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Full Length Research Paper

Phytoplankton dynamics and seasonal variation in Tungabhadra River, India

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Tungabhadra River, an important tributary of Krishna, flows in the district Davangere in the central part of Karnataka State, India. A total 64 species of phytoplankton were recorded during the present study period. These include 23 species of *Chlorophyceae*, 18 species of *Cyanophyceae*, 14 species of *Bacillariophyceae* and 9 species of *Euglenophyceae*. Water and algal samples were collected at regular intervals of 15 days at 2 stations from December 2006 to October 2007. The results of the summer (December-March), winter (April-July) and rainy (August-November) seasons indicate that the highest phytoplankton dynamics were represented by 39 species in the summer season. In this study green algae constituted the highest percentage of 35.29 and 36.67% followed by blue green algae (29.41 and 26.67%), Diatoms (23.53 and 20.00%) and *Euglenphyceae* (11.76 and 16.67%) at Stations 1 and 2 respectively. Maximum and minimum densities of 21,476 o/L and 16,682 o/L were recorded at Station S1 while those at Station S2 were 18,392 o/L and 12,729 o/L respectively. The diversity of species varied from 0.160 to 1.147 during the study period. Phytoplankton species richness ranged from 0.371 to 0.552 while the Phytoplankton species evenness varied from 0.079 to 0.671 during the study period.

Key words: Phytoplankton dynamics, algae species, river, statistical analysis, India.

INTRODUCTION

Phytoplanktons are microscopic single celled aquatic plants forming the prime component in the food chain of an aquatic ecosystem. Some phytoplankton species are also often used as good indicators of water quality including pollution Rajashree (1993). Phytoplankton can be used as bio-indicators since they reflect even the slight changes taking place in their immediate environment by changing their species composition, biomass, community structure, chlorophyll pigment content and productivity moreover and marine ecosystem is largely determined by their phytoplankton population Mohamed et al.(2009). Phytoplankton abundance and composition in aquatic ecosystems are regulated by abiotic factors such as, nutrients related to physico-chemical variability and biotic, trophic interactions (Sin et al., 1999; Lewis, 2000).

The seasonal variations of physical – chemical factors have a profound effect on the distribution and population density of both fauna and flora (Hassan, 1998). The abundance of phytoplankton and zooplankton in the fresh water bodies is greatly regulated by the physico-chemical factors (Munawar, 1970). In the present study phytoplankton dynamics and seasonal variations in Tungabhadra River are reported.

MATERIALS AND METHODS

Study area

Tungabhadra River in Karnataka is an important tributary of Krishna. The river flows in the district Davangere in the central part of Karnataka state (India). The district Davangere is located in the central part of Karnataka state (India) between latitude 14° 17' to 14° 35' N and longitude 75° 50' to 76° 05' E covering an area of 6500 km^2 at an average altitude of 540 m above Mean Sea Level (MSL). The river Tungabhadra is bifurcating the adjoining district namely Haveri. The river has a drainage area of 71,417 km^2 out of

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which 57,671 km^2 lies in the state. It covers a distance of 293 km in the state and is getting polluted due to rapid industrial growth, domestic and agricultural activities in the region. Pollution is as old as man himself. In prehistoric times, the population was very thin and people used to move from place to place in search of food and better living.

The water and algal samples were collected at regular intervals of 15 days at 4 stations for one year. During the present investigations four different stations were chosen on the basis of algal occurrence and human activities.

Station (S1): The site of this habitat is located upstream of the city before the river enters into city.

Station (S2): This station is located on the main stream of river Tungabhadra in a place just near the confluence point of Sulekere stream (see Figure 1).

Phytoplankton collection and preservation

Preservation: The water samples were collected in 1000 ml plastic cans and preserved by adding 5 ml of 4% formalin.

Concentration: The preserved samples were kept for 24 h undisturbed to allow the sedimentation of plankton suspended in the water. After 24 h, the supernatant was discarded carefully without disturbing the sediments and the final volume of concentrated sample was about 50 ml.

Qualitative and quantitative analysis of phytoplankton and Zooplankton*:* The qualitative and quantitative analyses of phytoplankton were done by Lackey's drop method and Sedgwick-Rafter cell (For Standardization). In Lackey's drop method, the cover slip was placed over a drop of water on the slide and whole of the cover slip was examined by parallel overlapping strips to count all the organisms in the drop. About 20 strips were examined in each drop. Standard method (APHA, 1995) was adopted for the purpose. The phytoplankton species like *Cyanophyceae, Chlorophyceae*, *Bacillariophyceae, Euglenophyceae* were identified using standard identification keys (Dhanapathi, 2000; Altaff, 2003).

