The Bioscan 5(3) : 377-382, 2010
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES

ALGAL DIVERSITY AND PHYSICO-CHEMICAL PARAMETERS IN HADHINARU LAKE, MYSORE, KARNATAKA STATE, INDIA

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KEY WORDS
Hadhinaru lake
Plankton
Correlation, Diversity
Similarity
Chlorococcales
Desmids
Euglenaceae

Received on : 07.04.2010
Accepted on : 21.07.2010

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ABSTRACT
Phytoplankton diversity in Hadhinaru lake of Mysore has been discussed. Five diversity indices have been derived using the PASTA software programme. They include, Shannon and Wiener index, Berger and Parker dominance index, Bellan and Santini index, Simpson index and Pielous evenness index. A total of 29 algal species were recorded during December 2008 to November 2009.Chlorococcales was recorded in higher numbers, while Cyanophyceae and Desmidaceae were low in number. The evenness and dominance of species in the lake was not well marked. The lake becomes heavily polluted during March, May, October and November. The Bray and Curtis Similarity index reveals that *Euglena oxyuris, Cymbella cymbelliformis, Pinnularia gibba, Actinastrum hantzschii, Tetradron lobatum, Euglena elastica and Lepocinclis ovum* have the highest similarity and can co-exist in a common cluster. Diversity indices serve as an important tool in understanding the distribution of phytoplankton in lakes.

INTRODUCTION

Along with the pressures from direct consumption and use of water by humans, freshwater face many stress related factors which enhance degrading process in the form of pollution from point and non point sources. These factors increase in spatial scale by cumulative impacts and enhanced anthropogenic activities in the water body. Along with these pressures it is not only difficult to protect and maintain the diverse biota of fresh water but also to conserve the water resources of lakes. Regular environmental monitoring allows detection, assessment and management of the negative effects on fresh water ecosystems (Karthick, 2010). Fresh water ecosystems vary in size and composition and contain a wide range of organisms, which interact with each other and with the environment. The dynamic and heterogeneous relationship gains varied physical, chemical and biological elements in the aquatic ecosystem, which can be recorded by regular monitoring to maintain the integrity and conserve the ecosystem (Ramachandran *et al*., 2002). Biological monitoring, especially species richness will allow detection of disturbances that might otherwise be missed (Eckhout *et al*., 1996). Bioindicators can be evaluated through their presence or absence, reproductive success, community structure and function (trophic state) (Hellawell, 1986, Landres *et al*., 1998). Biological indicators are sensitive to nutrient concentration changes (Pan *et al.,* 1996) and robust statistical and multi unit procedures can be used to analyze assemblages of data (Dixit *et al*., 1992). In an era of human impact on natural ecosystem a major challenge for ecosystems is to understand the structure and dynamics of biological communities in relation to environmental variability (Gaston and Blackburn 2000). Community diversity and the population abundance of species are controlled by immediate environment (Ricklefs, 1987; Kotliar and Wiens, 1990; Levins, 1992 and Wiens *et al*.1993).

During an extensive survey of lakes of Mysore, great fluctuation in water quality variables and the distribution of algae were recorded. In Hadhinaru lake 23 physico-chemical and 4 algal groups were analyzed. In order to trace relationship between the variables the data was subjected to statistical analysis. Water quality programmes involved in traditional physico-chemical measurements for assessing nutrients are an important guide for monitoring environmental changes. This paper explores the insights for bio assessment and ecological studies, focusing on the physical, chemical and algal communities in Hadhinaru lake at Mysore.

MATERIALS AND METHODS

The study area, Hadhinaru lake is located at 12°2' north latitude and 76°4' east longitude at an altitude of 753 meters above MSL and is situated 16 kms away from Mysore city. It has an independent catchment area of 9.57 sq.km with water spread over 10.10 hectares having a live capacity of 54.43 mcft. The maximum depth of the lake when full is five meters. Water samples from the study site were collected from December 2008 to November 2009 once in a month between 9 am and 10am. Water quality variables pH, water temperature (ºC), conductivity (µm), turbidity (NTU) were recorded on the spot by using EXTECH COMBO electrode and anion selective electrode. Other water quality parameters like DO, BOD, total hardness, calcium, magnesium, carbonate, bicarbonate, total phosphorous, sulphate, nitrite, nitrate, sodium, potassium, chloride (ppm) were analyzed in the laboratory as per the standard methods for the examination of water APHA, (1998) Chlorophyll a, chlorophyll b and total chlorophyll were determined as per the method described by the Trivedy and Goel (1984).

