* f. *rostrata* P.Rivera	18	12	8
10.	*Euglena sanguinea* Ehrenberg	21	47	16
11.	*Fragilaria intermedia* (Grunow) Grunow	57	61	54
12.	*Gomphosphaeria aponina* Kutzing	13	19	16
13.	*Gomphonema lanceolatum* var. curtum Skvortzov	41	15	46
14.	*Hantzschia amphioxys* (Ehrenberg) Grunow	38	31	26

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15.	*Hydrodictyon indicum* M.O.P. Iyengar	13	24	16
16.	*Oedogonium pyriforme* Wittrock ex Hirn	124	135	143
17.	*Scenedesmus dimorphus* (Turpin) Kützing	22	44	36
18.	*Spirogyra rhizoides* Randhawa	213	68	114
19.	*Stigeoclonium tenue* (C.Agardh) Kützing	28	54	36
20.	*Synedra ulna* f. *contracta* Hustedt	9	4	5
21.	*Zygnemopsis indica* (Randhawa) Randhawa	4	6	3

Table 2: Seasonal Variation in Algal Diversity Indices Based on Species Richness and Abundance.

	Pre-monsoon	**Post-monsoon**	**Winter**
Taxa_S	21	21	21
Individuals	885	827	838
Dominance_D	0.1206	0.09199	0.1173
Simpson_1-D	0.8794	0.908	0.8827
Shannon_H	2.469	2.636	2.429

Physico-chemical parameters:

The seasonal fluctuation in water quality parameters reflects the impact of climatic changes, rainfall patterns, runoff, and biological activity on aquatic ecosystems. These changes influence algal growth and community structure directly or indirectly. In the study area temperature ranges from 25.74°C (highest) to 13.4°C (lowest). Water temperature shows a clear decreasing trend from Pre-monsoon to Winter [25]. Higher temperatures in Pre-monsoon favor the growth of filamentous green algae like *Spirogyra* and *Oedogonium*, while lower temperatures in Winter promote the growth of cold-tolerant species like *Cladophora* [26]. pH shows ranges from 7.8 Winter to 8.5 Post-monsoon. All values fall within the slightly alkaline range, suitable for most aquatic life. Post-monsoon has the highest pH, possibly due to dilution from rainfall and reduced biological CO_2 production [27]. The slight acidification in Winter may result from organic matter decomposition and increased respiration [28]. TDS value peaks in post-monsoon 62 mg/L, lowest in pre-monsoon 53 mg/L. The electric conductivity value slightly increases from 105 µS/cm (Pre-monsoon) to 114 µS/cm (Winter). Post-monsoon runoff introduces more dissolved ions (TDS), contributing to higher EC [29]. Winter also exhibits higher EC due to concentration from evaporation and reduced dilution [30]. Dissolved Oxygen shows the highest in Pre-monsoon, 7.8 mg/L, and the lowest in winter, 6.8 mg/L [31]. Higher DO in Pre-monsoon is likely due to greater photosynthetic activity. [32]. Lower DO in winter could be attributed to higher biological oxygen demand (BOD) and less photosynthesis under low temperatures and light. Total Hardness increases seasonally from 112 to 136 mg/L. Ca^{2+} and Mg^{2+} also show a gradual increase. The increasing trend in hardness during winter could be attributed to reduced water inflow and concentration of dissolved salts [33]. High quantities of calcium and magnesium can promote diatom dominance and filamentous green algae [34]. Alkalinity increases from 67 mg/L pre-monsoon to 96 mg/L winter. Higher alkalinity in Winter may result from bicarbonate accumulation and less water turnover [35]. Alkalinity supports buffering capacity and pH stability, favouring consistent algal populations [36]. Nitrate concentrations are low in the post-monsoon season, at 0.001 mg/L, and rise in the winter to 0.1 mg/L. The amounts of phosphate are low during the pre- and post-monsoon seasons, at 0.001 mg/L and rise drastically in the winter to 0.011 mg/L. The rise in nutrient levels during winter indicates increased runoff, decomposition of organic matter and anthropogenic inputs [37]. Elevated nitrate and phosphate levels can lead to algal blooms, particularly favouring *Chlamydomonas, Scenedesmus,* and *Euglena* [38].

