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Studies on Assessment and Effect of Seasonal Variations on Zooplankton and Water Quality Parameters of Freshwater Habitats in Dera Ghazi Khan Region, Pakistan

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Abstract

Freshwater ecosystems are fundamental to the development and sustainability of human societies. The present study assessed water quality and planktonic communities at four sites within the Suleman Mountain Range, Dera Ghazi Khan Region, Punjab, Pakistan. This region supports distinctive freshwater habitats in the form of hill torrents and their associated pits and ponds. Physico-chemical parameters examined included humidity, air and water temperature, light penetration, pH, dissolved oxygen (DO), free carbon dioxide, carbonates, bicarbonates, total alkalinity, total hardness, sodium, calcium, magnesium, chlorides, sulphates, electrical conductivity (EC) and sodium adsorption ratio (SAR). Plankton density and diversity were evaluated through relative abundance and standard diversity indices (Margalef, Simpson, Shannon–Wiener, Evenness and Sørensen). Data were subjected to statistical analyses. Monthly variations in physico-chemical parameters were recorded across the four sampling sites. Water temperature ranged from 12.65 °C in January to 33.48 °C in July; light penetration from 15.43 cm in August to 31.75 cm in January; pH from 7.68 in January to 8.10 in May–July; DO from 5.77 mg L^{-1} in July to 8.65 mg L^{-1} in January; free CO_2 from 5.90 mg L^{-1} in December to 8.82 mg L^{-1} in June; carbonates from 11.03 to 17.90 mg L^{-1} (June); bicarbonates from 472.50 mg L^{-1} in December to 613.60 mg L^{-1} in March; total alkalinity from 276.75 mg L^{-1} in August to 342.50 mg L^{-1} in May; total hardness from 213.70 mg L^{-1} in September to 268.70 mg L^{-1} in April; sodium from 107.50 mg L^{-1} in July to 186.90 mg L^{-1} in April; calcium from 169.80 mg L^{-1} in September to 222.0 mg L^{-1} in May; magnesium from 44.28 mg L^{-1} in September to 64.20 mg L^{-1} in March; chlorides from 153.54 mg L^{-1} in February to 243.44 mg L^{-1} in April; sulphates from 204.84 mg L^{-1} in September to 319.20 mg L^{-1} in May; EC from 1.85 dS m^{-1} in August to 2.28 dS m^{-1} in April; and SAR from 1.89 in December to 3.26 in April. Several parameters exhibited significant site-related differences (TDS, pH, CO_2, CO_3^{2-}, HCO_3^-, total alkalinity, total hardness, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, EC and SAR). Temperature, light penetration, pH, DO and CO_2 showed significant seasonal variation, while temperature, light penetration, TDS, DO and CO_2 varied significantly among months. A total of 119 planktonic taxa were recorded, of which 83 belonged to phytoplankton and 36 to zooplankton. Among phytoplankton, Chlorophyta was the most species-rich group (33 taxa) and Xanthophyta the least (4 taxa).

Keywords: *Plankton, Phytoplankton, Zooplankton, Physico-chemical parameters, Seasonal variation, Hill torrents, Dera Ghazi Khan.*

Introduction

Fresh water is conventionally defined as water containing less than 500 parts per million (ppm) of dissolved salts (Dobson & Frid, 1998; Gleick, 1993). It constitutes only about 2.5–2.75 % of the Earth's total water budget, the remainder being marine. Of the freshwater fraction, a small proportion exists as surface water in rivers, lakes and wetlands, while the majority is locked in ice or occurs as groundwater. Freshwater habitats comprise both lentic systems (standing waters such as ponds, lakes and swamps) and lotic systems (flowing waters such as streams and rivers).

The scientific study of inland aquatic ecosystems is known as limnology. Limnology examines the physical, chemical and biological structure of these systems together with the fluxes of energy and materials that sustain them (Goldman & Horne, 1983; Schwoerbel, 1987). Physical attributes include water temperature, light penetration and current velocity; chemical attributes encompass dissolved oxygen, alkalinity, hardness and nutrient concentrations; biological attributes focus on the diversity and abundance of plankton, macroinvertebrates and fish.

Freshwater ecosystems function as discrete spatial units that nevertheless interact continuously with their surrounding terrestrial environment (Jeffries & Mills, 1990). They supply essential resources—water, nutrients and food—to human societies (Baron et al., 2002; Dudgeon et al., 2006). Historically, major civilisations have developed along the banks of rivers and lakes (Van De Meene et al., 2001).

