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Limnological Studies with reference to Phytoplankton Diversity in Ponds of Semi arid zone of Western Uttar Pradesh

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ABSTRACT: Study of two ponds of semiarid zone of Western Uttar Pradesh was carried out in Aligarh to determine its limnology, in relation to diversity of phytoplankton population. Main water supply is rainwater and surface runoff from surrounding areas. Species diversity ranged from 3.058 (December, 2006) to 3.275 (February, 2007) in Pond I and 3.118 (May, 2007) to 3.335 (February, 2007) in Pond II. Species Evenness ranged from 0.906 (November, 2006) to 0.944 (February, 2007) in Pond I and 0.926 (May, 2007) to 0.945 (February, 2007) in Pond II. In the present study it was noted that no single environmental factor was responsible for the production of phytoplankton organisms but a number of factors acted together to bring the cumulative effect. Most of the phytoplankton were found to flourish at mesophytic environment. Growth of phytoplankton was directly or indirectly dependent upon the concentration of nutrients in both the ponds as evident by the study.

Keywords: Diversity, Phytoplankton, Minerals.

INTRODUCTION

A study was carried out to determine the effect of limnological factors on the diversity of phytoplankton population of two ponds. As we all know that phytoplankton are important for trophic dynamics as they are the chief primary producers of aquatic environment (Wetzel, 1975) which fix solar energy by the process of photosynthesis assimilating carbon-dioxide and water to produce carbohydrates. They serve as important links between the abiotic factors and the biota in the aquatic system (Saha *et al.,* 2000). Diversity is a concept that refers to the range of variations or differences among some set of entities. Biological diversity thus refers to the variety within the living world. Biodiversity is very commonly used as a synonym of species diversity. Phytoplankton has great importance from ecological point of view (Kumar and Gupta, 2002).

MATERIALS AND METHODS

The ponds, Pond I and Pond II were seasonal ponds receiving surface runoff and sewage from the surrounding areas. They were used by the washermen, and, as a result, heavy input of detergents was found. The shoreline was observed to be almost irregular. They were also used by cattles for drinking and bathing purposes. Area varied from 0.03 - 0.05 hactares during different seasons of the year. Depth, during different seasons, varied between 1-2 mt. Samples were collected from the pond fortnightly between 8 – 10 am. Various physico – chemical parameters were worked out following (Trivedy and Goel, 1984; APHA, 1998; Barnes, 1959). For phytoplankton analysis, information given in (Edmondson, 1959; Needham and Needham, 1962) was utilized. Species Diversity was determined following (Ludwig and Reynold, 1988). Evenness was calculated using formula given by (Pielou, 1975). The study was carried from October, 2006 to September, 2007. Map in Fig. 1 shows the locations of Pond I and Pond II on which the study was carried out. For Phytoplankton analysis Metzer inverted microscope was used. pH meter was used to measure pH. Air and water temperatures were recorded with the help of mercury thermometer graduated up to 100°C. Secchi Disc was used to measure the transparency. Spectrophotometer was used to determine the values of various nutrients.

RESULTS AND DISCUSSION

Temperature: Temperature regulates various physico-chemicals as well as biological activities. Changes in temperature govern biological processes like growth, development, reproduction and other life processes of the biota (Wetzel, 1983). In Pond I, air temperature varied from 21(December, 2006 & January, 2007) to 36°C (July, 2007) whereas water temperature from 18 (January, 2007) to 35°C (July, 2007).

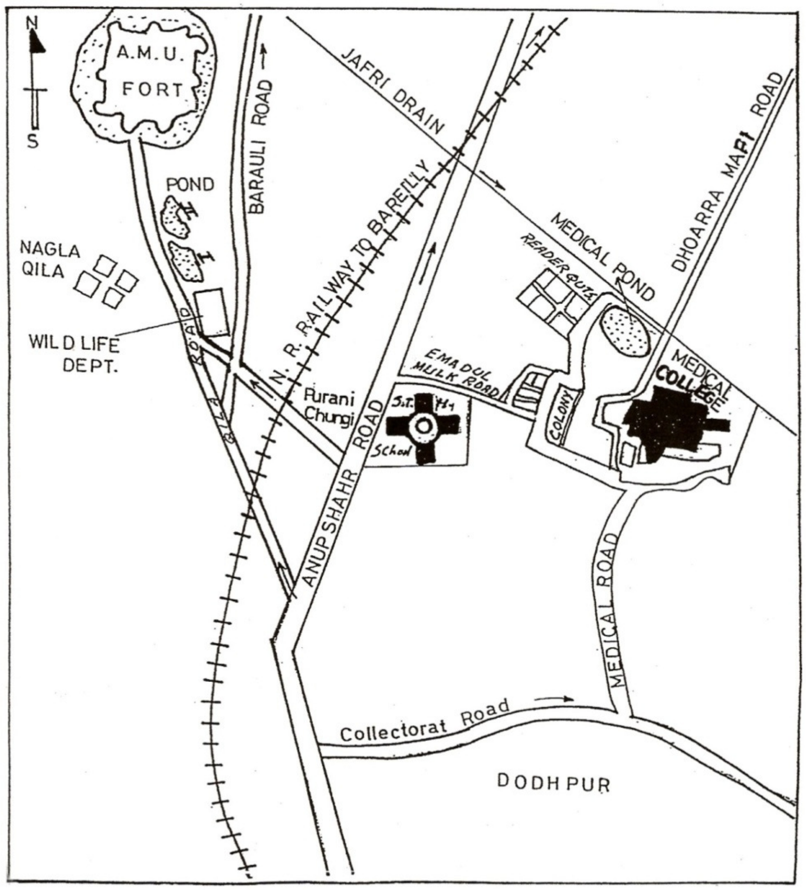


Fig. 1. Study area.

In Pond II, air temperature ranged from 20 (December, 2006 & January, 2007) to 34°C (July, 2007) and water from 16.5 (January, 2007) to 33°C (July, 2007). Haque, 1991 and several others have found positive correlation between these two variables (Table 1).

Transparency: The Secchi disc transparency is essentially a function of the reflection of light from its surface and is, therefore, influenced by the absorption through water and dissolved and particulate matter (Wetzel, 1983). In Pond I Transparency ranged from 8.5 (December, 2006 and May, 2007) to 30.5 cm (October, 2006) and in Pond II from 7.5 (December, 2006) to 14.5 cm (October, 2006). Higher values during the post monsoon months were recorded which might be due to the settlement of the incoming colloidal matter, silt and clay entering during the monsoon season (Table 1).

Dissolved Oxygen: In Pond I Dissolved oxygen varied from a minimum of 2.8 mg/L in July, 2007 and maximum of 9.8 mg/L in February, 2007. Pond II showed a minimum of 2.5 mg/L in July, 2007 and maximum of 9.5 mg/L in January and February, 2007. Solubility of oxygen in water, intensity of light, loss due to chemical and biological oxidation, diffusion and absorption from the atmosphere, presence and abundance of green aquatic organisms and photosynthesis (Wetzel, 1983) are the factors that affect the fluctuations in dissolved oxygen. Higher values of dissolved oxygen might be attributed to intense photosynthetic activity of phytoplankton and other green aquatic plants present in these water bodies. Lower values might be due to its utilization during decomposition of organic matter, low photosynthetic rate, respiration by micro and macro – organisms (Kaushik and Saxsena,1999) (Table 1).

pH: Sample of Pond I exhibited minimum pH, 8.4, during December, 2006 and June and August, 2007 and maximum, 9.5, during May and July, 2007. Pond II showed the minimum pH, 8.3, during December, 2006 and January and August, 2007 and maximum 9.2, during September, 2007.

Table 1: Monthly variations in Air Temperature, Water Temperature, Transparency, Dissolved Oxygen and pH in Pond I and Pond II.

Months	Air Temperature (°C)		Water Temperature (°C)		Transparency (cm)		Dissolved Oxygen (mg/L)		pH	
	Pond I	Pond II	Pond I	Pond II	Pond I	Pond II	Pond I	Pond II	Pond I	Pond II
October, 06	25	28	30.5	14.5	23	27	3.4	4.4	9.2	9.0
November	24	24	14.5	12.5	22	23	7.6	5.2	9.4	9.0
December	21	20	8.5	7.5	20	18	7.0	7.2	8.4	8.3
January, 07	21	20	13.5	12.0	18	16.5	9.0	9.5	8.5	8.3
February	22	22	12.0	11.0	19	20	9.8	9.5	8.8	8.8
March	28	26	11.5	8.0	25	24	9.6	5.4	8.5	8.5
April	29	28	11.0	8.2	26	27	7.0	7.2	8.8	8.7
May	32	31	8.5	7.8	29	30	6.5	7.0	9.5	8.5
June	33	33	9.0	8.0	33	32	4.8	5.9	8.4	8.7
July	36	34	12.0	9.5	35	33	2.8	2.5	9.5	8.4
August	30	32	11.0	10.5	29	29	3.3	3.0	8.4	8.3
September	28	30	25.0	8.0	26	28	5.4	4.2	8.6	9.2

These are shallow water bodies and they are subjected to disturbances caused by washer men's activity, wind action and cattles which may be the reason of fluctuations in pH. When there is entry of surface runoff material, it increases turbidity thus reducing transparency and, hence, light intensity. It results in the reduction of photosynthetic activity reducing pH in some months (Table 1).