Statistical analysis: Analysis of various (two way ANOVA) was used to test the homogeneity of various physicochemical parameters studied. Multiple regressions also analyzed to find out the influence of independent physic-chemical parameters against plankton bloom. The phytoplankton groups were studied using the indices of dominance, evenness, richness and diversity (Shannon and Weaver, 1963; Pielou, 1966).

Simple correlation co-efficient analysis between different parameters and the analysis of variance (ANOVA) were employed for the statistical interpretation of data obtained from the study. The phtyoplankton groups were studied using the indices of dominance, evenness, richness and diversity (Shannon and Weaver, 1963; Pielou, 1966).

RESULTS AND DISCUSSIONS

Parameters

The seasonally average values of physico-chemical parameters of 2 stations along the river are shown in (Table 5). The algal composition of 4 groups of phytoplankton of the river is as shown in (Table 1). Correlation coefficients (r value) have been studied to find out the inter-correlation among various physico-chemical parameters and phytoplankton groups which are given in Tables (6 and 7).

Variations of water temperature were well marked with respect to different seasons. The study of temperature plays an important role in controlling the abundance of phytoplankton (Singh, 1960). The maximum pH value of 8.20 was recorded in summer at Station S1 and minimum of 7.50 in rainy season at Station S1. The pH of river water was observed to be in the range of 7.5 to 8.2 indicating alkaline throughout the period of study. Generally, the pH of water promotes the growth of algae (Geroge, 1961). In the present study, higher values of pH were recorded in winter and lower pH values during the monsoon season. Similar observations have been reported by Gopal (1990).

Dissolved Oxygen content is important for the direct needs of many organisms and affects the solubility and availability of many nutrients. Therefore, the productivity of aquatic ecosystem is based on oxygen concentration (Wetzel, 1983). In this study, the lowest average value of dissolved oxygen of 7.1 mg/l was obtained in Station S1 and highest value of dissolved oxygen to 8.6 mg/l recorded at Station S2. Higher dissolved oxygen indicates the abundance growth of phytoplankton (De, 1999) and related phytoplankton leading to higher biological activity which was observed in river water. A low content of dissolved oxygen is a sign of organic pollution.

The tolerance limit of dissolved oxygen is (not less than) 6 mg/l (Kudesia, 1985). The factors affecting the oxygen balance in water bodies are input due to atmosphere and photosynthesis, and output from respiration, decomposition and mineralization of organic matter losses the oxygen to atmosphere. Hence, the oxygen balance in water becomes poorer as the input oxygen at the surface and photosynthetic activities of heterotrophs are enhanced.

Biochemical Oxygen Demand (BOD) is the most important parameter to measure the pollution load in an aquatic system. In this study, high values of BOD and Chemical Oxygen Demand (COD) of 5.10 mg/l and 85.0 mg/l were reported at Station S2. As the oxidation of the organic waste by natural microorganisms causes high BOD levels, the same trend has been noticed for COD (Basu, 1996). In general, thevalues of the COD and BOD are not related since the two tests measure different characteristics. On the other hand, if the effluents do not change drastically the COD/BOD ratio for polluted water usually remains fairly constant (Kshirsagar, 1968).

Nitrate in water bodies is responsible for the growth of blue or green algae Abdul (1998). A high concentration of nitrate is an indication of organic pollution and eutrophication. In the present study relatively low values

Figure 1. Location map of study area along River Tungabhadra in Karnataka India.

Table 1. List of identified Phytoplankton species recorded from December 2006 to October 2007 at Station S1 and Station S2.

Chlorophyceae		Cyanophyceae		Bacillariophyceae		Euglenophyceae
Chlorell sp.	*1*	*Nitschia sp*	*1*	*Spirulina sp*	*1*	*Euglena sp*
Clesteriom sp.	*2*	*Navicula sp*	*2*	*Microcystis sp*	*2*	*Pahcus sp*
Cosmarium sp.	*3*	*Cyclotella sp*	*3*	*Phermidium sp*	*3*	*Euglena minuta*
Pediastrum duplex	*4*	*Amphora sp*	*4*	*Lyngbya sp*	*4*	*Euglena spirogyra*
Scenedesmus sp.	*5*	*Pinnularia sp*	*5*	*Phormodium*	*5*	*Trachelomonas sp.*
Spirogyra sp	*6*	*Diatoma sp.*	*6*	*Anabaena*	*6*	*Euglena proxima*
Ulotrix sp	*7*	*Fragilaria*	*7*	*Oscillotoria sp*	***7***	*Phacus tortus*
Kirchineriella sp.	*8*	*Melosires*	*8*	*Nostoc sp*	*8*	*Phacus indicus*
Glosterium	*9*	*Nitschia*	*9*	*Spirulina sp*	*9*	*Euglena tuba*
Ankistrodesmus Sp.	*10*	*Nitschia sp*	*10*	*Gomphonema sp.*		
Pediastrum simplex	*11*	*Lyngbya sp.*	*11*	*Merismopedia elegans*		
Microspotrum sp.	*12*	*Spirulina sp.*	*12*	*Ocillatoria acuta*		
Coelastrum sp.	*13*	*Trichodesmium sp.*	*13*	*Phormidium fragile*		
Schroderia sp.	*14*	*Synedra Lenera*	*14*	*Spirulina major*		
Tetrastrum sp.	*15*	*Thalassosira gravida*				
Oedogonium sp.	*16*	*Stauronies sps*				
Staurastrum wilde	*17*	*Nitzschia acicularis*				
Tetraedon trilobulatum	*18*	*Melosira distans*				
Oocystis gigas						
Dimorphococcus lunatus						
Ankistrodesmus spiralis						
Chlorella vulgaris						
Elkatothrix gelatinosa						

