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UNVEILING THE SECRETS OF KARNATAKA'S STREAM WATER QUALITY THROUGH DIATOM ECOLOGICAL SIGNATURES

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Abstract

Stream physicochemical and biological quality declines due to changes in water chemistry and physical habitat characteristics. Due to their ability to integrate water chemistry through time and to represent the combined effects of numerous stressors on stream biota, diatoms are frequently employed to evaluate the quality of stream water. But, particularly in upstream regions, knowledge of the primary diatom community patterns in streams is still restricted. This study's objective was to look into how stream diatom communities are impacted by water chemistry and catchment factors. The environmental quality of the habitat and water characteristic variation were established using canonical correspondence analysis, and the surface type, temperature of the water, oxygen concentration, and nutrient substance showed significant correlations. Achnanthidiumminutissimum, Cocconeisplacentula, and Oricymba japonica were shown to have strong affinities with habitats containing fixed surfaces with transparent water. Our findings demonstrate the synergistic effects of multiple factors that influence diatom patterns and demonstrate the relationship between diatom biodiversity and stream conditions.

Key words: Diatoms, Physico-chemical parameters, Diversity, CCA, Streams.

Introduction

Aquatic systems are intricate and have varied habitats that sustain a range of biota with distinctive characteristics and specialized niches Dudgeon et al. (2006). Running water's structural properties are significant since they characterize the related species. Sadly, the rising reliance on freshwater resources for a variety of human purposes has had a significant negative influence on the systems and creatures.

The primary producers in the freshwater ecosystem, phytoplankton are crucial for comprehending the aquatic ecosystem, biomonitoring ecological perturbations brought on by various physico-chemical variables, and solving various environmental issues. Phytoplankton sustains true potamoplanktonic groups only in the largest delta rivers reported by Allan, 1995.In

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smaller streams, "phytoplankton" is made up of floating algae that has been cut away from the sediment at the bottom or from lakes and ponds upstream. Stream communities usually have a substantial spatially-structured variety when evaluated across vast areas (Li et al., 2001; Heino et al., 2003; Parsons et al., 2003). Therefore, it's crucial to accurately identify the proportional contributions of small-scale spatial components and local environmental variables.

The environmental conditions of waters are assessed using several kinds of species, such as fish, macroinvertebrates, and algae. A variety of biological characteristics, including diversity, abundance, and functional categories, are frequently used to describe biological assemblages. Measures of diversity are crucial in bioassessment since they are thought to be correlated with environmental well-being (Magurran, 2004). Depending on the type of pollution, diversity can either grow or decrease in response to disturbance (Patrick et al., 1954; Patrick, 1967; Stevenson, 1984, 2006).

The composition of algae species in a particular location is heavily influenced by various environmental factors such as salinity, temperature, pH levels, water flow speed, shading, water depth, and the availability of substrate for growth, along with the chemical makeup of the water. Consequently, the presence of specific algae species in a body of water can provide valuable insights into the characteristics of that water. Algae serve as reliable indicators of water quality, making them a crucial element in assessing aquatic ecosystems. Diatoms, a type of algae, offer the advantage of easy species-level identification and can be found in various river environments. However, the diversity and abundance of diatom species can vary significantly due to their preferences for specific microhabitats within these rivers (Vyverman et al., 2007).

The flow patterns and substrate types, which are distinctive features of lotic ecosystems, play a significant role in shaping diatom populations. High and low flow conditions, as highlighted by Francoeur and Biggs (2006), have the potential to influence ecosystem structure. Diatom habitats are known for their diversity, and some species exhibit a unique affinity for specific microhabitats (Tang et al., 2006), which explains their uneven distribution across different areas (Stevenson and Pan, 1999; Rimet, 2009).

Diatoms are valuable indicators of water quality due to their characteristics such as preferential colonization and responsiveness to changes in nutritional conditions (Hering et al., 2006; Neustupa et al., 2013; Fidlerová and Hlbiková, 2016).