Biodiversity encompasses the number, variety and variability of living organisms across genetic, species and ecosystem scales (Wilcox, 1984; Mace et al., 2005). Monitoring species status provides a practical indicator of biodiversity trends and underpins the objectives of the Convention on Biological Diversity (IUCN, 2001). Identification and characterisation of taxa of ecological or economic importance remain prerequisites for effective conservation (Wilson, 1988; Nielsen, 1995).

Extensive research has documented plankton dynamics and productivity in temperate (Mallin et al., 1994; Watson et al., 1997; Huszar & Caraco, 1998; Trifonova, 1998), tropical (Figueredo & Giani, 2001; Nogueira, 2000; Talling, 1987) and sub-tropical (Harris & Baxter, 1996; Silva, 2005; Rajagopal et al., 2010) freshwater systems. Within Pakistan, numerous studies have characterised the physico-chemical conditions and biotic communities of rivers, lakes and reservoirs (Hussain et al., 2014; Chughtai et al., 2011, 2013; Khan et al., 2013; Ghazala & Arifa, 2011; Iqbal et al., 2004; Baloch et al., 2005; Ali et al., 2003, 2005; Rafique et al., 2002). More recent investigations have extended this knowledge to additional water bodies across the country, including Kallar Kahar Lake, Chashma Lake, Dor River and various reservoirs in Khyber Pakhtunkhwa (Zafar et al., 2025; Abidin et al., 2025; Rehman et al., 2024; Ali et al., 2024; Ullah et al., 2025). Nevertheless, detailed limnological studies of hill-torrent ecosystems in the sub-tropical Suleman Mountain Range remain scarce. The present work therefore provides the first comprehensive account of planktonic diversity, its spatial and temporal patterns, and the relationships between community structure and environmental variables in this distinctive habitat type.

Materials and Methods

Study Area

The Suleman Mountain Range extends across South Waziristan, northern Balochistan and south-western Punjab. Eastward it enters Rajanpur and Dera Ghazi Khan districts before approaching the Indus River near Mithankot. The study region (approximately 28°28′–31°18′ N, 69°20′–70°55′ E) covers about 12 000 km² and is bordered by Musa Khel and Barkhan districts to the west, Dera Ismail Khan to the north, Muzaffargarh and Layyah to the east, and Jacobabad to the south.

Thirteen major catchment areas (hill torrents, locally termed nallahs or rodhkohi) drain the range (Malkani, 2010). Four of these catchments were selected for water-quality and plankton sampling.

The climate is sub-tropical with four distinct seasons: summer (May–August), post-monsoon (September–October), winter (November–February) and spring (March–April) (Chaudhry & Rasool, 2004). Mean annual precipitation is approximately 350 mm, occurring mainly as seasonal rainfall that generates intermittent hill torrents. Associated pits and ponds, together with scattered cold- and hot-water springs, maintain permanent or semi-permanent standing water that permitted year-round sampling.

Mean elevation of the range is about 1 100 m (range < 300 m to > 2 000 m). Approximately 55 % of the area lies between 900 m and 1 300 m. Lithology is dominated by limestone, shale and sandstone (65 %), with gravelly loamy soils (30 %) and loamy silt (5 %) (Hanson et al., 1995).

Water Sampling and Analysis

Water samples were collected monthly from January to December at four sites (WSS-1 to WSS-4). Samples were taken from the subsurface (30 cm depth) in the middle of standing-water bodies. Air and water temperature, light penetration, pH, electrical conductivity and dissolved oxygen were measured in situ. Remaining chemical parameters were determined in the laboratory of the Water and Soil Laboratory, Agriculture Department, Government of the Punjab, Dera Ghazi Khan, following standard protocols (APHA, 1998). Samples for plankton analysis were preserved with 4 % formaldehyde (Battish, 1992). Average water depth at sampling points ranged from 3 to 10 feet. Anthropogenic influences, principally agricultural activity, were noted in the vicinity of the sites.

Statistical Analyses

All statistical analyses were performed with SPSS version 20. Effects of month, season and site on physico-chemical parameters and on plankton abundance, richness and diversity were examined by one-way analysis of variance (ANOVA) after verification of normality and homogeneity of variance. Pearson correlation coefficients were calculated among water-quality variables. Diversity indices (Margalef, Simpson, Shannon–Wiener, Evenness and Sørensen) were computed according to standard formulae.