of nitrate were observed. The nitrate concentration varied from 1.8 to 8.3 mg/l. The minimum value was obtained at Station S1 in summer while the maximum value was obtained at Station S2 during winter.

Sulphate is an important mineral substance for phytoplankton growth (Boney, 1989). Sulphate enters into the water body from the catchment area through surface run off. Since the study area is bordered by agricultural lands where large quantities of sulphate fertilizers are used, the relatively high concentrations of sulphate observed could be attributed to the runoff water from these agricultural lands.

Phytoplankton composition

A total of 72,173 o/L and 33,323 o/L of phytoplankton made up of 64 species from 4 species were recorded. The phytoplankton dynamics indicates that the conditions in the study area are good for fisheries. According to Townsend et al. (2000) and Miller (2005), planktons form the prime component in the food chain of aquatic ecosystems.

In this study 64 species of phytoplankton have been recorded of which 23 belong to *Chlorophyceae*, 18 to *Cyanophyceae,* 14 to *Bacillariophyceae* and 9 to *Euglenophyceae* (see Table 1). The annual periodicity shows *Chlorophyceae* dominance with 35.29% and 36.67% of the total phytoplankton population. This was followed by *Cyanophyceae* with 29.41 and 26.67%, *Bacilleriophyceae* with 23.63 and 20.00% and *Euglenophyceae* with 11.76 and 16.67% of the total phytoplankton population. These were recorded respectively at Stations S1 and S2 and summarized in (Table 1 and Table 2).

George (1961) observed that high pH values promote the growth of algae. Similar results were observed in this study. It was also observed that the pH favored the growth of *chlorococales* as observed by Gonzalves and Joshi (1946) and Zafar (1964). The concentration of Dissolved Oxygen decreased along the stretch of river from Stations S1 to S4. This is due to the addition of domestic, agricultural and industrial waste to the water. The Dissolved Oxygen content was observed to be higher in the rainy and winter seasons in the present investigation. The results obtained are in agreement with the findings of Singh (1960).

Review of literature reveals that there are two types of growth periods for phytoplankton. Many researchers have found that the maximum development of phytoplankton is during summer and minimum in winter (Philipose, 1960; Kumar and Dutta, 1991). However, Kimar (1990)

Table 2. Concentration of phytoplankton in Tungabhadra River during study period.

Station S1				Station S2			
S/ No	Taxa	Species	%	S/ No	Taxa	Species	%
1	Chlorophyceae	12	35.29	1	Chlorophyceae	11	36.67
2	Cyanophyceae	10	29.41	2	Cyanophyceae	8	26.67
2	Bacileriophyceae	8	23.53	2	Bacileriophyceae	6	20.00
3	Euglenophyceae	4	11.76	3	Euglenophyceae	5	16.67

Table 3. Average values showing the different Indices of phytoplankton.

	Station S1				Station S2			
Month	s	H	e	d	s	H	e	d
Dec	4.713	1.390	1.989	0.291	4.703	1.323	1.907	0.243
Jan	4.709	1.402	2.005	0.250	4.713	1.467	2.099	0.242
Feb	4.709	1.423	2.036	0.245	4.713	1.396	1.997	0.272
Mar	4.714	1.409	2.015	0.279	4.706	1.338	1.915	0.261
Apr	4.713	1.420	2.032	0.271	4.710	1.394	1.995	0.260
May	4.714	1.447	2.070	0.263	4.713	1.380	1.974	0.273
Jun	4.708	1.352	1.935	0.271	4.716	1.359	1.945	0.299
July	4.715	1.393	1.994	0.282	4.716	1.449	2.073	0.266
Aug	4.712	1.377	1.970	0.277	4.718	1.345	1.924	0.304
Sep	4.707	1.347	1.928	0.266	4.717	1.315	1.881	0.309
Oct	4.710	1.375	1.968	0.275	4.716	1.410	1.930	0.273
Nov	4.708	1.403	2.007	0.251	4.707	1.352	1.935	0.256
Where:	H = species diversity				s = richness			
	d =- dominance				e =evenness			

observed that the intensity of phytoplankton is higher during summer, premonsoon and winter and is lowest in monsoon (Saha and Chaudhary, 1985). The results obtained from this study indicate that the maximum densities of phytoplankton occurred during July while the minimum valuese occurred during January in Tungabhadra river. Significant correlations were estimated between diversity index and physico-chemical parameters of water (Tables 6 and 7).