Research on diatoms within the Indian peninsula has historically been limited to a select few streams and water sources in specific states with varying physiography (Nandan and Patel, 1984; Mishra and Saksena, 1993; Trivedy and Khatavkar, 1996; Nautiyal et al., 2004; Sharma et al., 2007; Nautiyal and Verma, 2009; Ramanujam and Siangbood, 2009; Sah and Hema, 2010; Baba et al., 2011; Siangbood and Ramanujam, 2014; Dwivedi and Misra, 2015).

While there is a substantial body of periphyton research in southern Indian water bodies, the majority of these studies primarily focus on the diversity of the algal community (Suresh et al., 2011; Selvin-Samuel et al., 2012). However, a limited number of studies delve into the ecological aspects of these species and ecosystems (Venkatachalapathy and Karthikeyan, 2012; Venkatachalapathy et al., 2013).

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Hence, the primary objective of this study was to conduct a comprehensive analysis and documentation of the benthic diatom community composition. Additionally, we aimed to establish the connections between these diatom communities and various environmental variables across different geographic regions within the upland area along the main river and its tributaries in the Thungabhadra river system in Karnataka.

Materials and Methods

Study area

Karnataka's rivers serve various vital functions within the state, including providing drinking water and supporting domestic needs. They play a crucial role in agriculture, serving as a source of irrigation, and contribute to the generation of electricity. Additionally, in certain regions, these rivers serve as a means of transportation and are integral to the state's tourism industry.

Within the geographical boundaries of Karnataka, numerous rivers traverse both eastward and westward directions. The majority of these rivers originate in the Western Ghats and flow towards the eastern part of the state. These rivers, which ultimately drain into the Bay of Bengal, rank among the largest in Karnataka. Consequently, most of the major east-flowing rivers in the state are interstate rivers, which means they cross state borders.

The study sites selected for this research encompass the Krishna River and its tributaries, namely the Jaladurga and Kodli rivers (Figure 1). The Krishna River originates in the Western Ghats near Mahabaleshwar, flows through Wai, and continues its journey eastward until it eventually meets the Bay of Bengal. Additionally, the study includes the HuthurPalar Dam on the Kaveri River, located at Bethri, Madapura. The Kaveri River, originating in Karnataka's Coorg district within the Brahmagiri range of the Western Ghats, flows through various regions, including Kirugunda, Harihalli, and Herur before merging with the Hemavathi River. The Hemavathi River, originating in Karnataka's Western Ghats, begins in the mudigere taluk of Chikmagalur district and flows through Hassan district, where it converges with its primary tributary, the Yagachi River, before eventually joining the Kaveri River near Krishnarajasagara.

The study also encompasses the Badra River, featuring sites like Kolale, Badra, Gorigandi, Jenugadde, Basaravalli, Aldur, and Kolale. Originating in the Western Ghats, the Bhadra River flows eastward across the southern section of the Deccan Plateau. Along its course, it is joined by the Somavahini River between places such as Hbbe, Thadabehalla, and Odirayanahalla.

Lastly, the Tunga River and its associated sites, including Jannapura, Jayapura, Kuluru, Tunga, and Honnali, are part of the study. The Tunga River originates in the Western Ghats, specifically on a peak known as VarahaParvata near Gangamoola. It flows through two districts in Karnataka, namely Chikmagalur and Shimoga.

Diatom sample preparation and analysis

Taylor et al. (2005) outlined their methodology for the collection, processing, and analysis of diatom samples. Epiphytic diatoms were collected from aquatic vegetation at all sampling sites. Specifically, they extracted ten submerged stems, each ranging in length from 10 to 15 cm. These stems were then placed in zip-top bags along with 50 cc of lake water. To separate the diatoms

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from the stems, they were vigorously rubbed. The resulting water, containing the diatoms, was carefully transferred into sterilized honey jars containing 70% ethanol. It's important to note that the final concentration of ethanol did not exceed 20%, and this was done to preserve the collected diatom samples.