Water samples for plankton analysis were collected for a period of one year. Such samples were sedimented (Welch, 1948); Hosmani and Bharathi, 1980) preserved and the plankton identified using standard monographs of Desikachary (1959), Desikachary (1986-1989), Philipose (1967), Prescott (1982), Scott and Prescostt (1961). Plankton count was done by Lackey's drop method (1938) modified by Suxena (1987). The algae were expressed as organisms per mL and for the purpose of calculating diversity indices the data for planktonic count was subjected to PAST program (Hammer *et. al.*, 2001) Shannon and Weiner (1949) index (H) assumes that all species are represented and sample randomized = ″pi inspi; pi proportion of the i[th] species and 'in' is natural log; Dominance index (Bellan-Santini, 1969) = I-J; J = H/Hmax = H/log_2S.'J' is evenness of relative diversity (H/H max), where absolute evenness = 1.

Simpson's index (D) (1949), DS = ″(ni(ni^{-1}PN(n-1) where Ds is bias corrected from Simpson's index, ni is the number of individuals of species I, N is total number of species in community which all explain that as diversity increases index values get smaller. Pielou's evenness index (1975) is expressed as J = H / log_2S. The plankton data was also subjected to Bray and Curtis (1957) distance similarity index to determine co-existence of different species in the lake. The data of the physico-chemical and biological analysis was subjected to Pearson's correlation matrix to obtain clusters of parameters.

RESULTS AND DISCUSSION

The results of the pysico-chemical analysis of Hadhinaru lake are presented in Table 1. The values do not present a periodic variation but show an uneven distribution pattern. pH values were high during December and July while electrical conductivity reached its maximum during May. Turbidity of the water ought to have been high during June, because of rain fall and the water being agitated; never the less it was least during this month. Variation in dissolved oxygen content was high and fluctuated between 4.8 and 10.13 ppm while BOD values reached a maximum of 6ppm during November. During the month of November total hardness, calcium and magnesium varied to a little extent. Bicarbonates were in excess during most months of collection and reached values as high as 300ppm with the highest recorded values during (516ppm) July. Total phosphorous, an important factor was nil, so also nitrate, nitrite and ammonia content of the water. Sodium and potassium values were well balanced but with low values and the distribution of the chloride in Hadhinaru

Table 1: Physico-chemical and bilogical characteristic in Hadhinaru Lake

Parameters	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
pH	9	8	8	8	7.5	8	8	9	8	7	7	7
Temperature (ºC)	24	26	26	30	33	33	34	31	28	28	32	26
Conductivity (µh)	256	260	74.4	770	860	1006	920	1002	640	600	560	590
Turbidity (NTU)	0.88	1.26	3.64	4.2	11.2	10.6	4	10.4	1.52	Nil	2	1.8
DO (ppm)	8.24	7.4	5.79	3.79	8.9	5	6.2	7.18	7.32	10.13	7.47	4.8
BOD (ppm)	5.6	4.8	3.7	5.2	2.1	2.3	2.6	3.8	4	1.5	3.8	6.2
Total hardness (ppm)	200	208	202.5	206.4	190	218.4	190	172	165.3	137.4	214	148
Calcium (ppm)	36	22.9	13.82	10.7	32	15.6	17.63	12.02	32.7	25.8	32	38.4
Magnesium (ppm)	26	36.6	40.82	43.6	26.7	43.5	35.4	34.5	20.2	17.7	32.5	9.2
Carbonate (ppm)	24	56	78	82.4	130	68.6	99.4	117	100	70	40	20
Bicarbonate (ppm)	228	420	582.4	535.6	560	514.5	614.2	596	500	380	220	60
Total phosphorus (ppm)	Nil	8	Nil	3	Nil	6.4	4	Nil	8	Nil	0.85	Nil
Sulphate (ppm)	160	120	160	200	36.5	70	280	240	80	22.1	100	480
Nitrite (ppm)	1	0.07	Nil	Nil	Nil	Nil	Nil	Nil	Nil	4	Nil	Nil
Nitrate (ppm)	0.5	1	17.2	Nil	Nil	Nil	Nil	1	0.6	0.5	0.1	0.6
Sodium (ppm)	23	26	34	35	57	84.2	104	80	38.5	35.1	40	37.5
Potassium (ppm)	0.6	1.2	1.8	3	5	4	14	15	4	2	3	2
Chloride (ppm)	99.38	72.6	95.6	102.5	56.9	45.8	106.8	103.2	81.6	113.9	85.4	55.18
Ammonia (ppm)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Chlorophyll a (mg/L)	0.448	0.38	1.33	0.74	0.32	0.99	0.748	0.293	0.543	0.305	1.28	1.245
Chlorophyll b (mg/L)	0.812	0.69	2.421	1.35	0.58	1.79	1.36	0.532	0.985	0.553	2.34	2.268
Total Chlorophyll (mg/L)	0.912	0.885	3.62	1.85	0.69	2.09	1.969	0.632	1.317	0.708	3.32	3.618
Sechi's disc transparency	14.2	34	17	27	14	18	28	18	28	33	43	52
Bacillariophycea (o/L)	84000	14000	10500	Nil	Nil	Nil	31500	7000	14000	21000	7000	14000
Chlorococcales (o/L)	7000	Nil	Nil	Nil	14000	49000	14000	35000	28000	77000	Nil	Nil
Cyanophyceae (o/L)	Nil	Nil	7000	7000	24500	Nil	7000	10500	7000	14000	Nil	Nil
Desmides (o/L)	3500	Nil	Nil	Nil	7000	Nil	Nil	3500	3500	24500	Nil	Nil
Euglenaceae (o/L)	3500	Nil	Nil	Nil	7000	Nil	7000	Nil	14000	38500	Nil	Nil