Phosphate – phosphorus: Main supply of phosphate in these ponds were observed to be drainage, sewage effluents, domestic wastes, along with surface run off from the surrounding field and cattle dung. Municipal waste waters and industrial wastes containing phosphate compounds were the other major sources of phosphate in the surface waters. It is used extensively as fertilizer to replace or supplement natural quantities on agricultural lands. In Pond I and Pond II, values ranged from 0.399 (January and May, 2007) to 0.797 mg/L (April, 2007) and 0.389 (January, 2007) to 0.890 mg/L (July, 2007), respectively (Table 2). Higher values of phosphorus during the monsoon and post monsoon months or winter months might be due to regeneration of phosphorus in these ponds. Higher values were found during the summer months and found to be related with evaporation due to increased temperature which affects water level and concentration. At increased temperature decomposition of organic matter increases which further add phosphorus content to the water body. Kant and Raina, 1990; Prasad 1990 and Kaushik *et al*. 1991 have also reported higher concentrations during summer and gave similar reasons. Low values during winter months and also during some other months might be due to several factors such as utilization by algae and macrophytes for growth, sedimentation in the form of ferric complexes in bottom soil, low calcium level in water and low water temperature as also reported by Seenayya 1971; Khan and Siddiqui 1974; Sarkar 1989; Kaushik *et al*. 1989.

Nitrate – Nitrogen: Values of NO_3-N ranged from minimum value of 0.085 during October, 2006 and maximum 1.135 mg/L during June, 2007 in Pond I whereas Pond II showed minimum value (0.060 mg/L) during May, 2007 and maximum (0.150 mg/L) during September, 2007. NO_3-N showed wide seasonal fluctuations during the study period (Table 2). Pond II showed higher concentration of NO_3-N during monsoon and post monsoon months indicating that it receives the nitrogen supply through drainage, catchment area and surface run off. In the present study, negative correlation between NO_3-N and phytoplankton was found in Pond II ($r = -0.198$), while positive correlation was found in Pond I ($r = 0.220$). Negative correlation between NO_3-N and phytoplankton might be due to lowering of its utilization by increased phytoplankton for their growth and reproduction. Sarwar, 1999 has also reported negative correlation between these two variables, while Haque, 1991 has reported a positive and significant correlation between these two variables.

Nitrite – nitrogen: Values of NO_2-N varied from 0.130 (June, 2007) to 0.325 mg/L (August, 2007) in Pond I while values in Pond II ranged from 0.135 (June, 2007) to 0.350 mg/L (August, 2007) (Table 2). It showed almost the same trend as followed by NH_3-N and NO_3-N.

Higher values of nitrite-nitrogen, might be mainly due to the action of certain nitrifying bacteria (*Nitrosomonas*) during the decomposition of green aquatic organisms including both phytoplankton and macrophytes. Several workers (Qadri and Yousuf, 1980; Goel *et al*., 1986; Kaushik *et al*., 1991) have reported high nitrite - nitrogen levels during warmer months. Contrary to this, Gaur, 1998 has reported lower concentrations during summer months in a lechate water body reasoning its utilization by green aquatic organisms as nitrogen source. Wetzel, 1975 has also reported lower values during summer, caused by the conversion of NO_2-N into NO_3-N, by the action of certain nitrifying bacteria (*Nitrobactor*). Higher values during monsoon months might be due to entry of surface run off water from the surrounding fields, whereas lower concentration of NO_2-N may be due to low water temperature, higher dissolved oxygen content, less deposition of organic matter and greater sedimentation rate (Kaushik and Saksena,1999).

Ammonia – Nitrogen: Goldman and Horne, 1983 suggested that ammonia - nitrogen provides a source of recycled nitrogen for speedy growth of phytoplankton and macrophytes when other forms of nitrogen are exhausted. Sufficient amount of NH_3-N is liberated during the decomposition of planktonic organisms, may be due to direct bacterial action or without the formation of soluble intermediate products (Von Brand and Rakestraw, 1940). It is also one of the excretory products of aquatic animals as well as it is also produced by the bacterial reduction of nitrate (Hutchinson, 1975). Higher levels of ammonia - nitrogen in water column have been reported to be toxic to many aquatic animals. For example, levels >1.0 mg/L NH_3-N in a stream has negative impact on the fish communities (Miltner and Ranken,1998).

Values of NH_3-N in Pond I showed minimum value (48.0 µg/L) during March, 2007 and maximum (111.0 µg/L) during July, 2007 whereas Pond II showed minimum value (43.0 µg/L) during May, 2007 and maximum (115.0 µg/L) during September, 2007 (Table 2). Generally, higher concentrations were recorded during late summer and monsoon months. It started increasing in June, 2007 (77 µg/L) that went upto 115 µg/L during September, 2007 and was found to be associated with higher rate of decomposition of dead and decayed organisms and the amount of sewage enter into these water bodies. Higher values during summer months were also reported by Seenayya,1971; Haque,1991. Lower values, during winter months, might be due to slower bacterial activity at low temperature causing inhibition of decomposition activity and so release of ammonia - nitrogen is retarded. It might also be due to direct utilization of ammonia - nitrogen by phytoplankton during the period. Paul and Verma,1999 have also reported high ammonical nitrogen during summer and low during winter in a tropical water body. They attributed it to increase and decrease in temperature during summer and winter, respectively, and to direct utilization of ammonia - nitrogen by phytoplankton as also reported by Rao and Govind 1964.

Silica: Pond I and Pond II showed minimum 0.012 mg/L (February, 2007) and 0.019 mg/L (February, 2007) and maximum 0.088 (June, 2007) and 0.085 mg/L (June, 2007) respectively (Table 2).

Table 2: Monthly variations in PO_4–P, NO_3–N, NO_2–N, NH_3–N and Silica in Pond I and Pond II.

Months	PO_4–P (mg/L)		NO_3–N (mg/L)		NO_2–N (mg/L)		NH_3–N (µg/L)		Silica (mg/L)	
	P.I.	P.II	P.I.	P.II	P.I.	P.II	P.I.	P.II	P.I.	P.II
October, 06	0.770	0.500	0.085	0.140	0.310	0.315	95.0	100.0	0.030	0.036
November	0.650	0.590	0.100	0.120	0.200	0.240	84.5	78.0	0.025	0.027
December	0.600	0.500	0.105	0.105	0.195	0.215	75.0	80.0	0.025	0.025
January, 07	0.399	0.389	0.090	0.085	0.280	0.265	66.0	67.0	0.014	0.020
February	0.685	0.450	0.100	0.090	0.270	0.275	95.0	76.0	0.012	0.019
March	0.775	0.500	0.180	0.080	0.165	0.180	48.0	58.0	0.044	0.028
April	0.797	0.710	0.190	0.075	0.180	0.195	53.0	67.0	0.037	0.036
May	0.399	0.640	1.120	0.060	0.200	0.155	64.6	43.0	0.085	0.056
June	0.550	0.845	1.135	0.070	0.130	0.135	88.0	77.0	0.088	0.085
July	0.675	0.890	0.140	0.135	0.295	0.320	111.0	96.0	0.022	0.031
August	0.691	0.701	0.120	0.145	0.325	0.350	100.5	103.0	0.042	0.036
September	0.750	0.690	0.100	0.150	0.310	0.315	107.0	115.0	0.040	0.040

Higher concentration of silicates during post-monsoon months may be due to incoming drainage and surface run off which react upon with CO_2 to produce silica as also reported by Hutchinson, 1975. Increase in Si concentrations at Pond I and Pond II during summer may be due to evaporation of water. Further higher values during summer may also be attributed to release of silica during decomposition of organic matter at higher temperature as also suggested by Khan and Siddiqui,1974; Ramanibai and Ravichandran, 1987. Silica showed negative correlation with diatoms in Pond I and Pond II (r = -0.328 & -0.079) (Fig. 9). Occurrence of low silica, during winter season and some other months of the present study, was found to be related to its continuous utilization by phytoplankton, specially diatoms and certain macrophytes present in the water body and less decomposition activity because of low water temperature and higher sedimentation rate (Ganapati, 1956; Kilham,1971; Cole, 1983; Saha, 1993).

Phytoplankton: In the present investigation, groups of planktonic algae were found in the following order of abundance – *Chlorophyceae* > *Bacillariophyceae* > *Myxophyceae* > *Euglenophyceae* > *Desmidiaceae* in Pond I and Pond II. Total phytoplankton population showed a negative correlation with water temperature in Pond I (r = - 0.147) and Pond II (r = - 0.488) . With dissolved oxygen, positive in Pond I (r = 0.169) and Pond II (r = 0.349). Phytoplankton showed negative correlation with pH in Pond II (r = - 0.041) while positive in Pond I (r = 0.281).

Myxophyceae

They are unicellular, filamentous and colonial forms and most are enclosed in mucilaginous sheath either individually or in colonies (Wetzel, 1983). Gaur, 1994 also opined that its presence and abundance indicate the eutrophic nature of the water body. This group was represented by the genera, namely *Anacystis, Agmenellum, Nostoc, Anaebena, Tetrapedia, Oscillatoria* and *Spirulina* (Plate I).

Anacystis sp.: It was found abundant among myxophycean genera during almost every month of investigation in both the ponds. The distribution was found to be polymodal in Pond I and bimodal in Pond II. It was observed that the cells were spherical and irregularly distributed through the gelatinous matrix or in a series of rows in 3 planes perpendicular to each other Edmondson,1959.