Since diatom samples typically contain a significant amount of organic detritus, the researchers employed the hot HCl and KMnO4 technique to create diatom microscope slides, as described by Taylor et al. (2005). Initially, the samples were allowed to settle for 24 hours. Marked test tubes were then filled with 2-3 ml of the agitated sample, treated with KMnO4, and left for another 24 hours. Following this, 1-2 ml of 32% HCl was added based on the material concentration. The sample was heated on a hotplate and treated with a single drop of hydrogen peroxide to ensure complete digestion of organic matter. After centrifugation, the samples were cleaned by repeatedly resuspending them in distilled water. This process was repeated four times. The diluted diatom samples were then carefully pipetted onto clean coverslips and mounted onto microscope slides using Pleurax (with a refraction index of 1.73).

To examine the diatoms, a Nikon 80i compound light microscope with a 100 1.4 NA oil immersion objective with differential interference contrast (DIC) was employed. They aimed to identify diatoms at the species level whenever possible, and if not, they were identified at the genus level. Following identification, diatom valves were counted until 400 were found or the entire microscope slide was thoroughly examined, following the methods outlined by Archibald (1966) and Taylor et al. (2007).

Water sampling and laboratory analysis

Water samples were collected from the uppermost 20 cm of the water column using a bottom-weighted polyethylene flask. Before use, these flasks were meticulously cleaned in the laboratory using a sequence of lapoline, 10% HCl, and water samples from each sampling location to ensure they were free from contaminants.

For the purpose of this study, various water quality parameters were measured, including temperature, pH, electrical conductivity (EC), turbidity (T), total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), magnesium (Mg2+), chloride (Cl-), nitrate (NO3-), silica, phosphate, sulfate (SO4 2-), dissolved oxygen (DO), chemical oxygen demand (COD), and biological oxygen demand (BOD). The methods and standards for these measurements were in accordance with the guidelines set forth by the American Public Health Association (APHA) in 2005.

Statistical Analysis

We employed Canonical Correspondence Analysis (CCA) for our analysis. To meet the homoscedasticity assumptions, we initially transformed the parameters into logarithmic form, and the diatom taxonomy data were transformed into square root form. To assess the statistical significance of each variable, we conducted a Monte Carlo permutation test with 500 permutations. The data analyses were conducted using PAST (version 2.15) software, as outlined in the work of Hammer et al. (2001).

Result

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There was no noticeable variance existed between the means of the sampled locations temperatures, which ranged from 18 to 22 °C at all of the sites. The pH ranged from 6.8 to 7.62, the conductivity ranged from 33 to 56, the total solids ranged from 13 to 23, the alkalinity ranged from 20 to 54, the nutrient contents ranged from phosphate 0.03 to 0.11, chloride 3.3 to 22.6, sulphate 0.3 to 12, silica 0.14 to 0.28, and sodium 1.1 to 16, and the dissolved oxygen ranged from 3.7 to 6.8. The COD ranged from 2.3 to 5.9 while the BOD ranged from 2.1 to 5.7.

The 87 species of epiphytic diatoms collected during this investigation came from 20 river sections, including the Karnataka River's main river and its tributaries. Sample collections had several different species, with the majority having between 12 and 22 different species. With 219 species, Kuluru (S5) had the most species per site, and Huthur (S20), with 123 species, had the fewest.

The most species-rich genera were Eunotia and Gomphonema, each representing 19 species, followed by Pinnularia, Surirella, and Cymbella, each with 21 species, respectively. Regardless of stream habitat conditions, certain taxa were prevalent, including Achnanthesbiasolettiana, Achnanthidiumexigum, Achnanthidiumminutissimum, Cocconeisplacentula v. euglypta, Cocconeisplacentula v. lineata, Cymbellaturgidula, Gomphonemaangustatum, Gomphonemadiminutum, Naviculaheimansioides, Oricymba japonica, Planothidiumrostratum, Brachysirawygaschii, Gomphonemaexilissimum, andGomphonemalagenula. These species were found across sites, even those affected by various activities. With the exception of a few locations, diatom diversity remained consistently high due to the variability of microhabitats (Table 1).