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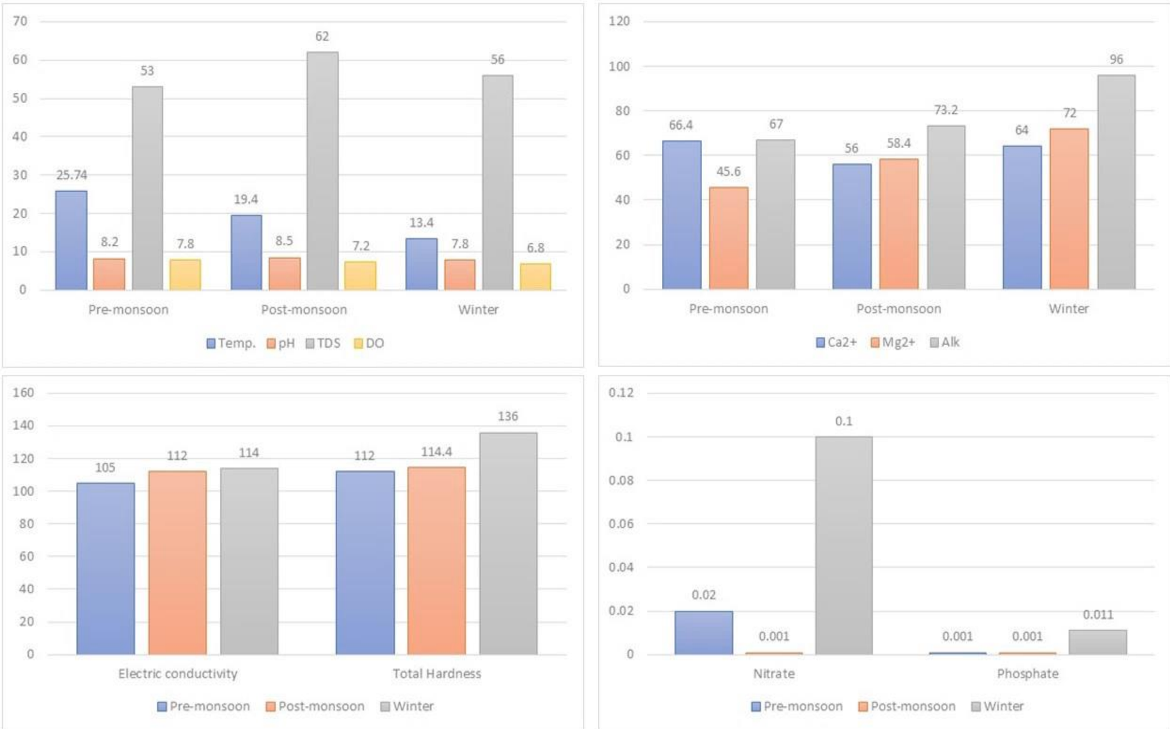

Figure 1: Seasonal Variation in Physicochemical Parameters of Water.

Principal Component Analysis

PCA analysis was used to find major trends between physico-chemical variables and seasons [39]. PCA analysis identified seasonal trends in physico-chemical parameters. Statistical data analysis was done in PAST [40]. PCA is a statistical method that reduces complex data into a few principal components (PC1 and PC2) to explain most of the variation. Together, PC1 + PC2 = 100% of the variance, which is excellent and means that the two PCs fully describe the seasonal data patterns. PC1 (Principal Component 1) has an eigenvalue of 618.312 and explains 89.136% of the total variance. Winter shows a strong positive score on PC1 (27.46), meaning winter season conditions are significantly different, mainly influenced by factors loading onto PC1. Pre-monsoon has a high negative score on PC1 (-20.995) but a positive score on PC2 (6.8377), meaning it differs from winter mainly along PC1. Post-monsoon is negative for both PC1 and PC2, showing that it is intermediate between pre-monsoon and winter. Winter is distinct from the other seasons mainly because of changes in key water quality parameters. Pre-monsoon and post-monsoon are closer to each other as compared to winter, but still have differences, especially along PC2. The major variability (89.136%) is explained by PC1, meaning seasonal changes in water quality are mostly captured by a single strong pattern (PC1).

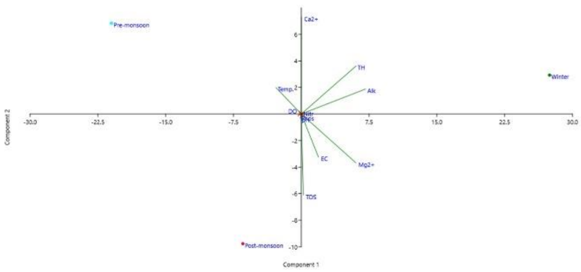

Figure 2: Principal Component Analysis (PCA) biplot showing seasonal variations and physico-chemical parameters in Lingti Stream, Kangra District, Himachal Pradesh.

Table 3: Shows Seasonal scores PC1 and PC2.

Season	PC-1 Score	PC-2 Score
Pre-monsoon	-20.995	6.8377
Post-monsoon	-6.4644	-9.7665

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Winter	27.46	2.9288

Table 4: Principal Component Analysis showing Eigenvalues and Percentage Variance explained by the first two principal components.

Synthesis	PCA	
	PC- 1	PC- 2
Eigenvalue	618.312	75.3589
% of variance	89.136 %	10.864 %

Conclusion:

The Lingti Stream had constant algal diversity throughout the year because it consistently maintained a species richness level of Taxa_S = 21, despite varying abundance levels. The algal community maintained equilibrium throughout the winter months according to diversity indices because it contained more diverse species alongside an even population distribution. The analysis through Principal Component Analysis proved that alkalinity, together with total hardness and magnesium, served as the primary factors affecting algal diversity, yet TDS, along with calcium ions, played the most significant role in creating seasonal changes to algal diversity. Regular monitoring remains critical for protecting Lingti Stream's ecological health because physico-chemical conditions affect algal diversity patterns Throughout the several seasons.

Conflict of interest: The authors have no Conflict of interest.

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