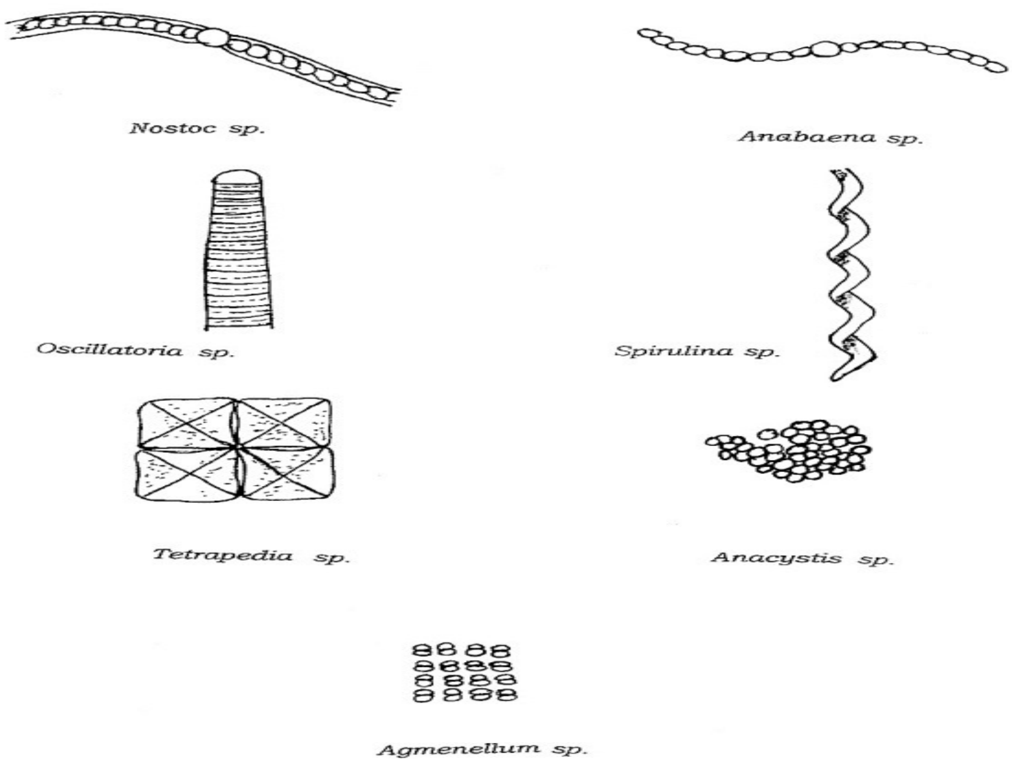


Plate 1. Myxophyceae (*Anacystis, Agmenellum, Nostoc, Anaebena, Tetrapedia, Oscillatoria* and *Spirulina).*

***Agmenellum sp.*:** Studied showed that cells were ovoid, arranged regularly in series of rows perpendicular to each other Edmondson, 1959. In Pond I also single peak was found during February, 2007 (15 No./mL). Uneven distribution was recorded in Pond I showing low density during the rest of the year. In Pond II, it was more or less uniformly distributed.

***Nostoc sp.*:** In Pond I, it was polymodal, showing three peaks of abundance during January, 2007 (22 No./mL), June, 2007 (15 No./mL) and August, 2007 (20 No./mL), whereas in Pond II, two peaks were recorded, first during October, 2006 (25 No./mL) and second in September, 2007 (20 No./mL). It was a filamentous form. Trichomes were straight and broad. Filaments were more or less straight and within a gelatinous sheath (Needham and Needham,1962).

***Anabaena sp.*:** Its filaments are aggregated without order (Needham and Needham,1962). It showed more or less uniform distribution throughout the year in all the three Ponds. Maximum concentration was noted in Pond I, where number varied from 1 – 9 No./mL during different months.

***Oscillatoria sp.*:** It was a filamentous form. Trichomes were straight and may be flexuous (Needham and Needham,1962). In Pond I, maximum numbers were recorded during October, 2006 and during September, 2007. Pond II showed abundance during October, 2006 (19 No./mL) and November, 2006 (20 No./mL). It showed polymodal distribution in Medical Pond and bimodal in Pond I and Pond II.

***Spirulina sp.*:** Studied showed its spiral nature and filaments were enclosed in a gelatinous sheath (Needham and Needham,1962). Pond I showed abundance during November, 2006 (25 No./mL), October, 2006 and July, 2007 (19 No./L). Pond II had peaks during October, 2006 (11 No./mL), March, 2007 (11No./mL) and August, 2007 (20 No./ml). Polymodal pattern of distribution was noted in all the three ponds throughout the year.

Chlorophyceae

The chlorophyceae is a large and important group of freshwater green algae. They come in wide variety of shapes and forms, including free swimming unicellular species, colonial forms, non-flagellate unicellular and filamentous forms.

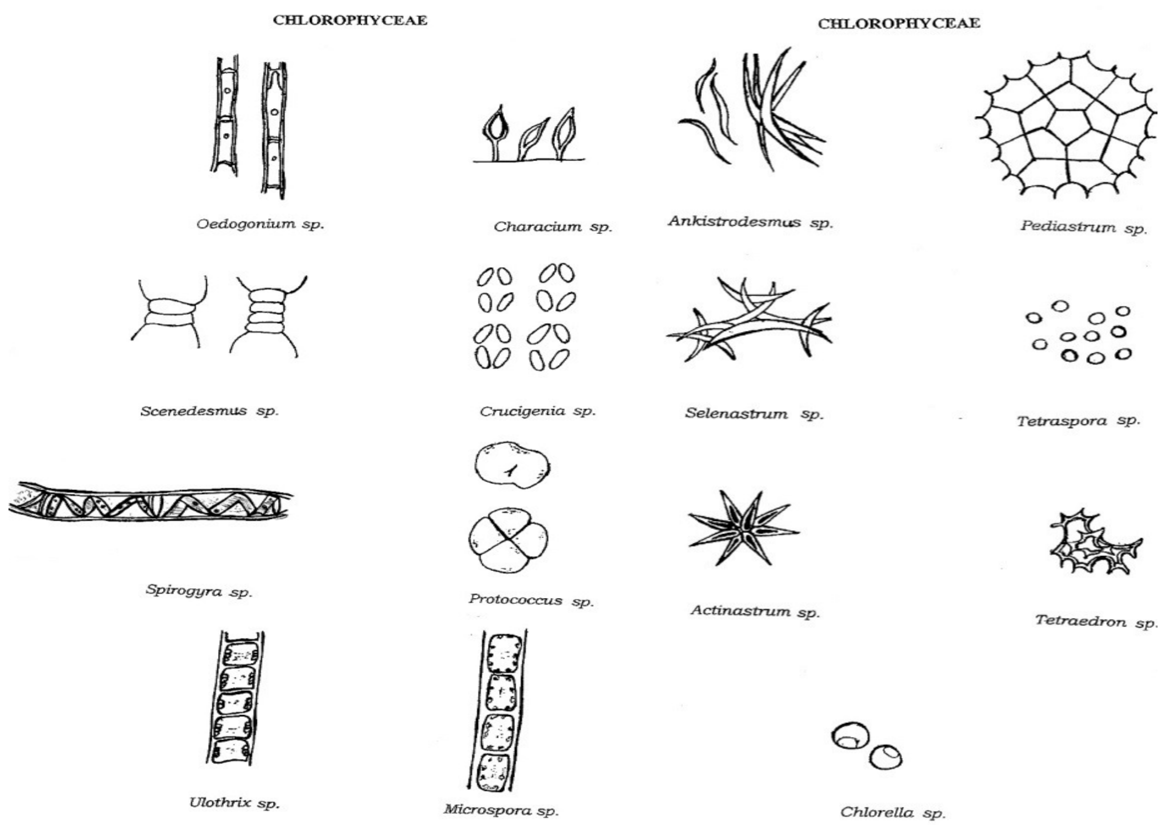


Plate II & III. *Chlorophyceae* (*Oedogonium, Characium, Scenedesmus, Crucigenia, Tetraspora, Spirogyra, Protococcus, Ulothrix, Microspora, Ankistrodesmus, Pediastrum, Actinastrum, Selenastrum, Tetraedron* and *Chlorella).*

It forms the major group of phytoplankton. It is an extremely large and morphologically diverse group of algae and found in almost all the fresh water bodies (Wetzel, 1983). Lin 1972 ; Bais *et al*. 1993 have reported that besides physico-chemical parameters the presence of myxophyceae also control the fluctuations in green algae populations. Chlorophyceae was the most dominant group constituting about 50.1 % in Medical Pond. In the present investigation, this group was represented by the genera, *Oedogonium, Characium, Scenedesmus, Crucigenia, Tetraspora, Spirogyra, Protococcus, Ulothrix, Microspora, Ankistrodesmus, Pediastrum, Actinastrum, Selenastrum, Tetraedron* and *Chlorella* (Plate II and III).

In this group, *Ankistrodesmus* was the most dominant species. Chlorophyceae population ranged from 157 (October, 2006) to 228 No. /mL (December, 2006).

Oedogonium sp.: Cells were long and filaments unbrached (Edmondson,1959). In Pond I, it was more or less uniformly distributed throughout the year showing maximum number in September, 2007 (6 No./mL). In Pond II, its density varied from 1 – 6 No./mL during different months of the study.

Characium sp.: It was found to be unicellular and solitary. Cells were differentiated into base and apex (Needham and Needham,1962). It showed uneven distribution during study period depicting maximum number during September, 2007 (40 No./mL).

Distribution was irregular showing absence and presence during different months of the study. In Pond I, it was abundant during October and December, 2006 (11 No./mL) and September, 2007 (9 No./mL). In Pond II, it was exclusively found from October, 2006 to April, 2007 and then became absent during rest of the period.

Scenedesmus sp.: Cells formed colonies, each of a single row(Needham and Needham,1962). In Pond I, maximum densities were noted during April, 2007 (10 No./mL) and August, 2007 (11 No./mL). However, it was found absent during December, 2006 and January and February, 2007 in the same pond. Pond II depicted maximum values during March, April and August, 2007 (9 No./mL).

Crucigenia sp.: Studied showed that cells were variable and united in a regular flat plate (Needham and Needham,1962). In Pond I, maximum density (21 No./mL) was recorded during March, 2007 whereas, in Pond II, maximum density (15 No./mL) was recorded during March, 2007 and June, 2007 showing bimodal pattern of distribution.