Results

Physico-chemical Parameters

Mean values of physico-chemical parameters at the four sites are summarised in Table 1. Water temperature was highest at Site-4 (27.82 ± 5.81 °C) and lowest at Site-1 (22.73 ± 8.29 °C). Dissolved oxygen declined from Site-1 (7.30 ± 1.16 mg L^{-1}) to Site-4 (6.63 ± 0.84 mg L^{-1}). Electrical conductivity and SAR were markedly elevated at Site-4, indicating greater mineralisation. Significant site effects were detected for TDS, pH, free CO_2, carbonates, bicarbonates, total alkalinity, total hardness, sodium, calcium, magnesium, chlorides, sulphates, EC and SAR.

Seasonal patterns (Table 2) revealed the expected thermal cycle: water temperature rose from 16.27 °C in winter to 32.01 °C in summer. Light penetration and dissolved oxygen were highest in winter and spring and lowest in summer and post-monsoon. Free CO_2 and pH increased during the warmer months. Significant seasonal effects were recorded for water temperature, light penetration, pH, DO, free CO_2 and SAR.

Table 1. Mean values (± SD) of physico-chemical parameters at four water sampling sites.

Parameter	Site-1	Site-2	Site-3	Site-4
WT (°C)	22.73±8.29	24.10±8.02	24.62±7.02	27.82±5.81
LP (cm)	23.86±7.04	23.32±6.42	28.48±6.63	26.50±4.88
TDS (mg L^{-1})	1182.50±198.50	1174.17±180.0	1209.33±123.1	1636.58±126.1
pH	7.85±0.24	7.91±0.31	8.02±0.29	7.85±0.27
DO (mg L^{-1})	7.30±1.16	7.29±1.10	7.03±0.91	6.63±0.84
EC (dS m^{-1})	1.90±0.32	1.91±0.28	1.96±0.32	2.57±0.20
SAR	1.86±0.46	2.32±1.02	1.77±0.13	3.30±0.46

WT = water temperature; LP = light penetration; TDS = total dissolved solids; DO = dissolved oxygen; EC = electrical conductivity; SAR = sodium adsorption ratio. Means with different superscript letters differ significantly (LSD, $p < 0.05$).

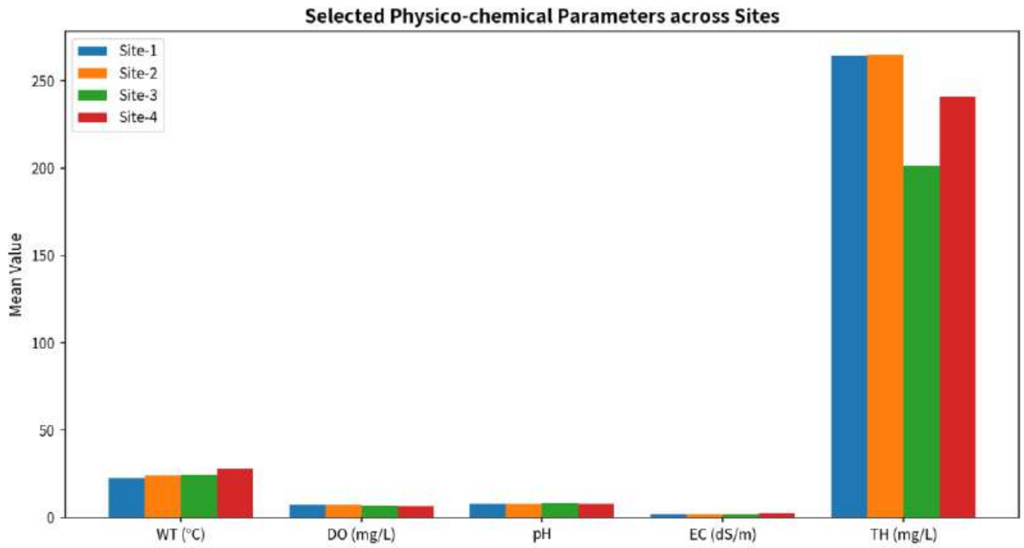

Figure 1. Selected physico-chemical parameters (means) across the four sampling sites.