Species richness varied from 1.315 to 1.467 during the study period. At Station S1, a minimum of 1.347 was recorded in September while the maximum value of 1.447 was recorded in May. At Station S2, the minimum value of 1.315 was recorded in September and a maximum of 1.467 was recorded in January (see Table 3 and Figure 2).

The low species richness that was recorded during the monsoon season and slightly higher values that were recorded during the other seasons could be correlated with the low and high salinity values during the periods (Mani, 1992). The high diversity index was associated with high evenness index, reflecting the multi-dominance pattern in clusters (Balloch, 1976). Diversity indices greater than 3 indicate clean water. Diversity indices ranging from 1 to 3 are characteristics of moderately polluted conditions while values less than 1 indicate heavily polluted conditions (Mason, 1991). In this study, the diversity of phytoplankton ranged from 4.70 to 4.72. As these are greater than 3, the water quality in the stretches can be described as good. Phytoplankton species are found to increase in their population during some periods of the year. Margalef (1968) recorded that higher diversity is a clear indication of longer food chains.

Evenness index (Table 4 and Figure 3) of phytoplankton species was observed to be higher during the summer and lower in rainy period during the study period. The results showed competition under optimum conditions because no adverse environmental factors were noticed in this bionetwork. Odum (1971) observed that when stress occurs in a community dominated by a few species, a large number of dominated species is eliminated and evenness increases. In this study, phytoplankton species were showing maximum diversity and species richness during the summer and the rainy seasons when conditions were relatively stable.

In general, in all the stations, richness and evenness of phytoplankton were comparatively low in winter and rainy periods. During these periods the phytoplankton

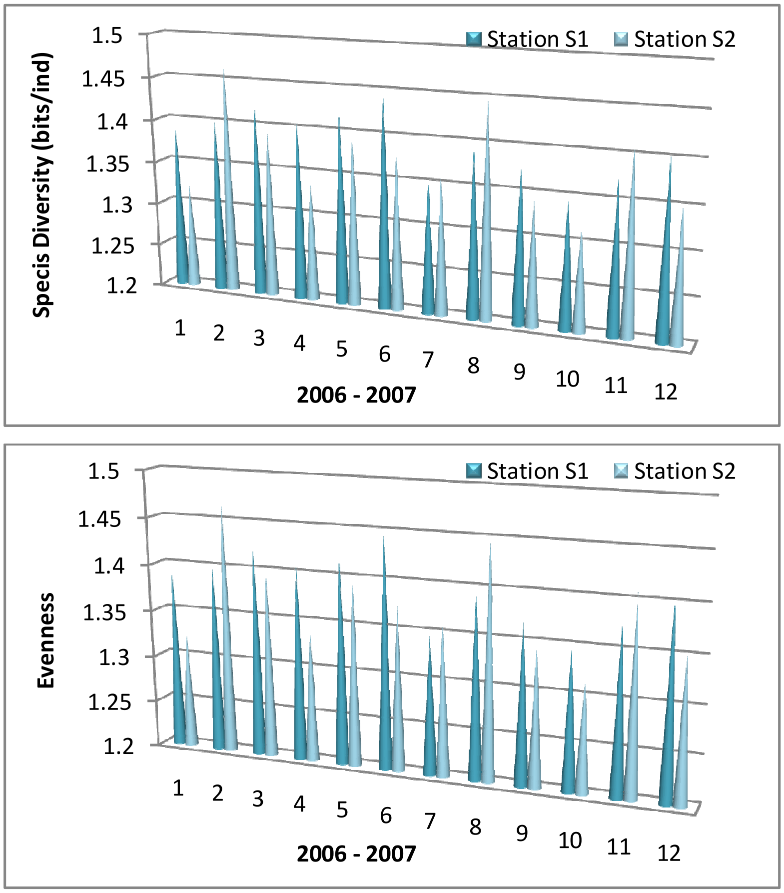

Figure 2. Phytoplankton diversity.

Table 4. Analysis of variance (F-value) for the phytoplankton between Stations S1 and S2 from December 2006 to November 2007.