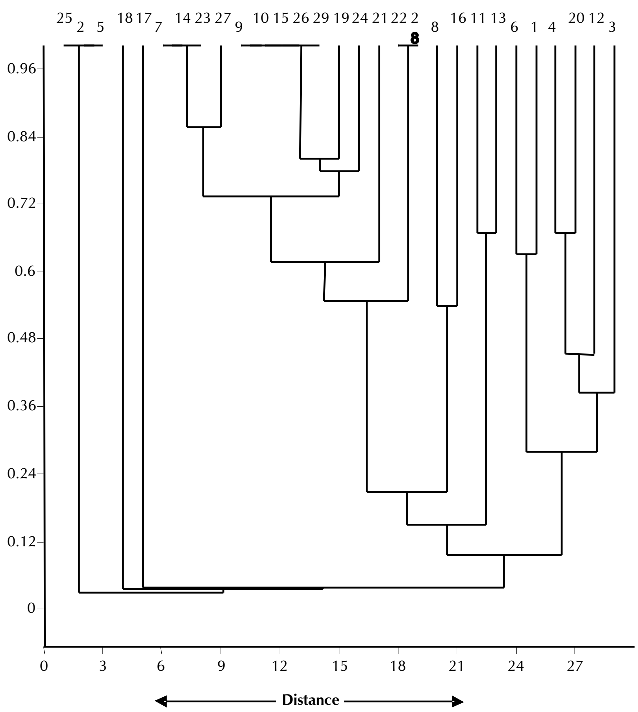

Figure 1: Bray-curtis similarity index distribution of species

lake was not quite significant. Added to these the transparency of water was always below 52cms resulting in great variation of plankton population. These results indicate that the physico-chemical parameters quite often changed during various seasons. Many researches have also recorded such variations in their studies. The lake receives water from a tributary of Cauvery River which also flows through agricultural land covered with ionic and nutrient rich, notify that the water chemistry variables were decided by land cover. Many studies have reported that urban and agriculture land use play a primary role in degrading water quality in adjacent aquatic systems, by altering the soil surface condition and generating pollution (Tong and Chen, 2002; White and Greer, 2006). Studies have also shown that the percentage of agriculture at water shed scale, which is true to the lake under consideration is a primary predictor for nitrogen and phosphorous (Smart *et al*., 1998; Ahearn *et al*., 2005). Similar conditions may operate in the present study.

In order to understand the relationship between the varied parameters, the data was subjected to Pearson's correlation matrix (Table 2) to obtain clusters using the squared Elucidation distance (Kazi *et al*., 2009). This helps in partition of a set of parameters into two or more groups based upon the similarity of objects with respect to a chosen set of characters so that similar objects are in the same class (Jackson, 1986; Hair *et al*., 1995). Cluster analysis helps to group observations that are described by a series of unrelated variables of measurements.