Canonical Correspondence Analysis (CCA) was conducted to identify patterns among species and sites influenced by environmental variables. The first axis, accounting for 18.2%, and the second axis, explaining 16.0% of the species-environment variation, had eigenvalues of 0.79 and 0.69, respectively. The first axis reflected a gradient in water parameters that differentiated locations based on silica levels and the concentration of dissolved oxygen in the water. Moreover, the proportion of habitat dominated by macrophytes increased along with diatom abundance. Each species' position in the CCA ordination plane represented its environmental preference.

Dissolved oxygen concentration (loading factor: 0.69, p-value: 0.70), water temperature (loading factor: 0.79, p-value: 0.97), sulfate, and chloride (loading factor: 0.6) were prominent factors in the first two components. Other variables had little influence. The second CCA axis described the gradient of water quality, with sites and species arranged in the ordination plane. Sites S7, S8, and S15 exhibited higher values for dissolved oxygen, total solids, and pH.These streams were mostly home to Naviculaheimansioides, Cymbellaturgidula, and Achnanthidiumminutissimum. The sites had anthropogenic disturbances such as stream diversion for agriculture and recreational purposes. The right side of the CCA plot's site placement and species clustering were determined by temperature, turbidity, phosphate, and sulphate levels; as a result, S1, S4, S6, S14, and S18 are positioned closer together. The species Achnanthidiumminutissimum, Achnanthesinflata, Sellaphorabacillam, and Brachysirawygaschii were common in areas with greater chloride levels. Gomphonemaangustatum,

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Achnanthesmicrocephala, Gomphonemaexilissimum, Diploneissubsmithii, Cocconeisplacentula v. lineata, Oricymba japonica. These species are known to favor silica-enriched water, which may account for the high concentrations of silica S3, S9, S12, and S16 at the appropriate places (Figure 2). Figure 3 displays the identification of diatom species under a 100X magnification microscope.

Discussion

The assessment of aquatic ecosystem quality relies on monitoring the concentration of water quality indicators present in the environment. Nutrients play a pivotal role in aquatic ecosystems as they form the foundation for plant growth, as acknowledged by DWAF 1996, Dallas and Day (2004), Clark and Tilman (2017), and Tromboni and Dodds (2017). Wetland ecosystems, given their role as nutrient sinks, are particularly susceptible to nutrient enrichment, as noted by Humphries and Benitez-Nelson (2013). However, the abundance of aquatic macrophytes can influence nutrient concentrations in the ecosystem. Consequently, even when nutrient concentrations appear modest, an aquatic habitat may exhibit eutrophic characteristics, as described by Kock (2019).

Alterations in interisland flow patterns exert intriguing effects on diatom distribution in lotic environments. The quality of river systems and the biota they support is shaped not only by streams and small river networks but also by the terrain through which they traverse, as elucidated by Brown (2000). In this study, the presence and distribution of diatom taxa were correlated with in-stream habitat features, resulting in a high representation of epiphyton in sites with submerged plants. Additionally, the prevalence of fine and coarse sand influenced species distribution, leading to differences in species composition based on sandy substrate abundance. For instance, Achnanthidiumminutissimum was more prevalent in sites occasionally influenced by stream water flow, such as S4, S6, S14, S15, and S18, which exhibit varying levels of sandy substrate influence, a phenomenon also observed in unstable sandy substrates (Passy and Bode, 2004). Conversely, Oricymba japonica was exclusively found in locations with lower sand concentration, such as S16, attributed to its sensitivity to silt.

Diatoms exhibit specific distribution preferences based on water quality, with tolerant species capable of surviving in disturbed areas, while sensitive species are confined to clean, undisturbed regions (Potapova and Charles, 2005). Notably, certain species like Cocconeisplacentula v. euglypta, Planothidiumrostratum, and Brachysirawygaschii thrived in areas with higher nutrient levels, such as Honnali (S3), Jannapura (S7), and Harihalli (S16), while Naviculaheimansioides, Oricymba japonica, and Gomphonemaangustatum were abundant in these regions as well. Temperature composition was also associated with diatom community richness (Leland et al., 2001).