Parameter	Station S1					Station S2				
	Sum of Squares	df	Mean Square	F	Sig	Sum of Squares	df	Mean Square	F	Sig
Between People	0.013	11	0.001			0.031	11	0.003		
Within the people										
Between Items	128.483	3	42.828	29211.398	0.000	128.159	3	42.720	82101.411	0.000
Residual	0.048	33	0.001			0.017	33	0.001		
Total	128.531	36	3.570			128.176	36	3.560		
Total	128.563	47	2.735			128.189	47	2.727		
Grand mean	**2.0814**					**2.0925**				

abundance was also low due to rain as the rain water causes strong currents which wash away the phytoplankton. Ramanujan (1994) noted that the depletion of phytoplankton naturally affects the population of zooplankton.

According to Whiltaker (1963) the value of dominance index is always higher where the community is dominated by fewer numbers of species and when the dominance is shared by a large number of species. The results of this study correlates well with these findings. High values of dominance index in the Tungabhadra River were registered during the monsoon periods. The present investigation also indicates that, whenever the dominance index of phytoplankton species was high, the evenness index was low and vice versa as reported by Walting et al. (1979).The results of this study confirm the

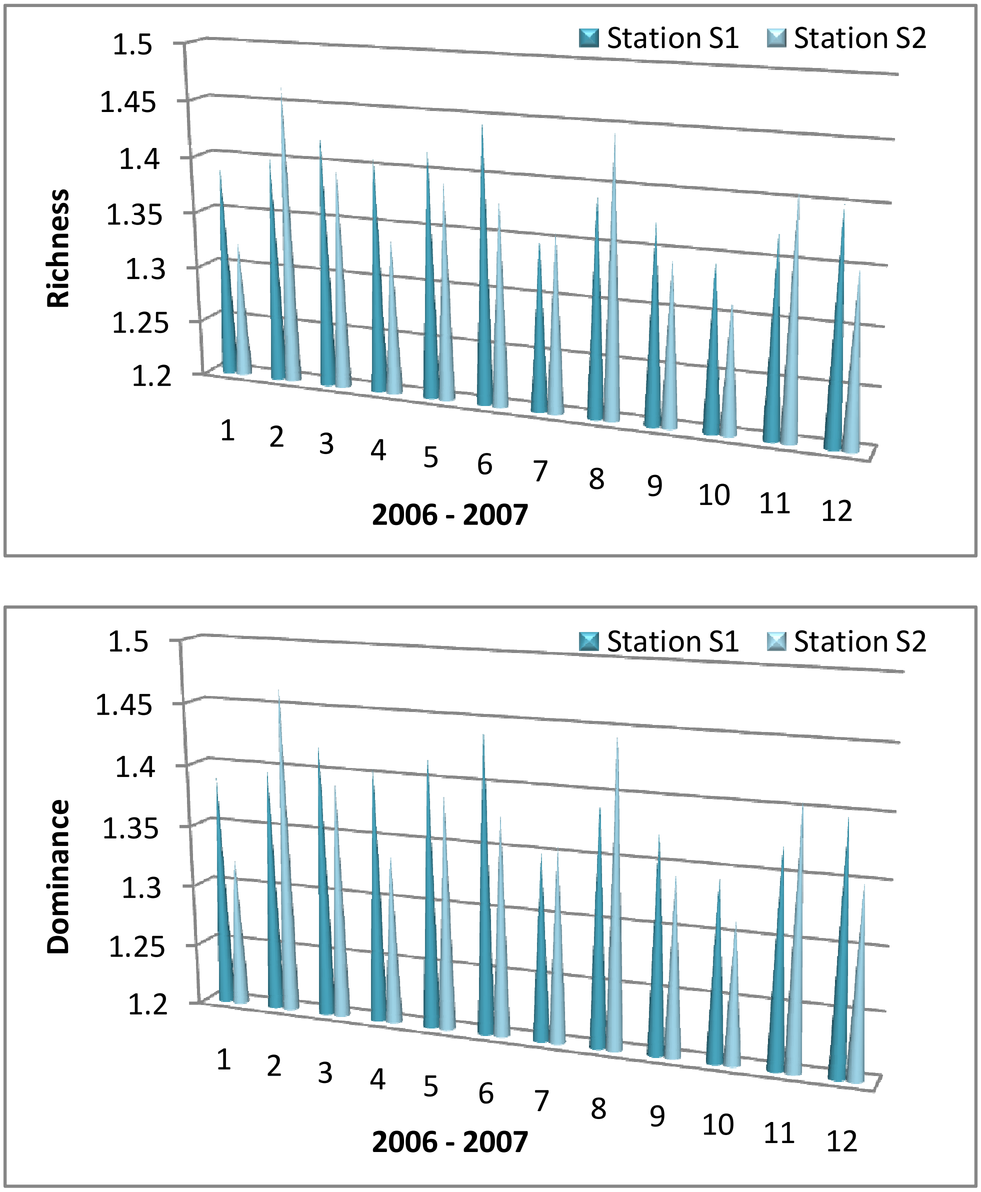

Figure 3. Phytoplankton richness.

findings of Watling et al. (1979).