***Spirogyra sp.*:** Observation depicted that thallus was unbranched thread of similar cells. Chloroplasts consisted of spiral bands (Needham and Needham, 1962). In Pond I, it was abundant during November, 2006 (20 No./mL) and December, 2006 (23 No./mL), while in Pond II, it showed peaks during March, 2007 (25 No./mL) and May, 2007 (32 No./mL).

***Protococcus sp.*:** Study exhibited unicellular and globular nature of filaments and were found in damp places (Needham and Needham, 1962). In both the ponds, its abundance was consistent. In Pond I, peaks were seen during October, 2006 (21 No./ml), January, 2007 (22 No./ml), April, 2007 (24 No./mL) and September, 2007 (20 No./mL), whereas in Pond II, it was found regularly but in low profile.

***Ulothrix sp.*:** Its chromatophore was homogeneous zonate band, with one to several pyrenoids (Needham and Needham, 1962).Cells were shorter than wide or may be equal in dimensions (Edmondson,[7]). In both the Ponds, its distribution was regular showing presence in all the months of investigations.

***Microspora sp.*:** Observation depicted that chromatophores were granular, covering more or less completely the whole cell wall (Needham and Needham, 1962). In Pond I, two peaks of abundance were found, first during January, 2007 (8 No./mL) and second during July, 2007 (15 No./mL), whereas in Pond II, its abundance was recorded throughout the period of investigation, also showing maximum densities as compared to other Pond.

***Ankistrodesmus sp.*:** It was solitary and loosely grouped in irregular bundles (Needham and Needham,1962). In Pond I, it was abundant during October, 2006 (38 No./mL), November, 2006 (35 No./mL), December, 2006 (37 No./mL), May, 2007 (32 No./mL) and September, 2007 (35 No./mL), whereas in Pond II, it showed less densities, but regular in distribution throughout the period of investigation.

***Pediastrum sp.*:** Cells were in a flat plate and colonial in nature (Needham and Needham, 1962). In Pond I, it was rich during December, 2006 and January, 2007 showing 25 No./mL and 23 No./mL respectively, whereas in Pond II, it was rich during October, 2006 and November, 2006 and March and June, 2007 showing consistent distribution.

***Actinastrum sp.*:** Studies showed that cells were united centrally at points of mutual contact (Edmondson 1959). In Pond I, two peaks of maxima were noted during May, 2007 (10 No./ml) and second in August, 2007 (13 No./mL) whereas in Pond II only one peak of abundance was found during December, 2006 (24 No./mL). Polymodal pattern was found in Medical Pond, bimodal in Pond I and unimodal in Pond II.

***Selenastrum sp.*:** Cells were lunate and arranged back to back. It was colonial in nature (Needham and Needham, 1962). In Pond I, it was consistently abundant throughout the period of investigation showing densities during most of the months, whereas it was found totally absent in Pond II.

***Tetraedron sp.*:** It was tetrahedral to variously lobed and irregular (Edmondson, 1959). It was found totally absent in Pond I, whereas in Pond II it was scarcely distributed and showed low densities.

***Chlorella sp.*:** Studies showed that it was tetrahedral to variously lobed and irregular (Edmondson, 1959). In Pond I, it was found absent in all the samples collected during the whole period of investigation. In Pond II, maximum values were noted as 6 No./mL (December, 2006) and 7 No./mL (January, 2007). They are either unicellular or colonial forms (Wetzel, 1983). Most species are sessile and associated with littoral substrate. Diatoms contribute about 20-25% of the net primary productivity on the earth which is 1.4×10^{14} kg dry weight (Werner 1977).

Bacillariophyceae

In present investigation, this group was represented by the genera, namely *Cyclotella, Amphora, Diatoma, Navicula, Nitzschia, Synedra, Fragillaria, Gyrosigma, Gomphonema, Melosira, Stephanodiscus* and *Frustulia* (Plate IV and V).

***Cyclotella sp.*:** Cells were single, girdle side not sculptured and without spine (Needham and Needham, 1962). In Pond I, maximum density was recorded during during November, 2006 (6 No./mL), whereas in Pond II, it was more or less uniform in distribution throughout the year, but showed higher densities as compared to other ponds.

***Amphora sp.*:** Its valves were convex (Needham and Needham, 1962). In Pond I, it was found absent throughout the period of investigation, whereas in Pond II it was abundant during January and February, 2007 and absent during June, July and August, 2007.

***Diatoma sp.*:** Observation depicted that **v**alves were with transverse ribs (Needham and Needham, 1962). In Pond I, maximum values were recorded during February, May, June and July 2007, whereas in Pond II, its distribution was regular and almost uniform throughout the period of investigation.

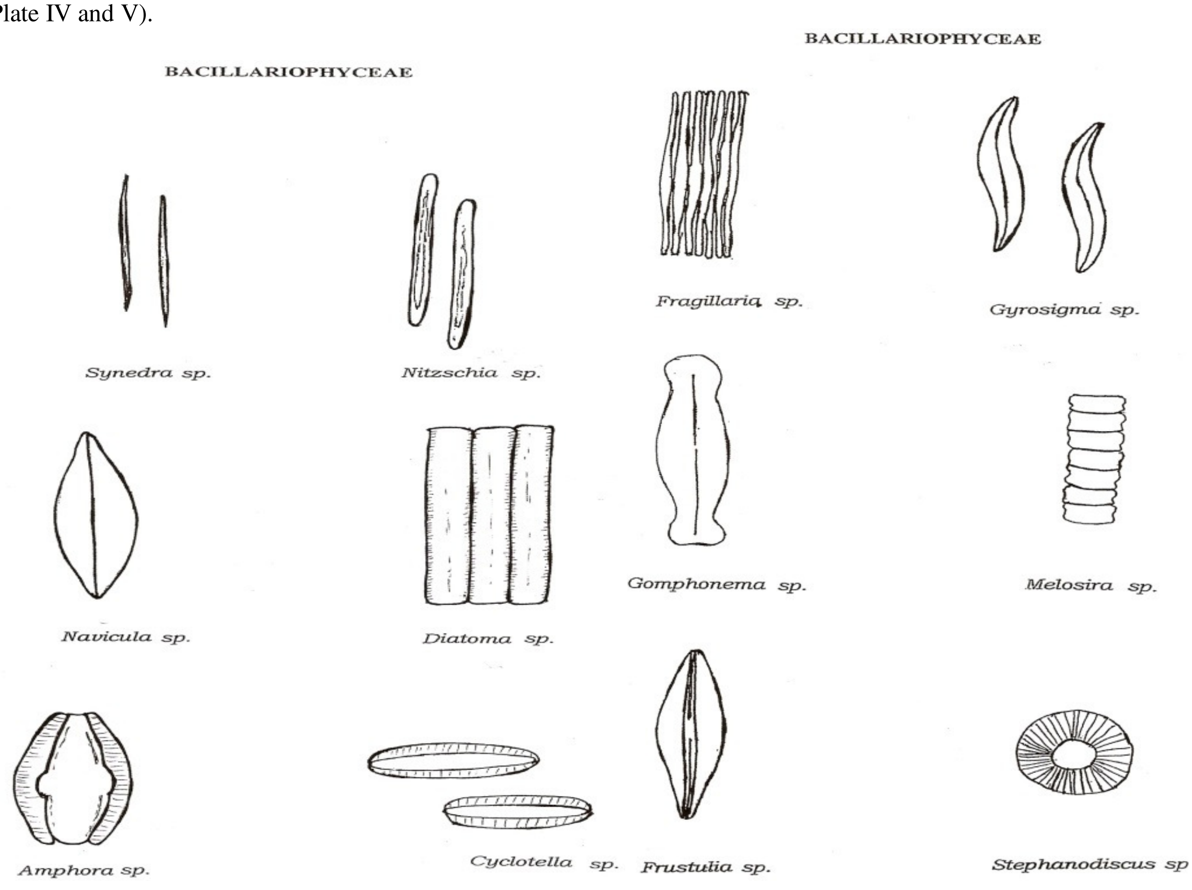


Plate IV and V. Bacillariophyceae (*Cyclotella, Amphora, Diatoma, Navicula, Nitzschia, Synedra, Fragillaria, Gyrosigma, Gomphonema, Melosira, Stephanodiscus* and *Frustulia).*

***Navicula sp.*:** Cells were straight in girdle view (Needham and Needham,1962). In Pond I, it was found uniformly distributed showing maximum densities during November, 2006 (7 No./mL), February, March (7 No./mL), May (8 No. /mL), June (9 No./ml), July, August, 2007 (7 No./mL) and September, 2007 (9 No./mL), whereas in Pond II, it was found regularly in all the samples, but in low profile.

***Nitzshcia sp*.:** Its axis was lateral, less often median and punctate (Needham and Needham, 1962). In Pond I, its occurrence was consistent with higher densities. Pond II too showed similar type of distribution with respect to occurrence and densities.

***Synedra sp.*:** Cells were single or forming fan like clusters (Needham and Needham, 1962). In Pond I, it was more or less uniformly distributed with higher densities during November and December, 2006 (21 No./mL) and May (26 No./mL), July (21 No./mL) and September, 2007 (18 No./mL). It was found absent throughout the period of investigation in Pond II.

***Gyrosigma sp.*:** Raphe strongly sigmoid (Needham and Needham, 1962). In Pond I, it was more or less uniform in distribution during the study period, whereas in Pond II, it showed maximum density (15 No./mL) during February, 2007. It was also abundant during March (11 No./mL), April, May (10 No./mL) and July, 2007 (10 No./mL) in Pond II.