In sites with fairly high total solids and pH, such as Jannapura (S7) and Kirugunda (S15), planothidiumfrequentissimum, Naviculaheimansioides, and Gomphonemalagenula exhibited high abundances. Diatom community richness was found to be linked to ionic composition (Leland et al., 2001), with distribution patterns varying along distinct gradients of total dissolved solids (TDS) (Tudor et al., 1991; Stevenson and Pan, 1999). It is important to note that human disruptions can lead to changes in water quality and diatom habitat.

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Oligotrophic species like Cocconeisplacentula v. lineata, Achnanthidiumminutissimum, Gomphonemadiminutum, and Naviculaheimansioides were present in both disturbed and minimally impacted sites. However, variations in their abundance suggest that seemingly undisturbed streams may have experienced recent anthropogenic impacts, as indicated by Fore and Grafe (2002) and Bellinger et al. (2006). For instance, N. palea, a species thriving in deforested streams and biologically polluted waters, was found in such sites. Changes in land use and land cover significantly impact algae diversity, adversely affecting the quality and quantity of freshwater resources (Li et al., 2008; Walsh and Wepener, 2009). Diatom assemblages in streams are typically influenced by physical habitat conditions, including riparian conditions, instream habitat, and channel morphology (Pan et al., 2006; Veselá and Johansen, 2009), although nutrients and salinity may have a more pronounced impact than physical factors (Leland et al., 2001).

Temperature, pH, total solids, dissolved oxygen, and other physiochemical parameters varied among sites, influenced by flow dynamics and the presence of organic matter. This was particularly evident in the sites sampled, with parameter differences attributed to in-stream characteristics. Rapids, common in upland rivers, carry organic loads in the form of drift and dissolved solids, which agitate along their course, enriching the water with dissolved oxygen. Bathra (S6) and Basaravalli (S12) exhibited higher levels of dissolved oxygen and dissolved solids, reflecting similar conditions. We investigated whether diatom community composition at each site could account for habitat changes, seeking to establish the link between environmental factors and diatom diversity. It is worth noting that dynamic streams with minimal human disruptions may better preserve the complexity and integrity of lotic systems (Palmer et al., 2005). Furthermore, disturbed sites often exhibit greater diatom diversity compared to less impacted sites, owing to the availability and abundance of both moderately sensitive and tolerant species (Yu and Lin, 2009). Macrophyte diversity plays a significant role in shaping epiphyton diversity, which extends beyond the scope of this study but is influenced by environmental factors and changes.

Conclusion

The identification of the critical factors linked to community variability is one of the primary objectives of stream diatom investigations, however this objective is challenging to reach. Our findings demonstrated how stream diatom communities behaved on various scales to environmental gradients. Water temperature, pH, turbidity, dissolved oxygen, alkalinity, conductivity, silica, and other crucial streamside variables all had a significant impact. In general, the study's findings showed how stream conditions' diatom biodiversity and environmental parameters are related.

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Figure(s)