The phytoplankton population dynamics might have been influenced by sand mining and other human activities around Station S2. Any depletion in phytoplankton adversely affects the normal food web pattern of the river water and in turn leads to destruction of the environmental conditions of the river. So the conservation and maintenance of the river is very essential for future generations.

Significant correlations were estimated between the diversity index and physico-chemical parameters of water (Tables 6 and 7). Species diversity showed highly significant and positive correlation with temperature, nitrate and phosphate at Station S1 but negative correlation with pH, BOD, nitrite and silica at Station S2. The richness showed strong negative correlation with Ammonia, nitrogen and free carbon dioxide in Station S1 and with BOD at Station S2. The evenness showed strong negative correlation with silica and the dominance showed strong negative correlation with BOD whereas a strong positive correlation was obtained with nitrite and silica.

The present correlations between phytoplankton groups with one or other parameters of water are in agreement with earlier observations of Anjana (1998), Munawar (1970, 1974) and Verma and Mohanty (1995). Thus it may be concluded that the density of phytoplankton is dependent on different abiotic factors

Table 5. Seasonal variation of physico-chemical parameters in Tungabhadra River.

Parameter	Station S1			Station S2		
	Summer	Winter	Rainy	Summer	Winter	Rainy
	Mean ±Sd (Min-Max)	Mean ±Sd (Min-Max)	Mean ±Sd (Min-Max)	Mean ±Sd (Min-Max)	Mean ±Sd (Min-Max)	Mean ±Sd (Min-Max)
Air temperature	29.9 ± 1.9 (27.8 – 31.3)	29.8 ± 0.3 (29.5 – 30.0)	29.0 ± 0.4 (28.0 – 29.0)	30.4 ± 1.6 (28.8 – 32.0)	29.6 ± 0.3 (29.3 – 29.8)	28.8 ± 0.3 (28.5 – 29.0)
Water temperature	28.3 ± 1.5 (26.5 – 29.3)	26.8 ± 1.1 (25.8 – 28.0)	25.6 ± 0.5 (25.0 – 26.0)	28.4 ± 1.5 (26.8 – 29.5)	27.5 ± 0.4 (27.3 – 28.0)	25.9 ± 0.1 (25.8 – 26.0)
pH	8.0 ± 0.1 (7.9 – 8.2)	7.9 ± 0.1 (7.9 – 8.1)	7.9 ± 0.07 (7.8 – 8.0)	8.1 ± 0.2 (7.9 – 8.3)	7.8 ± 0.3 (7.6 – 8.1)	7.8 ± 0.3 (7.5 – 8.1)
Dissolved oxygen	7.7 ± 0.4 (7.4 – 8.2)	7.9 ± 0.7 (7.1 – 8.4)	7.3 ± 0.2 (7.1 – 7.5)	7.9 ± 0.3 (7.7 – 8.3)	7.9 ± 0.6 (7.4 – 8.6)	7.7 ± 0.4 (7.4 – 8.1)
Biological oxygen demand	4.5 ± 0.2 (4.3 – 4.7)	4.5 ± 0.3 (4.1 – 4.7)	4.2 ± 0.1 (4.1 – 4.3)	4.6 ± 0.3 (4.3 – 4.9)	4.4 ± 0.7 (3.7 – 5.1)	4.4 ± 0.1 (4.3 – 4.6)
Chemical oxygen demand	44.5 ± 3.3 (41.0 – 47.5)	52.7 ± 12.1 (40.0 – 64.0)	54.3 ± 19.2 (37.0 – 75.0)	60.3 ± 2.1 (58.0 – 62.0)	71.0 ± 9.5 (62.0 – 81.0)	59.3 ± 22.5 (43.0 – 85.0)
Phosphate	0.3 ± 0.17 (0.1 – 0.4)	0.05 ± 0.02 (0.03 – 0.06)	0.11 ± 0.07 (0.06 – 0.20)	1.1 ± 1.5 (0.08 – 2.8)	0.2 ± 0.3 (0.04 – 0.5)	0.5 ± 0.4 (0.2 – 0.9)
Ammonia nitrogen	1.2 ± 0.4 (0.8 – 1.7)	1.7 ± 0.1 (1.7 – 1.8)	0.8 ± 0.07 (0.8 – 0.9)	1.1 ± 0.07 (1.0 – 1.1)	2.3 ± 0.7 (1.5 – 2.9)	1.0 ± 0.1 (0.9 – 1.2)
Nitrate	4.3 ± 2.2 (1.8 – 5.9)	6.7 ± 1.0 (6.0 – 7.8)	6.0 ± 2.1 (4.5 – 8.3)	4.1 ± 1.9 (2.5 – 6.2)	9.9 ± 4.8 (6.8 – 5.4)	6.6 ± 2.6 (4.6 – 6.5)
Nitrite	0.04 ± 0.02 (0.02 – 0.06)	0.02 ± 0.10 (0.02 – 0.20)	0.04 ± 0.01 (0.04 – 0.50)	0.03 ± 0.04 (0.00 – 0.08)	0.13 ± 0.10 (0.05 – 0.24)	0.05 ± 0.02 (0.04 – 0.08)
Free carbon dioxide	0.8 ± 0.04 (0.8 – 0.9)	0.8 ± 0.4 (0.5 – 1.3)	0.4 ± 0.3 (0.07 – 0.6)	1.1 ± 0.2 (0.9 – 1.4)	1.2 ± 0.4 (0.9 – 1.6)	0.6 ± 0.5 (0.1 – 0.9)
Silica	0.8 ± 0.5 (0.5 – 1.3)	0.8 ± 0.9 (0.8 – 1.2)	0.5 ± 0.2 (0.4 – 0.7)	0.9 ± 0.5 (0.6 – 1.5)	1.2 ± 0.3 (0.9 – 1.6)	0.4 ± 0.2 (0.2 – 0.6)