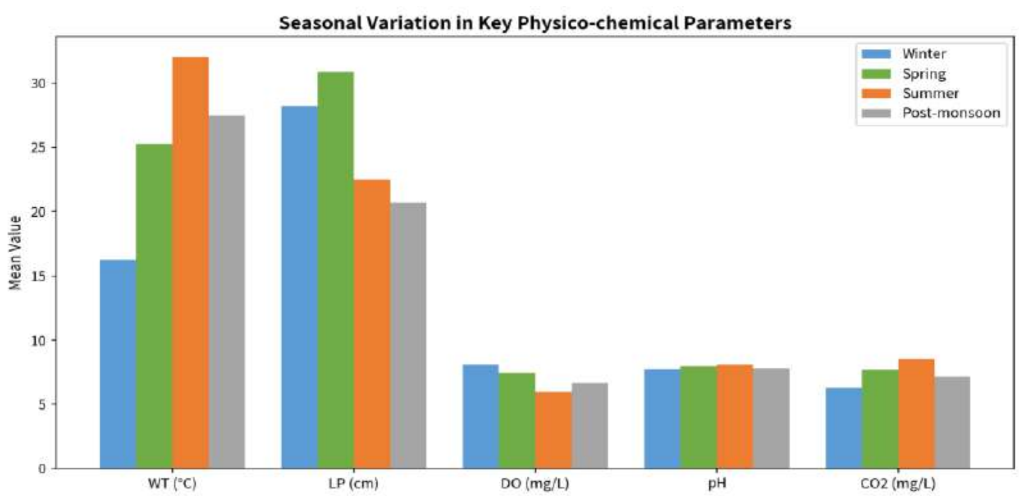

Figure 2. Seasonal variation in key physico-chemical parameters.

Planktonic Biodiversity – Species Richness

A total of 119 planktonic genera were recorded, comprising 83 phytoplankton and 36 zooplankton taxa. Phytoplankton groups included Cyanophyta (12 genera), Chlorophyta (33), Chrysophyta (7), Euglenophyta (6), Xanthophyta (4), Bacillariophyta (12) and Pyrrhophyta (9). Zooplankton groups comprised Protozoa (15 genera), Rotifera (11) and Cladocera (10).

Species richness varied among sites (Table 3). Total phytoplankton genera declined from 74 at Site-1 to 48 at Site-4; total zooplankton genera ranged from 34 (Site-1) to 21 (Site-4). Overall plankton richness was significantly higher at Site-1 (108 genera) than at Site-4 (69 genera) (ANOVA, df = 3, F = 6.60, p = 0.001). Chlorophyta, Protozoa and Cladocera also exhibited significant site differences.