According to the matrix the first cluster of parameters is observed between water temperature, conductivity and sodium and these two parameters negatively correspond to temperature. Sodium has a positive role in changing conductivity. Dissolved oxygen has a negative impact on desmids, while magnesium controls total hardness. Calcium, magnesium and bicarbonates constitute a common cluster of three parameters, which have an impact on the growth of cyanophyceae while low nitrate content helps desmids and

Table 2: Pearson's correlation matrix for various physico-chemical and biological characteristics (Hadhinaru Lake)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1																	
2	-.145	1																
3	.009	**.826****	1															
4	.273	.657*	.673*	1														
5	-.056	-.052	-.056	-.183	1													
6	.232	-.628*	-.428	-.404	-.310	1												
7	.301	.241	-.110	.266	-.236	.071	1											
8	-.376	-.344	-.268	-.412	.184	.258	-.341	1										
9	.416	.371	.095	.41	-.202	-.156	**.823****	**-.811****	1									
10	.218	.586*	.542	.631*	.229	-.584*	-.054	-.457	.277	1								
11	.403	.493	.364	.553	.058	-.543	.240	**-.752****	.630*	**.873****	1							
12	.120	.096	.100	-.064	-.233	-.011	.28	-.154	.278	.107	.275	1						
13	.024	-.183	.041	-.121	-.603*	.623*	-.261	.053	-.255	-.321	-.353	-.230	1					
14	-.273	-.244	-.131	-.398	.646*	-.389	-.556	.145	-.40	-.142	-.186	-.291	-.348	1				
15	.082	-.351	-.595*	-.070	-.277	.007	.146	-.317	.274	.028	.247	-.235	.008	-.105	1			
16	.187	**.802****	**.784****	.649*	-.348	-.518	.083	-.440	.314	.526	.532	.119	.134	-.258	-.212	1		
17	.366	.623*	.674*	.506	-.138	-.310	-.104	-.440	.206	.621*	.543	-.031	.255	-.242	-.185	**.845****	1	
18	.278	-.128	-.158	-.390	.464	-.058	-.195	-.326	.102	.122	.226	-.287	-.032	.447	.158	-.056	.283	1
19	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a	.a
20	-.391	.002	-.222	-.135	-.705*	.240	.275	-.003	.130	-.452	-.311	-.118	.381	-.380	.451	-.030	-.240	-262
21	-.393	.002	-.223	-.138	-.702*	.241	.275	-.002	.130	-.453	-.313	-.121	.382	-.380	.450	-.032	-.240	-.259
22	-.434	-.054	-.261	-.200	-.684*	.288	.170	.039	.038	-.450	-.346	-.174	.467	-.360	.471	-.072	-.226	-.217
23	-.697*	-.142	-.099	-.561	-.191	.340	-.354	.398	-.486	-.539	-.669*	.043	.459	.071	-.257	-.249	-.216	-.124
24	.432	-.503	-.411	-.465	.198	.306	-.045	.392	-.259	-.450	-.357	-.187	.103	.282	-.075	-.225	-.133	.369
25	-.077	.216	.418	.167	.336	-.688*	-.477	-.138	-.181	.266	.210	.033	-.438	.704*	-.235	.290	.170	.144
26	-.110	.363	.338	.439	.564	-.595*	-.332	-.077	-.123	**.783****	.514	-332	-.359	.247	.010	.186	.283	.130
27	-.302	-.081	.042	-.181	**.737****	-.540	-.644*	.163	-.457	.138	-.027	-.308	-.443	**.936****	-.148	-.163	-.114	.354
28	-.356	-.059	.038	-.337	.647*	-.549	-.669*	.191	-.487	.145	.011	-.090	-.422	**.893****	-.160	-.115	-.095	.386

Cont.......Table 2: Pearson's correlation matrix for various physico-chemical and biological characteristics (Hadhinaru Lake)

	19	20	21	22	23	24	25	26	27	28
19	a									
20	a	1								
21	a	1.000**1								
22	a	0987**	.988**1							
23	a	.401	.403	.475	1					
24	a	-225	-.225	-.221	-.182	1				
25	a	-.420	-.423	-.462	-.176	-.081	1			
26	a	-.506	-.505	-.465	-.409	-.288	.322	1		
27	a	-.517	-.517	-.488	-.027	.097	.766**	.535	1	
28	a	-.443	-.443	-.411	.070	.118	.752**	.446	.937**	1