either directly or indirectly.

Conclusion

The foregoing discussions are based on the seasonal studies of phytoplanktons and physico-chemical parameters in Tungabhadra river over a period of one year (that is from December 2006 to November 2007). The water and algal samples were collected at regular intervals of 15 days at 4 stations for one year. The most tolerant genera and species of groups of algae namely *Chlorophyceae, Bacilleriophyceae, Cynaophyceae* and *Euglenophyceae* indicate that total algal population is 71,476 at Station S1 and 32,323 at Station S2. Further, it was observed that the annual periodicity shows *Chlorophyceae* dominance and constituted 35.29% at Station S1 and 36.67% at Station S2 of the total phytoplankton population. This was followed by *Cyanophyceae* with 29.41 and 26.67% *Bacilleriophyceae* with 23.63 and 20.00% and *Euglenophyceae* with 11.76 and 16.67% at Stations 1 and 2 respectively.

Table 6. Simple Correlation Coefficient (r) Values between Physico-chemical Parameters and Phytoplankton from December 2006 to November 2007 at Station S1.

Parameter	A Temp	W.r Temp	pH	DO	BOD	COD	Am N	Nitra	Nitri	PO4	F CO2	Si	H	s	e	d
Air Temperature	1	00.924**	0.338	-0.297	0.537*	-0.114	0.149	0.304	-0.088	0.629*	-0.472	-0.703**	-0.038	0.612*	0.609*	-0.416
Water Temperature	0.924**	1	0.453	-0.332	0.613*	-0.092	0.313	0.444	-0.203	0.595*	-0.467	-0.669**	-0.076	0.541*	0.537*	-0.472
pH	0.338	0.453	1	-0.370	-0.239	-0.300	0.251	0.644*	-0.098	-0.009	-0.501*	-0.092	0.287	0.355	0.356	0.087
DO	-0.297	-0.332	-0.370	1	-0.205	0.339	-0.035	-0.186	0.375	0.006	0.328	0.419	-0.200	-0.182	-0.186	-0.115
BOD	0.537*	0.613*	-0.239	-0.205	1	-0.056	0.458	0.109	-0.290	0.598*	0.182	-0.455	-0.382	0.110	0.109	-0.534*
COD	-0.114	-0.092	-0.300	0.339	-0.056	1	0.042	-0.129	0.653*	-0.222	0.045	-0.151	-0.083	-0.186	-0.185	0.118
Phosphate	00.149	0.313	0.251	-0.035	0.458	0.042	1	0.401	-0.116	0.060	0.435	-0.023	-0.397	0.050	0.051	-0.492
Ammonia Nitrogen	00.304	0.444	0.644*	-0.186	0.109	-0.129	0.401	1	-0.229	0.116	-0.185	-0.258	0.095	0.390	0.394	-0.258
Nitrate	-0.088	-0.203	-0.098	0.375	-0.290	0.653*	-0.116	-0.229	1	-0.328	-0.086	0.178	-0.104	-0.217	-0.213	0.243
Nitrite	0.629*	0.595*	-0.009	0.006	0.598*	-0.222	0.060	0.116	-0.328	1	-0.190	-0.540*	0.141	0.451	0.445	-0.203
Free Carbon Dioxide	-0.472	-0.467	-0.501*	0.328	0.182	0.045	0.435	-0.185	-0.086	-0.190	1	0.564*	-0.632*	-0.625*	-0.626*	-0.189
Silica	-0.703**	-0.669**	-0.092	0.419	-0.455	-0.151	-0.023	-0.258	0.178	-0.540*	0.564*	1	-0.381	-0.765**	-0.765**	0.223
H	-0.038	-0.076	0.287	-0.200	-0.382	-0.083	-0.397	0.095	-0.104	0.141	-0.632*	-0.381	1	0.512*	0.515*	0.603*
s	0.612*	0.541*	0.355	-0.182	0.110	-0.186	0.050	0.390	-0.217	0.451	-0.625*	-0.765**	0.512*	1	10.000**	-0.315
e	0.609*	0.537*	0.356	-0.186	0.109	-0.185	0.051	0.394	-0.213	0.445	-0.626*	-0.765**	0.515*	10.000**	1	-0.312
d	-0.416	-0.472	0.087	-0.115	-0.534*	0.118	-0.492	-0.258	0.243	-0.203	-0.189	0.223	0.603*	-0.315	-0.312	1