***Gomphonema sp.*:** It's valves were found to be longitudinally symmetrical and cells were straight in girdle view (Needham and Needham, 1962). In Pond I, it was more or less uniformly distributed throughout the year, ranging from 1 No./mL (February, May & June, 2007) to 7 No./mL (September, 2007), whereas in Pond II the maximum density was 5 No./ml during November, 2006 and September, 2007, being more or less uniform in density during the rest of the year. It was also found absent during December, May and June, 2007

***Melosira sp.*:** Cells formed filament. Its girdle was sculptured and valve uniformly marked (Needham and Needham, 1962). In Pond I, four peaks of maxima were noted during November, 2006 (13 No./mL), February and March, 2007 (20 No./mL), May, 2007 (25 No./mL) and September, 2007 (13 No./mL), whereas in Pond II, three peaks of maxima were found, first during November, 2006 (14 No./mL) second in April, 2007 (25 No./mL) and third in September, 2007 (15 No./mL). It was also found in higher quantities during February, March, May and June, 2007.

***Stephanodiscus sp.*:** Cells were single and girdle side not sculptured, with circle of cilia (Needham and Needham,1962). In Pond I, it was found abundant during February, 2007 (16 No./mL), April, 2007 (9 No./mL) and May, 2007 (11 No./mL), whereas in Pond II, higher densities were found during October, 2006 (11 No./mL), March, 2007 (15 No./mL) and September, 2007 (11 No./mL).

***Frustulia sp.*:** Cells were straight in girdle view (Needham and Needham, 1962). In Pond I, higher densities were noted during February and March, 2007 (11 No./mL) and September, 2007 (12 No./mL) and absent during July and August, 2007. In Pond II, it showed higher densities during November, 2006 (12 No./mL) and December, 2006 (13 No./mL) and February, 2007 (11 No./mL), and found absent during May, June and July, 2007. Absence in both the ponds during monsoon months was mainly due to unfavorable and disturbed conditions during these months.

Euglenophyceae

Although euglenophyceae is a relatively large and diverse group, few species are truly planktonic (Wetzel, 1983). Almost all euglenoids are unicellular, lack a distinct cell wall and possess one, two or even three flagella that arise from an invagination in the cell membrane. They are rich in shallow water bodies which are having rich organic matter (Wetzel, 1983). In the present study, euglenoids were represented by only two genera, namely *Euglena sp.* and *Phacus sp.* (Plate VI).

***Euglena sp.*:** It formed green scum on water and showed pigmented eye spot (Edmondson, 1959). In Pond I, it was present during most of the months, showing variations from 5 – 15 No./mL during different months of investigation. In Pond II, higher densities were recorded during December, 2006 (15 No./mL), January, 2007 (17 No./mL), February, 2007 (16 No./mL), March, 2007 (16 No./mL) and July, 2007 (15 No./mL) showing almost uniform distribution (Plate VI).

***Phacus sp.*:** Body was flattened and often ridged (Edmondson, 1959). In Pond I, it had two peaks, first during March, 2007 (12 No./mL) and June, 2007 (14 No./mL). In Pond II, higher densities were found during January to March, 2007. One peak of abundance was also recorded during August and September, 2007 (16 & 17 No./mL) (Plate VI).

Desmidiaceae

According to Lefevere *et al*., 1952 blue - green algae have antagonistic effect on the distribution of desmids. The waters, possessing desmids as dominant phytoplankton, are chemically distinct from those which are rich in diatoms and blue-green algae (Welch,1952; Goldman and Horne,1983. This group is second last in population abundance. Hutchinson, 1975; Goldman and Horne, 1983 have reported that waters possessing desmids as a dominant group were in chemical sense distinct from those which are rich in diatoms and blue-green algae.

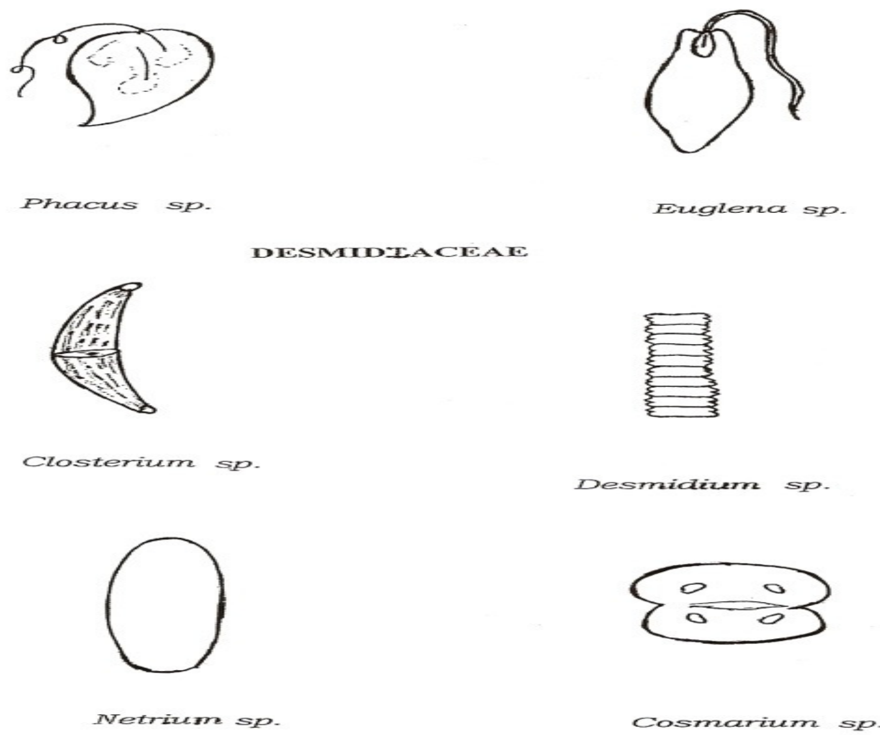


Plate VI. Euglenophyceae and Desmidiaceae (*Euglena sp.* and *Phacus sp. Closterium sp., Cosmarium sp., Desmidium sp.* and *Netrium sp.).*

In the present investigation, this group was represented by the genera, namely *Closterium sp., Cosmarium sp., Desmidium sp.* and *Netrium sp.* (Plate VI).

***Closterium sp.*:** Studied exhibited cells with constriction and are strongly attenuated towards each extremity (Needham and Needham,1962). In Pond I, two peaks were found, first during April, 2007 (15 No./ml) and second during October, 2006 (19 No./mL) (Table 8 b), whereas in Pond II, it was abundant during October, 2006 (17 No./mL), November, 2006 (19 No./mL), December, 2006 (18 No./mL), January, 2007 (17 No./mL), June, 2007 (20 No./mL), July 2007 (21 No./mL) and August, 2007 (24 No./mL) (Table 8 c) The distribution was almost regular in both the Ponds (Plate VI).

***Cosmarium sp.*:** Cells were often furnished with warts or spines (Needham and Needham,1962). In Pond I, it was found to vary from 3 (June and July, 2007) to 7 No./mL (January and February, 2007). In this pond, it was also found absent during August and September, 2007. In Pond II, it was sparsely distributed, showing maximum density during January, 2007 (9 No./mL) and absence during April – July, 2007 (Plate VI).

***Desmidium sp.*:** Cells were short. They might be circular with produced angles (Needham and Needham,1962). It showed lower densities in Pond I as compared to Medical Pond and Pond II, showing maximum densities during October, 2006 and July, 2007. In Pond II, it varied between 2 No./mL (September, 2007) to 6 No./mL (June, 2007) showing absence during July and August, 2007 (Plate VI).

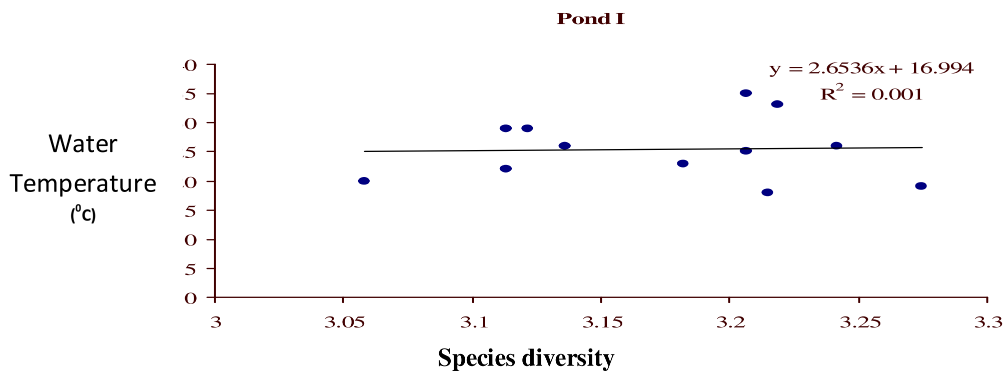
***Netrium sp.*:** Cells were cylindrical (Needham and Needham, 1962). In Pond I, it was sparsely distributed showing low profile during June to September, 2007 (2 No./mL) and absence during most of the months, whereas in Pond II, the distribution was irregular with low densities (Plate VI).

Diversity

Diversity is a concept that refers to the range of variations or differences among some set of entities. Biological diversity thus refers to the variety within the living world. Perhaps, because the living world is most widely considered in terms of species, biodiversity is very commonly used as a synonym of species diversity in particular of species richness. Sukumaran and Das, 2001 made an investigation on phytoplankton distribution and abundance in some selected freshwater reservoirs viz. Hemvathy Kabini V.V. Sagar, Bhadra etc. in Karnataka and reported the presence of algal groups, Myxophyceae, Chlorophyceae, Bacillariophyceae and Desmidiaceae.

Nandan and Aher, 2005 studied the algal community of Haranbaree dam and Mosam river of Maharashtra. Srivastava, studied the plankton status of Ravishankar Sagar reservoir in Chhattisgarh and reported that the phytoplankton was chiefly represented by Myxophyceae, Chlorophyceae, Bacillariophyceae and Desmidiaceae. Species diversity is one of the basic concepts of ecology that has been used to characterise communities and ecosystems: At first glance the concept appears to be rather simple but ecologists and mathematicians have been searching for ways to express the various aspects of diversity since 1922(Cole,1983). Species diversity increases as the number of species per sample increases and as the abundances of species within a sample become more even (Pielou, 1975).