1. pH, 2.Temperature, 3. Conductivity, 4.Turbidity, 5.DO, 6.BOD, 7.Total hardness, 8.Calcium, 9.Magnesium, 10.Carbonate, 11.Bicarbonate, 12.Total phosphorus, 13.Sulphate, 14.Nitrite, 15.Nitrate, 16.Sodium, 17.Potassium, 18.Chloride, 19.Ammonia, 20.Chlorophyll a, 21.Chlorophyll b, 22.Total Chlorophyll, 23.Sechi's disc transparency, 24.Bacillariophycea, 25.Chlorococcales, 26.Cyanophyceae, 27.Desmides, 28.Euglenaceae; *. Correlation is significant at the 0.05 level (2-tailed); **. Correlation is significant at the 0.01 level (2-tailed); a. Cannot be computed because at least one of the variables is constant.

Table 3: Distribution of phytoplankton in Hadhinaru lake (o/mL)

	Planktons Bacillariophyceae	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	*Cocconies placentala Her.*	4	2	1	0	0	0	2	0	2	0	0	0
2	*Cymbella cymbiformis (Ag) Kuetz.*	0	0	0	0	0	0	1	0	0	0	0	0
3	*Gomphonema gracile Ehr.*	2	0	0	0	0	0	2	2	0	0	0	0
4	*Nitzschia obtusa W. Smith*	2	0	0	0	0	0	0	0	0	0	0	0
5	*Pinnularia gibba Ehr.*	0	0	0	0	0	0	1	0	0	0	0	0
6	*Synedra ulna (Nitz) Ehr.*	8	2	2	0	0	0	2		2	4	2	2
	Chlorococales												
7	*Actinastrum hantzschi Lagerhaim*	0	0	0	0	0	0	0	0	1	2	0	0
8	*Dimorphococus lunatus A Braun*	0	0	0	0	3	8	4	6	0	4	0	0
9	*Pediastrum simplex Meyen*	0	0	0	0	0	0	0	0	0	2	0	0
10	*Pediastrum tetras (Ehr.) Ralfs*	0	0	0	0	0	0	0	0	0	2	0	0
11	*Scenedesmus obliquis (Turpin) Kuetz*	0	0	0	0	0	0	0	0	2	0	0	0
12	*Scenedesmus qudricandatus Chodat*	2	0	0	0	1	0	0	0	2	0	0	0
13	*Selenastrum gracile Reinsch*	0	0	0	0	0	0	0	0	1	0	0	0
14	*Tetraedron lobatum (Naeg.)*	0	0	0	0	0	0	0	0	1	2	0	0
	Cyanophyceae												
15	*Chroococus limeneticus Lemn*	0	0	0	0	0	0	0	0	0	2	0	0
16	*Merismopedia elegans A Br.*	0	0	0	0	6	0	2	2	2	4	0	0
17	*Merismopedia tenussima lemermanin*	0	0	0	0	1	0	0	0	0	0	0	0
18	*Oscillatoria subbrevis Schmidle*	0	0	2	2	0	0	0	1	0	0	0	0
	Desmidaceae												
19	*Clostrerium Chrenbergii Menegh*	0	0	0	0	0	0	0	1	0	2	0	0
20	*Cosmarium margiratum (Lund) Roy et Bisa*	1	0	0	0	0	0	0	0	0	0	0	0
21	*Cosmarium quadrifarium (Nords).*	0	0	0	0	2	0	0	0	1	2	0	0
22	*Staurastrum javanicum (Nordst.)*	0	0	0	0	0	0	0	0	0	1	0	0
	Euglenaceae												
23	*Euglena elastica*	0	0	0	0	0	0	0	0	1	2	0	0
24	*Euglena limmophyla Lemmermann*	1	0	0	0	0	0	0	0	0	2	0	0
25	*Euglena oxyuris Scharmarda*	0	0	0	0	0	0	1	0	0	0	0	0
26	*Euglena polymorpha Dangeard*	0	0	0	0	0	0	0	0	0	2	0	0
27	*Lepocinclis ovum (Ehrenb) Lemn*	0	0	0	0	0	0	0	0	2	2	0	0
28	*Phacus tortos (Lemn) Skuortzov*	0	0	0	0	0	0	0	0	0	1	0	0
29	*Trachelomonas charkowensis Swirenko*	0	0	0	0	0	0	0	0	0	2	0	0