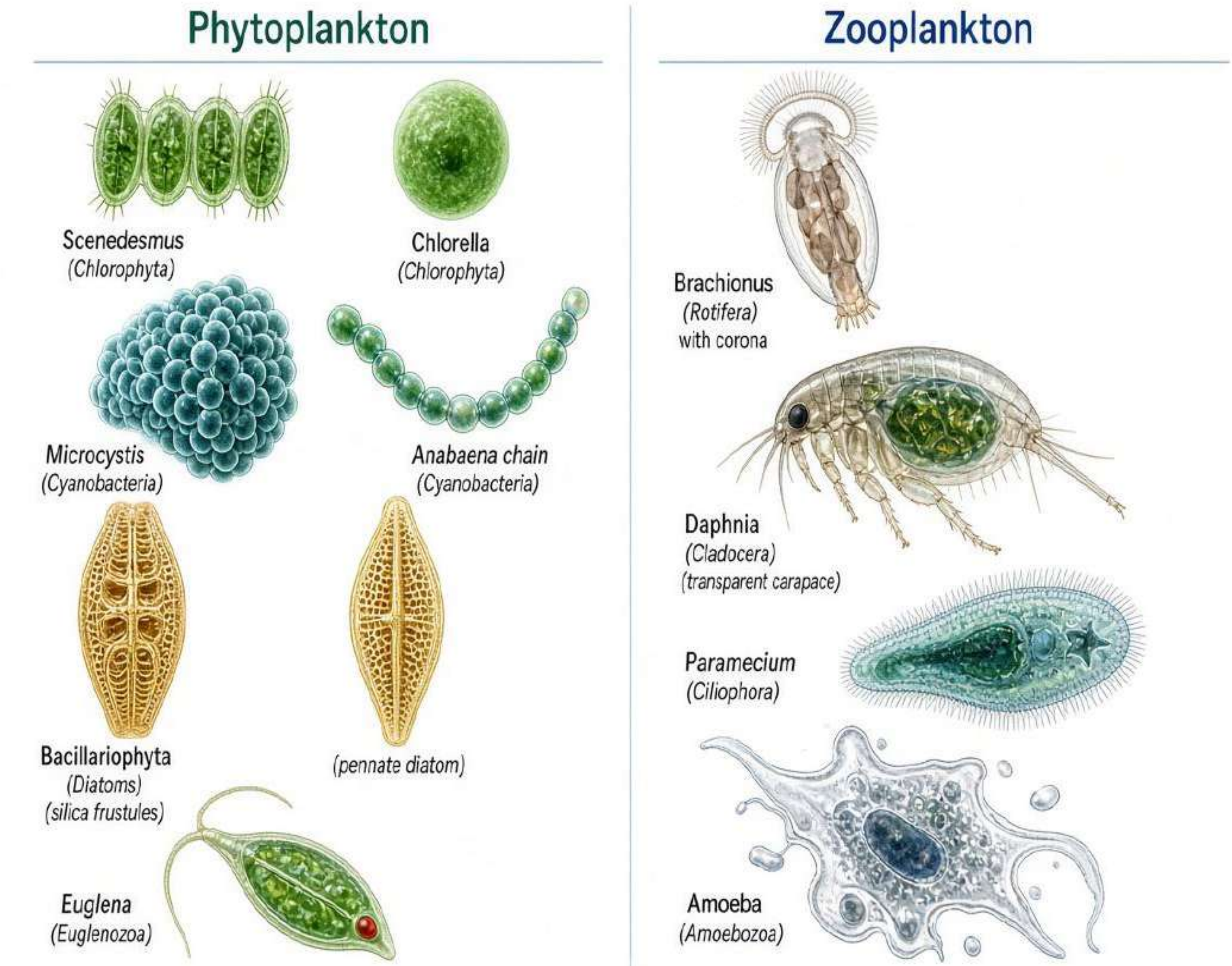

Figure.1 Illustration of Zoo & Phyto Planktons

Seasonal patterns (Table 4) showed maximum total plankton richness in winter (92 genera) and minimum in post-monsoon (67 genera). Bacillariophyta and Cyanophyta displayed significant seasonal variation, with higher richness in winter. Monthly maxima for total phytoplankton occurred in January (42 genera) and minima in September (25 genera).

Table 3. Species richness (number of genera) of major planktonic groups at four sampling sites.

Group	Site-1	Site-2	Site-3	Site-4	All sites
Cyanophyta	11	11	12	9	12
Chlorophyta	31	26	24	16	33
Bacillariophyta	11	12	11	9	12
Protozoa	13	10	12	10	15
Rotifera	11	8	10	7	11
Cladocera	10	5	5	4	10
Phytoplankton	**74**	**67**	**65**	**48**	**83**
Zooplankton	**34**	**23**	**27**	**21**	**36**
All phyla	**108**	**90**	**92**	**69**	**119**

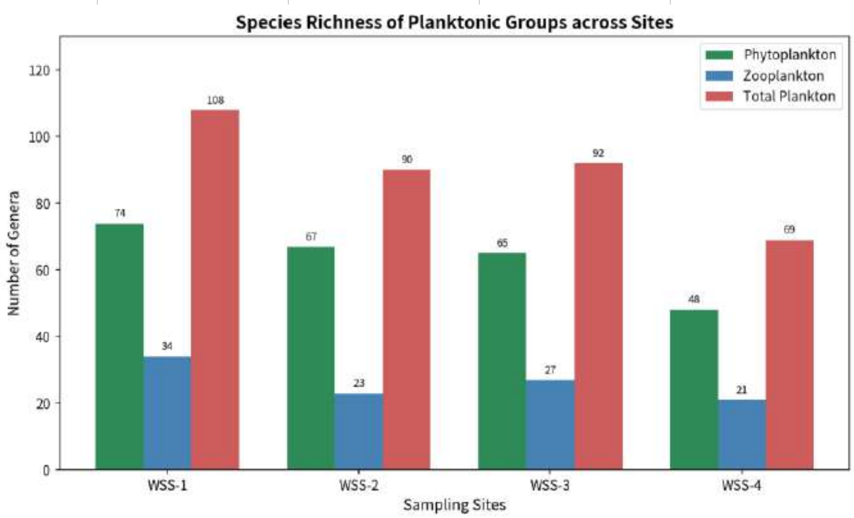

Figure 3. Species richness of phytoplankton, zooplankton and total plankton across the four sampling sites.