Species diversity increases as the number of species per sample increases and as the abundances of species within a sample become more even (Pielou, 1975; Kricher, 1972). Same relationship was also observed in our study as species diversity showed positive and significant correlation with evenness in Pond I (r = 0.712) and Pond II (r = 0.640) in case of phytoplankton (Fig. 8). Correlation between Species Diversity and physico – chemical parameters were also determined. In case of phytoplankton, species diversity showed negative correlation with water temperature in Pond II (r = - 0.757) whereas positive in Pond I (r = 0.031) Fig.1.



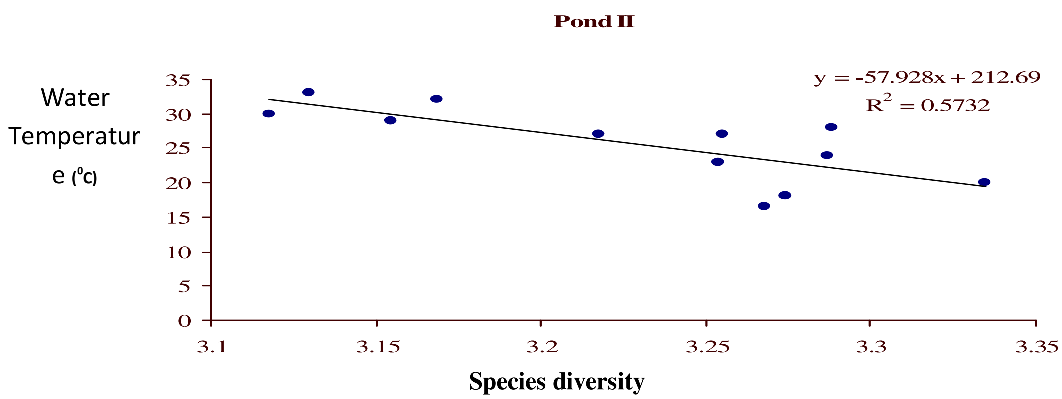


Fig. 1. Regression lines showing correlation between Phytoplankton Species Diversity and Water Temperature in Pond I and Pond II.

With pH, correlation was positive in Pond II (r = 0.385) whereas negative in Pond I (r = - 0.026) Fig. 2, whereas with PO_4-P, positive correlation was found in Pond I (r = 0.178) and negative in Pond II (r = - 0.732) Fig. 3. With NO_3-N, correlation was positive in both the ponds (Pond I: r = 0.004 & Pond II: r = 0.064) Fig. 4 and with NO_2-N, positive correlation was found in Pond II (r = 0.120) and negative in Pond I (r = - 0.053) Fig. 5. With NH_3-N, it was negative in Pond I (r = - 0.109) and positive in Pond II (r = 0.092) Fig. 6, while with dissolved oxygen it showed it showed positive correlation in both the ponds (Fig. 7). Species diversity of Phytoplankton in Pond I and Pond II is depicted in Fig. A.

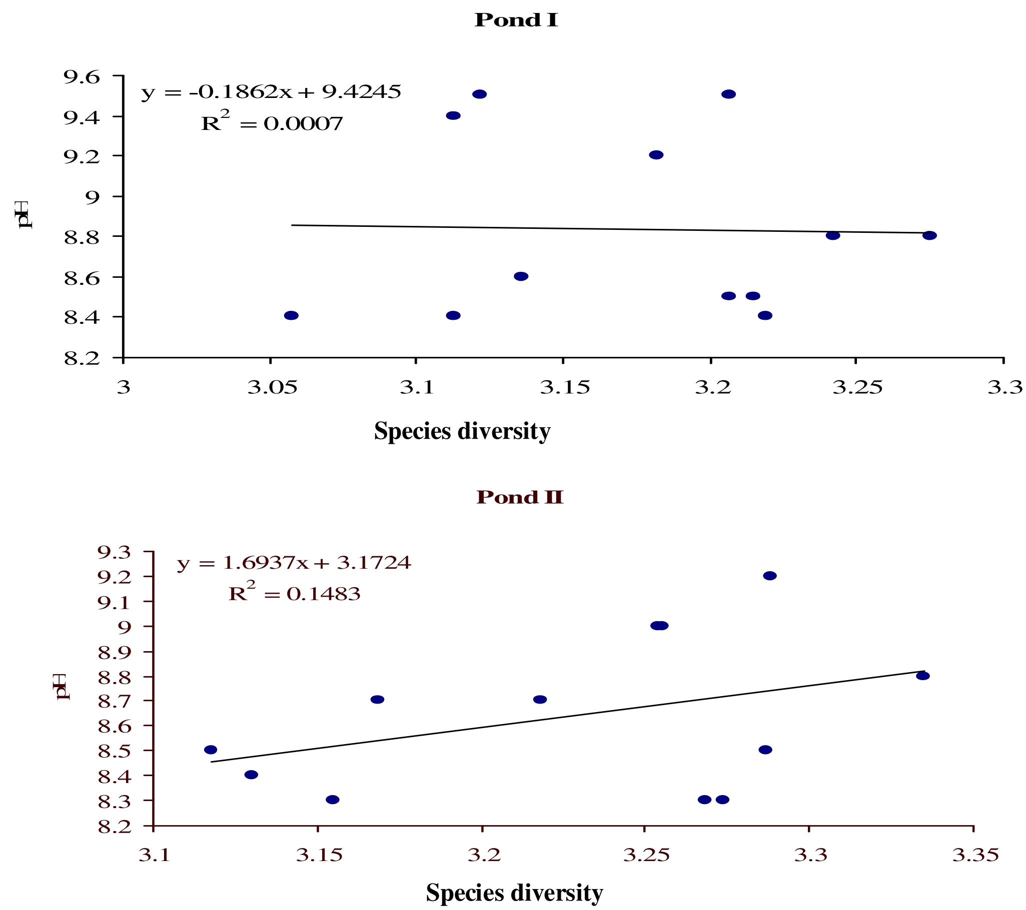
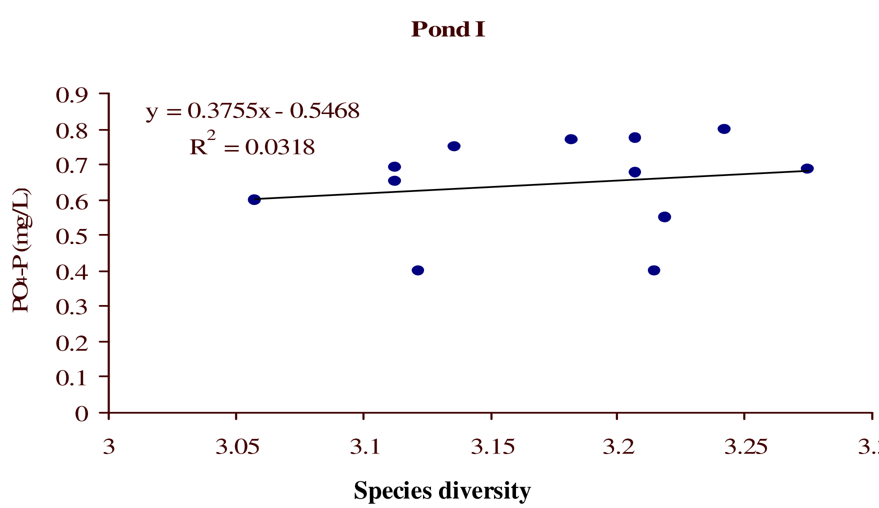


Fig. 2. Regression lines showing correlation between Phytoplankton Species Diversity and Water pH in Pond I and Pond II.



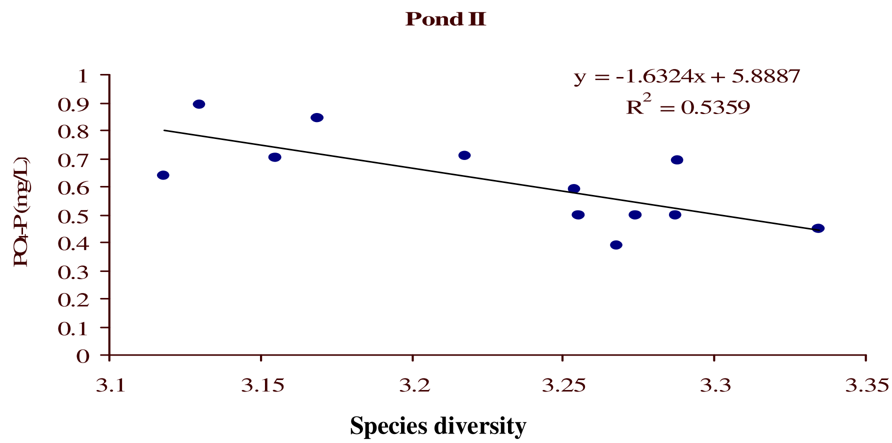


Fig. 3. Regression lines showing correlation between Phytoplankton Species Diversity and PO_4-P (mg/L) in Pond I and Pond II.