Table 4: Diversity indices in Hadhinaru lake

Months	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov
Taxa	7	2	3	1	5	1	8	5	11	17	1	1
Individuals	20	04	05	02	13	08	15	12	17	38	02	02
Shannon and Weiner index (1949)	1.69	0.69	1.05	0	1.38	0	1.96	1.36	2.34	2.76	0	0
Dominance Index Balan-Santini (1969)	0.24	0.5	0.4	1	0.30	1	0.15	0.31	0.10	0.07	1	1
Simpson index (1949)	0.76	0.5	0.64	0	0.69	0	0.84	0.68	0.89	0.93	0	0
Pielou's index (1975)	0.76	1.0	0.95	1	0.79	1	0.89	0.77	0.94	0.93	1	1

euglenaceae. As in often true sodium and potassium from a small cluster. Chlorophyll a, Chlorophyll b and total chlorophyll are very high indicating high number of planktonic individuals. Organisms of close association are members of the Chlorococcles, Desmids and Euglenaceae. Hosmani (1975) has pointed out a direct relationship between nitrates and phosphates. Cluster analysis therefore help in understanding the relationship between parameters and their variations during the different months.

A total of 29 species of algae were recorded from Hadhinaru lake (Table 3). The data of planktonic count was subjected to PAST soft ware program in order to obtain diversity indices. Four indices were selected for the present discussion. The taxa recorded, ranged from a minimum of 12 to a maximum of 17, while the number of individuals reached 38 during September. The values of the indices are presented in Table 4. The Bellan-Santini (1969) index indicates that species dominance was high during the month of March, May, October and November. While the dominance of algae was low during the other months indicating that dominance of species was not well marked.

The Shannon and Weiner (1949) index can also be used in determining the pollution status of the water body. The values of this index can theoretically range from zero to infinity. However normal values range from 0 to 4. This index is a combination of species present and the evenness of species. Examining the range of polluted and un polluted ecosystems, Willham and Dorris (1966) concluded that values of the index > 3 indicates clean water, values <3 are characterized as moderate pollution and values <1 are considered as heavily polluted. Applying the index to Hadhinaru lake data it is observed that the lake water becomes heavily polluted during the month of March, May, October and November. During August and September it almost reaches a status of clean water, while during the rest of the months it is characterized as moderately polluted. As far as diversity index is concerned it is very low during March, May, October and November. The reasons for such behavior can be attributed to the low flow of water in to the lake during these months. Diversity as per the index is very low and the water ranges from moderately polluted to heavily pollute during summer and winter.

The Simpson index (1949) is a measure of diversity and is often used to quantify the biodiversity of habitats. It takes into account the number of species as well as their abundance and the values range between 0 and 1. Greater the value greater will be the plankton diversity. The values reach almost 1 during the months of August and September indicating high diversity, while during March, May, October and November the diversity value is very low. The Pielous index (1975) states that evenness is also a diversity index. It quantifies how equal the community is numerically and is a constraint between 0 and 1. The less variation in communities between species the higher the value of the index. The evenness of species in the lake is not well marked. These variations may be attributed to anthropogenic activity, mainly fishing activity in the lake.

In order to understand the association of communities, similarity values of Bray-Curtis (1959) were also determined. Only values above 84% were accounted to study the distribution of species is the lake (Fig. 1). Occurrence of *Euglena oxyuris, Cymbella cymbilifermis. Pinnularia gibba, Actinasturm hantzschi, Tetradron labatum, Euglena elastica and Lepocinclis ovum* showed highest similarity of occurrence reaching almost 100%. These species have the capacity of close co-existence in the lake ecosystem. The lower range of similarity was between *Staurastrum jaranicum and Phacus tortus*. However similarity values less than 70% were high and the lowest similarity of taxa was between *Merismopedia tenussima and Oscillotaria subbrevis.*

It is often assumed that species rich communities are better than species poor communities and also adverse effects of pollution will be reflected in the reduction of the diversity (Hosmani, 2010). Patrick (1973) and Rosenberg (1976) are of the opinion that enriched ecosystems display reduction in diversity. Since river water flow in Hadinaru lake is not properly Regulated, during certain months and sometimes during November, the water level goes down and fluctuation of nutrients in water often may have an impact on plankton diversity as well as changes in the physico-chemical complexes. Other workers who have used a diversity index in ecological studies are Platt *et al.,* 1984 and Stoermer (1984).

ACKNOWLEDGEMENT

The first author is grateful to the Rajiv Gandhi National Fellowship, New Delhi, for financial assistance during the tenure of this research work.

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