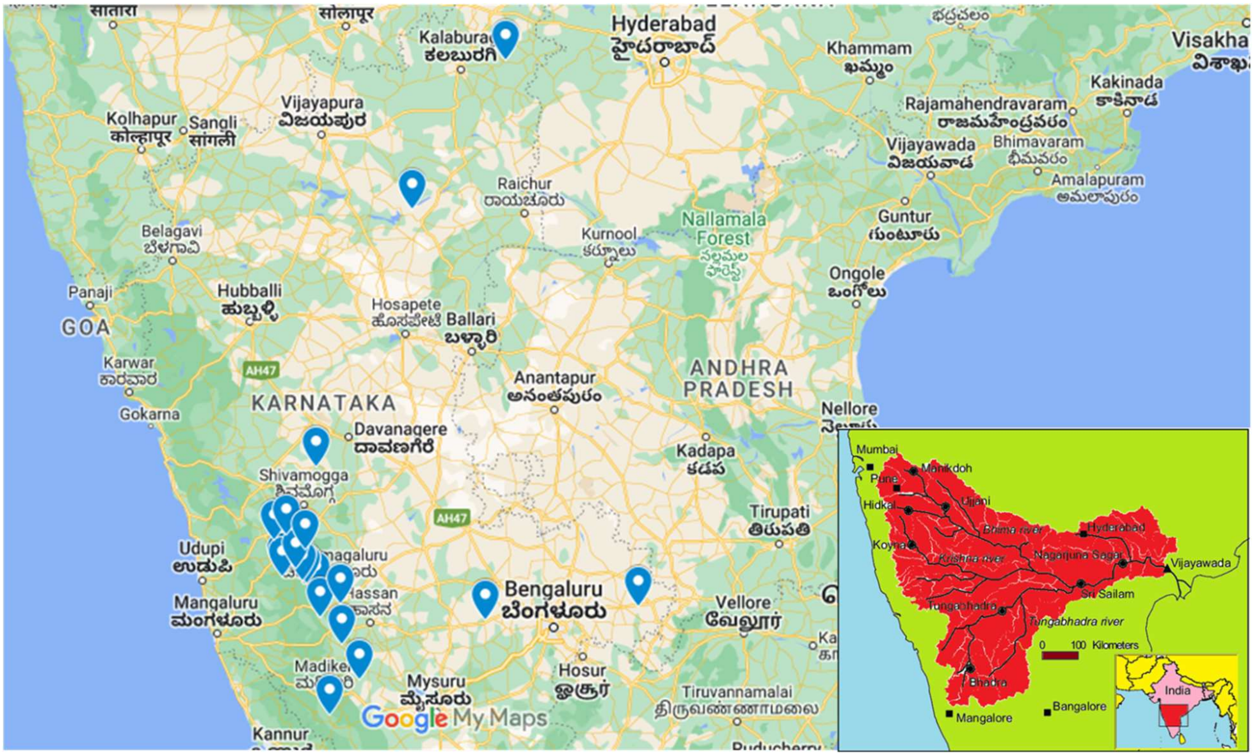

Figure 1: Study Location

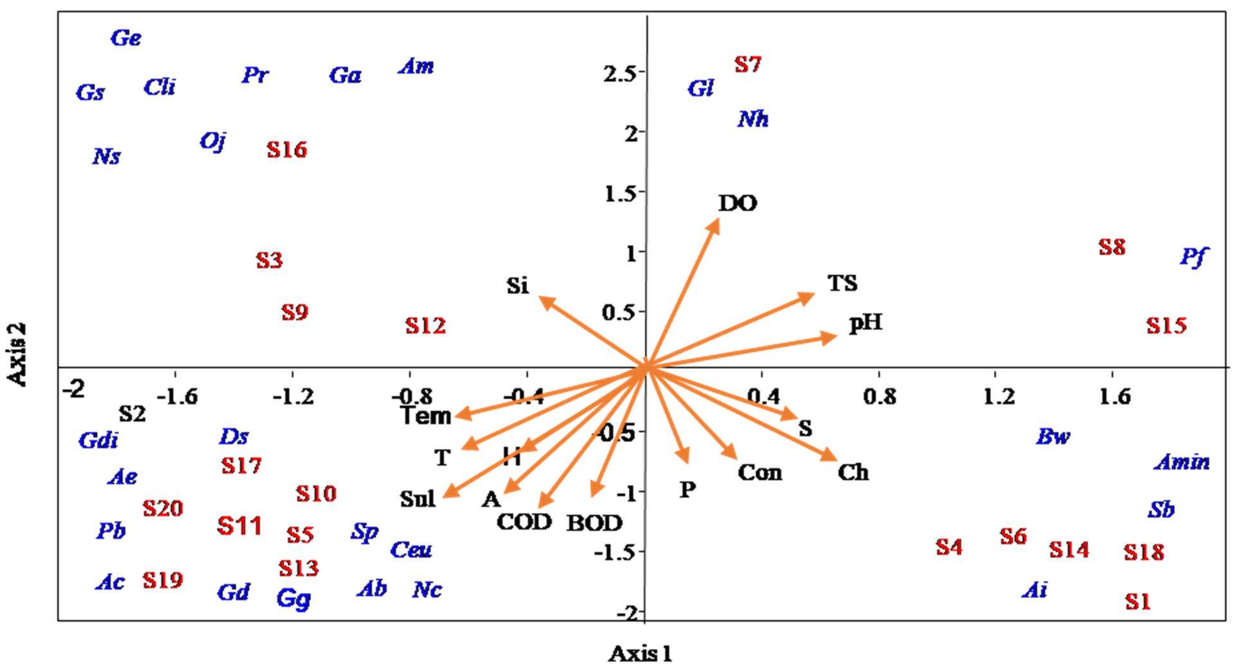

Figure 2: Canonical correspondence analysis (CCA) biplot illustrating the influence of the environmental variables on the diatom community of Karnataka streams.

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Figure 3: a. Achnanthidium exigum (Grunow) Czarnecki; b. Achnanthidium minutissimum (Kutzing) Czarneck; c. Cocconeis placentula v euglypta; d. Cocconeis placentula v lineate; e. Cymbella turgidula grun; f. Gomphonema angustatum Kutzing Rabenhorst; g. Gomphonema lagenula Kutzin; h. Oricymba japonica (Reichelt) Juttner, cox, Krammer and Tuji.

Tables

Species/Acronym/Sites		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
Achnanthesbiasolettiana	Ab	***	**	-	-	-	-	-	-	***	**	-	-	-	-	-	-	***	**	-	-
Achnanthesmicrocephala	Am	-	-	-	-	-	-	**	-	-	-	-	-	-	-	-	**	-	-	-	-
Achnanthidiumexigum	Ae	-	-	-	-	-	-	-	-	-	**	***	*	-	-	-	-	-	-	-	-
Achnanthidiumminutissimum	Amin	-	**	-	**	-	***	-	-	-	-	-	-	-	***	***	*	*	***	-	-
Brachysirawygaschii	Bw	-	-	-	**	-	**	*	*	-	-	-	-	-	-	-	-	-	-	-	-