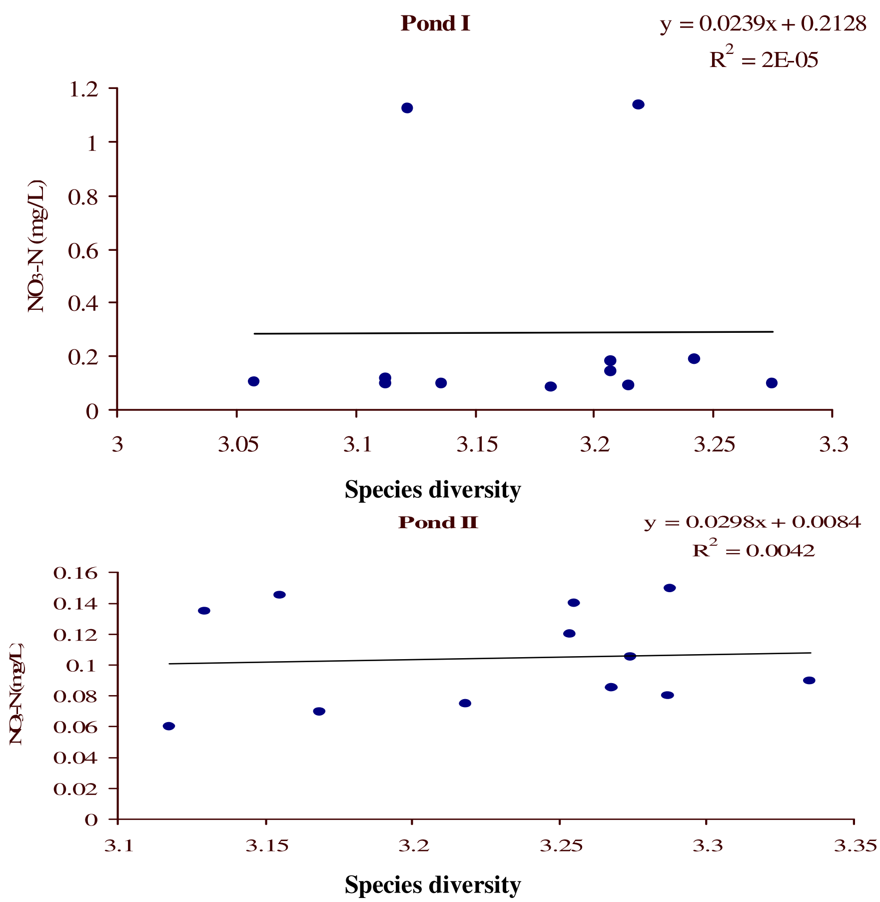
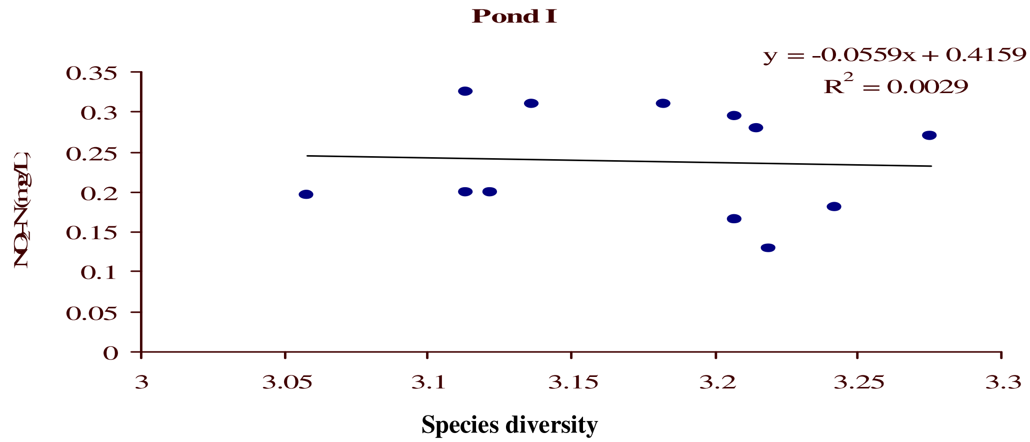


Fig. 4. Regression lines showing correlation between Phytoplankton Species Diversity and NO_3–N (mg/L) in Pond I and Pond II.



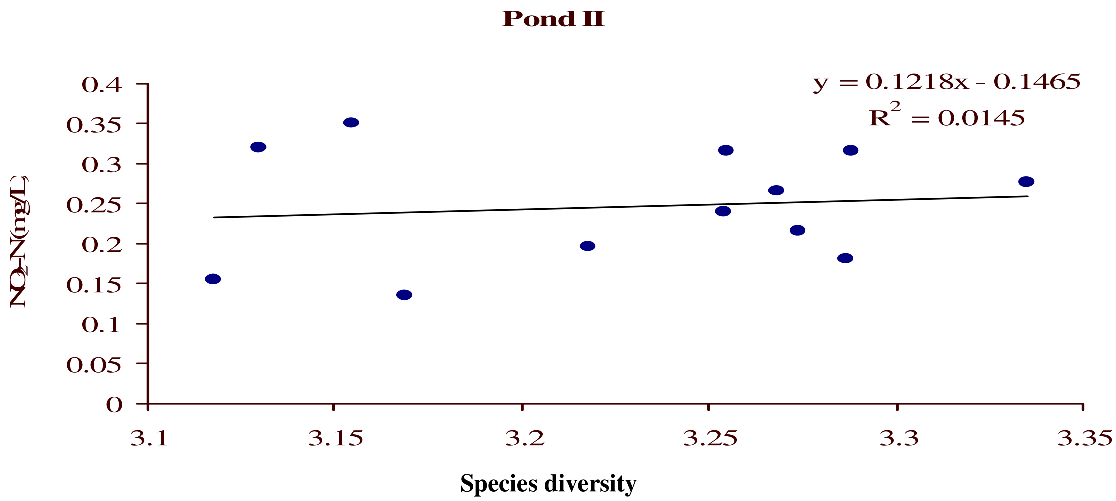
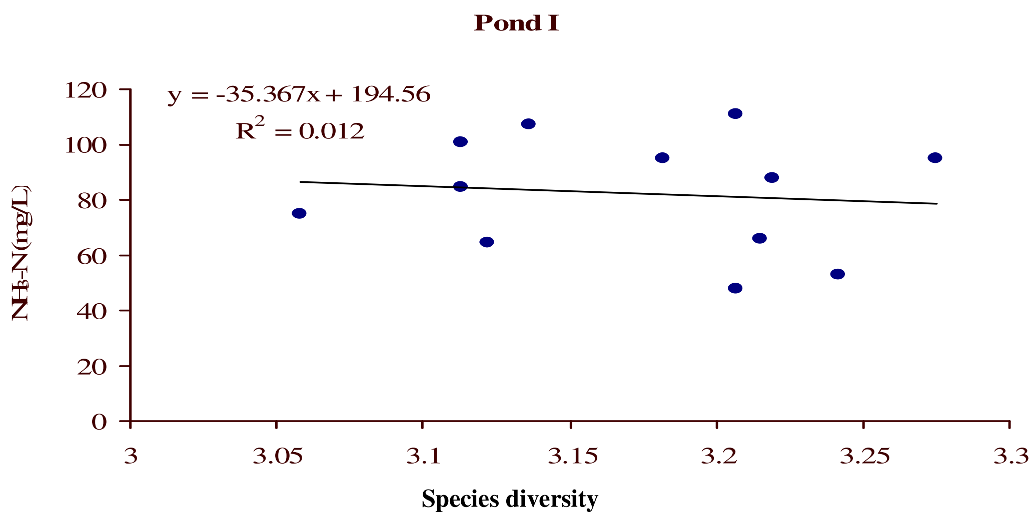


Fig. 5. Regression lines showing correlation between Phytoplankton Species Diversity and NO_2 –N (mg/L) in Pond I and Pond II.



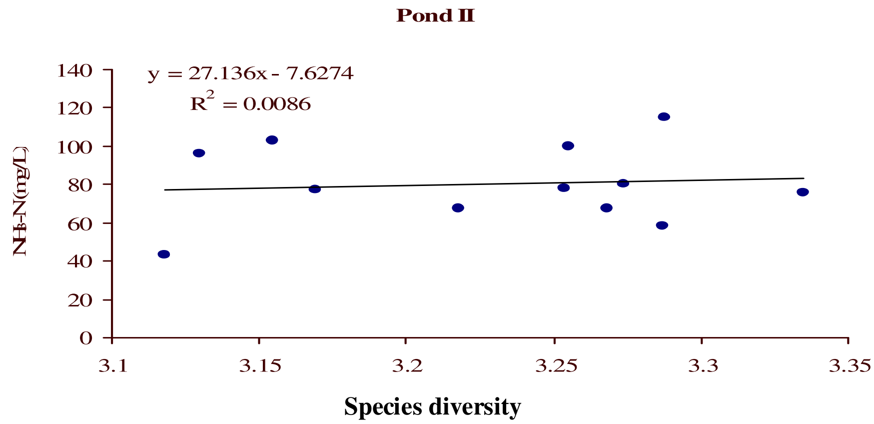


Fig. 6. Regression lines showing correlation between Phytoplankton Species Diversity and NH_3 –N (μg/L) in Medical Pond, Pond I and Pond II.