** Correlation is significant at the 00.01 level
* Correlation is significant at the 00.05 level

Table 7. Simple Correlation Coefficient (r) values between Physico-chemical Parameters and Phytoplankton from December 2006 to November 2007 at Station S2.

Parameter	A Temp	W.r Temp	pH	DO	BOD	COD	Am N	Nitra	Nitri	PO4	F CO2	Si	H	s	e	d
Air Temperature	1	0.895**	-0.110	0.588*	0.005	0.454	0.483	-0.754**	-0.691**	0.390	0.285	-0.693**	-0.423	0.466	0.610*	-0.642*
Water Temperature	0.895**	1	0.062	0.725**	0.072	0.550*	0.604*	-0.684**	-0.602*	0.427	0.422	-0.391	-0.270	0.348	0.429	-0.410
pH	-0.110	0.062	1	0.184	0.195	0.071	-0.010	0.039	0.078	0.253	-0.201	0.230	-0.370	-0.676**	-0.703**	0.077
DO	0.588*	0.725**	0.184	1	0.184	0.417	0.587*	-0.762**	-0.445	0.514*	0.354	-0.258	-0.295	0.207	0.204	-0.393
BOD	0.005	0.072	0.195	0.184	1	-0.249	0.175	-0.200	-0.135	0.004	0.303	-0.152	-0.536*	-0.425	-0.472	-0.153

Table 7 Contd.

COD	0.454	0.550*	0.071	0.417	-0.249	1	-0.019	-0.356	-0.460	-0.017	0.182	-0.256	-0.295	0.225	0.295	-0.473
Phosphate	0.483	0.604*	-0.010	0.587*	0.175	-0.019	1	-0.417	-0.420	0.814**	0.699**	-0.252	0.008	0.230	0.269	-0.076
Ammonia Nitrogen	-0.754**	-0.684**	0.039	-0.762**	-0.200	-0.356	-0.417	1	0.579*	-0.268	-0.179	0.483	0.539*	-0.330	-0.377	0.679**
Nitrate	-0.691**	-0.602*	0.078	-0.445	-0.135	-0.460	-0.420	0.579*	1	-0.379	-0.509*	0.741**	0.491	-0.445	-0.430	0.758**
Nitrite	0.390	0.427	0.253	0.514*	0.004	-0.017	0.814**	-0.268	-0.379	1	0.598*	-0.358	-0.081	0.057	0.099	-0.095
Free Carbon Dioxide	0.285	0.422	-0.201	0.354	0.303	0.182	0.699**	-0.179	-0.509*	0.598*	1	-0.315	-0.011	0.149	0.127	-0.058
Silica	-0.693**	-0.391	0.230	-0.258	-0.152	-0.256	-0.252	0.483	0.741**	-0.358	-0.315	1	0.626*	-0.349	-0.494	0.822**
H	-0.423	-0.270	-0.370	-0.295	-0.536*	-0.295	0.008	0.539*	0.491	-0.081	-0.011	0.626*	1	0.301	0.179	0.737**
s	0.466	0.348	-0.676**	0.207	-0.425	0.225	0.230	-0.330	-0.445	0.057	0.149	-0.349	0.301	1	0.927**	-0.402
e	0.610*	0.429	-0.703**	0.204	-0.472	0.295	0.269	-0.377	-0.430	0.099	0.127	-0.494	0.179	0.927**	1	-0.449
d	-0.642*	-0.410	0.077	-0.393	-0.153	-0.473	-0.076	0.679**	0.758**	-0.095	-0.058	0.822**	0.737**	-0.402	-0.449	1

The results of this study clearly indicate that the phytoplankton dominance, diversity, richness and evenness are associated with the environmental factors of the river. The phytoplankton population dynamics is found to be influenced by sand mining and other human activities. So the conservation and maintenance of the river is very essential for future generations.

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