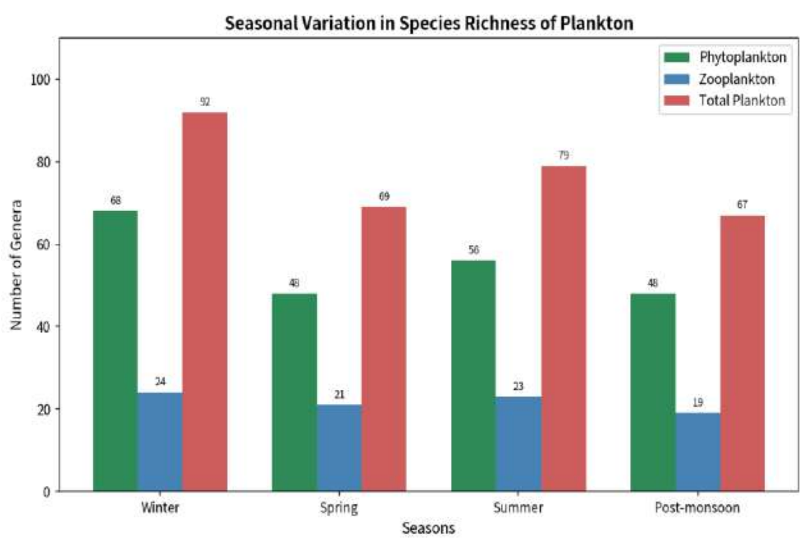

Figure 4. Seasonal variation in species richness of phytoplankton, zooplankton and total plankton.

Relative Abundance

Overall, phytoplankton contributed 81.86 % and zooplankton 18.14 % of total plankton abundance. Among phytoplankton, Chlorophyta (28.80 %) and Cyanophyta (26.82 %) dominated, followed by Bacillariophyta (13.53 %). Protozoa (11.57 %) were the most abundant zooplankton group, followed by Rotifera (5.78 %) and Cladocera (0.79 %). Relative abundances varied among sites and seasons; Bacillariophyta, for example, reached highest relative abundance in winter, whereas Cyanophyta and Chlorophyta peaked in summer.

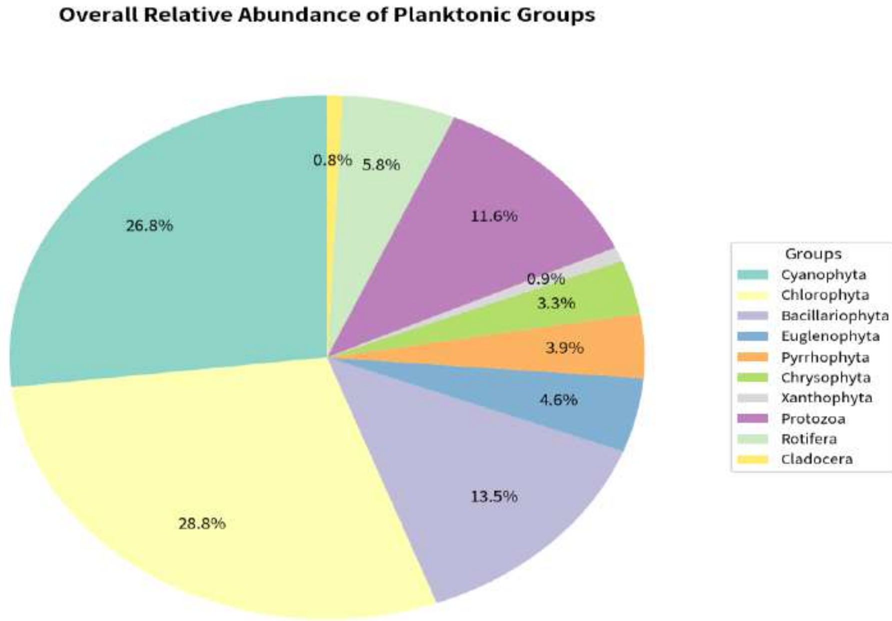

Figure 5. Overall relative abundance (%) of major planktonic groups across all sites.

Conclusions

1. Physico-chemical parameters of the hill-torrent habitats remained within ranges generally regarded as suitable for freshwater aquatic life.
2. Planktonic communities exhibited clear spatial and temporal variation, with highest species richness in winter and at the northernmost site.
3. Chlorophyta and Cyanophyta dominated the phytoplankton assemblage, while Protozoa dominated the zooplankton.
4. The diverse phytoplankton flora indicates that these underexplored hill-torrent systems merit further ecological and applied research, including potential beneficial uses of selected algal taxa.

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