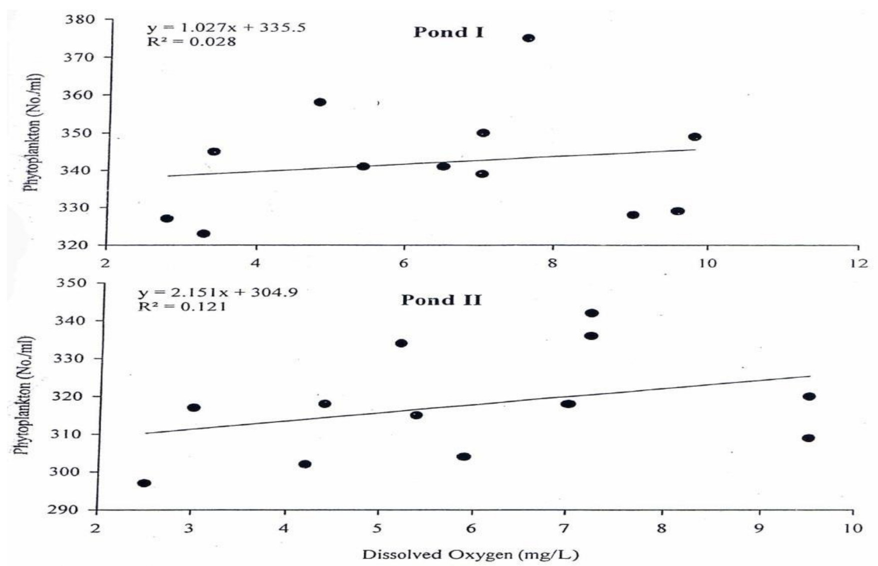
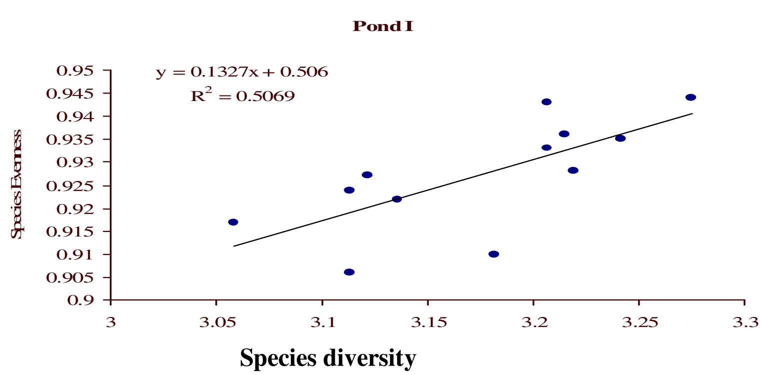


Fig. 7. Regression lines showing correlation between Phytoplankton (No./ml) and Dissolved Oyxgen of in Pond I and Pond II.



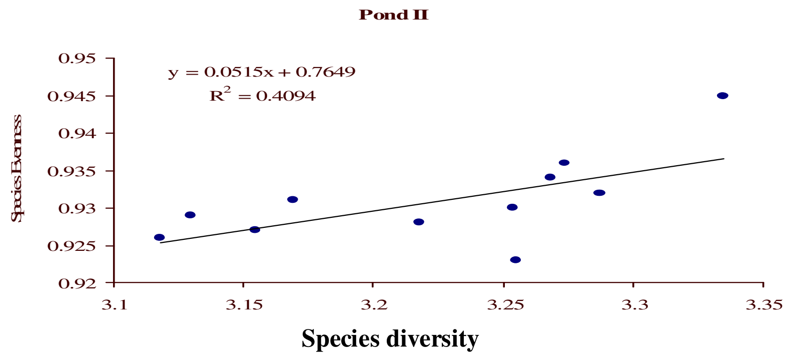


Fig. 8. Regression lines showing correlation between Species Diversity and Species Evenness of Phytoplankton (No./ml) in Pond I and Pond II.

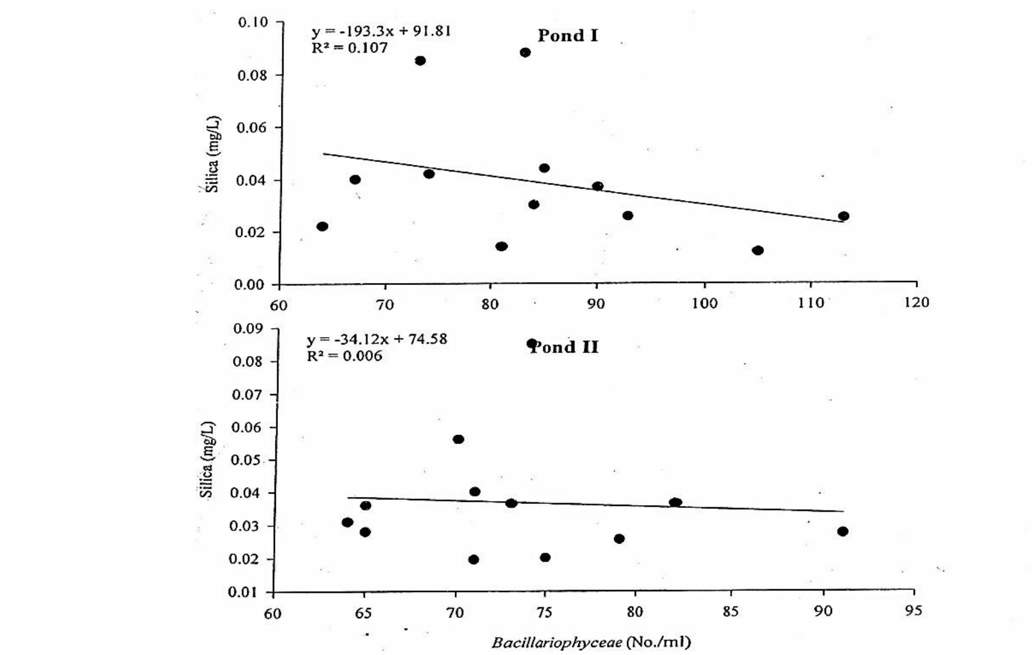


Fig. 9. Regression lines showing correlation between Bacillariophyceae (No/mL) and Silica in Pond I and Pond II.

Phytoplankton

Species diversity ranged from 3.058 (December, 2006) to 3.275 (February, 2007) in Pond I and 3.118 (May, 2007) to 3.335 (February, 2007) in Pond II. In Pond I, higher values were found during October, 2006 (3.182), February, 2007 (3.275), April, 2007 (3.242) and June, 2007 (3.219) and lower during December, 2007 (3.058). In Pond II, first maxima was recorded in December, 2006 (3.274) and second (3.335) during February, 2007. It then declined to a minimum during May, 2007 (3.118) and again increased during June, 2007 (3.169). One more higher value of species diversity was found during September, 2007 (3.288). Monthly variations are given in Table 3.

Species Evenness ranged from 0.906 (November, 2006) to 0.944 (February, 2007) in Pond I and 0.926 (May, 2007) to 0.945 (February, 2007) in Pond II. In Pond I, higher values of species evenness were found during February, 2007 (0.944), then declined and again increased during July, 2007 (0.933). Lowest value was found during November, 2006 (0.906).

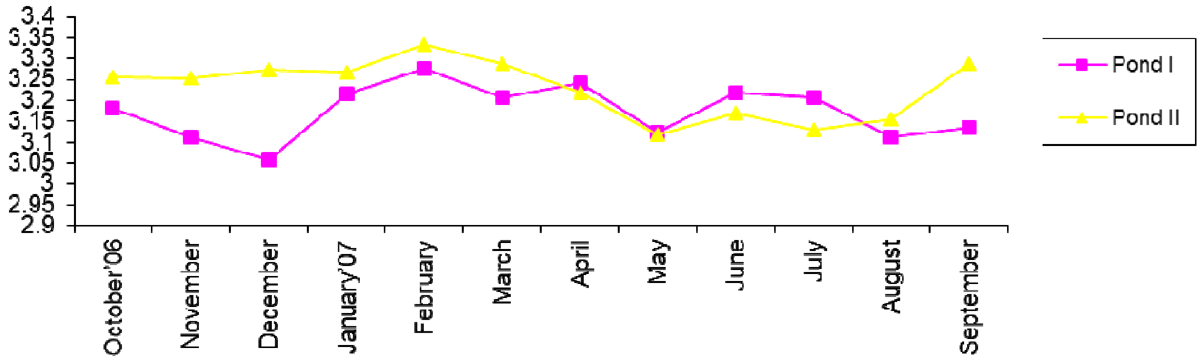


Fig. A. Monthly variations in Species Diversity of Phytoplankton in Pond I and Pond II.

Table 3: Monthly Variations in Species Diversity and Species Evenness of Phytoplankton in Pond I and Pond II.

Months	Species Diversity		Species Evenness	
	Pond I	Pond II	Pond I	Pond II
October'06	3.182	3.255	0.910	0.923
November	3.113	3.254	0.906	0.930
December	3.058	3.274	0.917	0.936
January'07	3.215	3.268	0.936	0.934
February	3.275	3.335	0.944	0.945
March	3.207	3.287	0.943	0.932
April	3.242	3.218	0.935	0.928
May	3.122	3.118	0.927	0.926
June	3.219	3.169	0.928	0.931
July	3.207	3.130	0.933	0.929
August	3.113	3.155	0.924	0.927
September	3.136	3.288	0.922	0.932

In Pond II, first maxima was found during February, 2007 (0.945), declining to a minimum of 0.926 during May, 2007 and then recorded another peak during June, 2007 (0.931) and September, 2007 (0.932). Monthly variations are given in Table 3.

CONCLUSION

In the present study it was noted that no single environmental factor was responsible for the production of phytoplankton organisms but a number of factors acted together to bring the cumulative effect. Most of the phytoplankton were found to flourish at mesophytic environment. Growth of phytoplankton was directly or indirectly dependent upon the concentration of nutrients in both the ponds as evident by the study. In pond I, as the water temperature increased so the diversity of phytoplankton also increased whereas the diversity was observed to be decreasing in Pond II with water temperature. As the pH increased so does the phytoplankton diversity that is the positive correlation in Pond II while negative in Pond I. With PO_4-P positive correlation was found in Pond I while negative in Pond II. With NO_3-N correlation was found to be negative in in both the Ponds which indicates that as the concentration of NO_3-N increased the it is utilized by phytoplankton for their growth. NO_2-Ncorrelation was positive in Pond II which might be due to its conversion into NO_3-N, while it is negative for Pond I. Occurrence of low silica, during winter season and some other months in the present study, was found to be related to its continuous utilization by phytoplankton, specially diatoms and certain macrophytes present in the water body so as a result Silica showed negative correlation with diatoms in Pond I and Pond II (r = -0.328 & -0.079).

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