Cocconeisplacentula v. euglypta	Ceu	-	**	-	-	**	-	-	-	**	***	**	-	***	-	-	-	**	-	***	***
Cocconeisplacentula v. lineata	Cli		***	-	-	**	-	-	-	-	-	-	***	-	-	-	-	**	-	-	-
Cymbellaturgidula	Ctr	-	-	*	-	*	-	-	***	-	**	**	-	-	*	-	-	-	-	*	*
Gomphonemaangustatum	Ga	-	*	*	-		*	-	-	*	-	-	-	-	-	*	***	-	-	-	-
Gomphonemadiminutum	Gdi	-	-		-	***	*	-	-	-	**	-	**	-	-	-	-	-	-	**	-
Gomphonemaexilissimum	Ge	-	-	*	-	-	-	*	-	-	-	-	**	**	-	-	-	-	-	-	-
Gomphonemalagenula	Gl	**	*		-	-	-	-	-	-	-	-	-	**	-	**	*	-	-	-	-
Naviculaheimansioides	Nh	-	-	-	-	-	-	***	*	*	-	-	**	-	-	*	*	-	*	-	-
Naviculasubrhynchocephala	Nsu	-	-	-	-	-	-	-	-	-	-	**	**	*	-	-	-	-	-	**	*
Oricymba japonica	Oj	-	-	***	*		*	*	-	-	*	-	*	-	-	*	*	-	-	-	-
Planothidiumbiporomum	Pb	-	**	-	-	**	*	*	*	-	-	-	-	-	*	*	-	-	-	-	*
planothidiumfrequentissimum	Pf	-	-	**	-	**	-	-	**	*	*	*	-	-	*	-	*	*	-	-	-
Planothidiumrostratum	Pr	-	-	*	-	**	-	*	-	**	**	*	*	*	-	-	-	-	-	-	-

Table 1: The Dominant Diatom species present in Karnataka streams (* 1-5%, ** 5-10%, *** 10-20%)

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