INTERNATIONAL JOURNAL OF APPLIED BIOLOGY AND PHARMACEUTICAL TECHNOLOGY

www.ijabpt.com Volume-3, Issue-2, April-June-2012 Coden : IJABPT Copyrights@2012 ISSN : 0976-4550

Received: 25th April-2012 *Revised: 28th April-2012* *Accepted: 30th April-2012*

Research article

SURVEY AND STUDY OF PHYTOPLANKTON ECOLOGY IN SUKHNA LAKE, CHANDIGARH, (INDIA)

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ABSTRACT: Phytoplankton biodiversity and water quality of national wetland, Sukhna Lake, Chandigarh (Lat. 30° 44'14 N, Long. 76° 47' 14 E), India were examined in the present study. During the present study (April 2009 to September 2009), phytoplankton composition and physico-chemical characteristics of water are indicative of mesotrophic condition in three different collection zones (Z_A, Z_B and Z_C) of the lake. The species richness displayed fair variety of algal species (89 taxa). The community was dominated by the members of chlorophyceae and cyanophyceae. Highest phytoplankton density (2082 individual/ L) and species diversity (0.928-2.628) was found during the summer season in the wild area (Z_A) where there was no anthropogenic activity. The area with maximum disturbance in water column (Z_C) showed minimum phytoplankton density (164/L) and species diversity (0.991-2.319). Phytoplankton densities have significantly positive correlation with TDS(r= 0.669, significant at 0.05 level), chloride(r= 0.717, significant at 0.05 level) and significantly negative correlation with BOD(r= 0.623, significant at 0.05) in Z_A and significantly positive correlation with bicarbonate alkalinity(r= 0.728, significant at 0.01 level) and calcium hardness(r= 0.672, significant at 0.05 level) in Z_B.

Key words: Lake Sukhna; Ecology; Physicochemical parameters; Phytoplankton; species diversity.

INTRODUCTION

Lentic ecosystem is one of the most productive ecosystems in the biosphere and plays a significant role in the ecological sustainability of the region. It serves many vital functions such as recycling of nutrients, restoration of ground water, purification of water, augmentation and maintenance of stream flow and habitat provision for wide variety of flora and fauna along with their recreational values. However, continuous inputs of various forms of pollution from a variety of human activities have seriously deteriorated the health status of Lake Ecosystem. If this trend continues, it may lead to the collapse of Lake Ecosystem (Goldman and Horne, 1983; Constanza *et a.l,* 1997; Westman, 1977; Rapport *et al.*, 1998). Failure to restore this ecosystem results in extinction of species or an ecosystem type and cause permanent ecological damage. Thus, studies on physico-chemical factors and phytoplankton standing crop of the habitat are essential for the proper management of water resources and for the prediction of the potential changes in the aquatic ecosystem (Kobbia, 1982; Descy, 1987) and protection and remediation of ecosystems (Varshney, 1989). So, the objective of the present work is to study various physico-chemical characteristics in relation to phytoplankton diversity which would help in assessing the trophic status of this lake. The data obtained would also help in arriving at appropriate conservation strategies or restoration methods towards the conservation, management and sustainable use of natural resource in addition to formulating the diversity of the lake.

DESCRIPTION OF STUDY AREA

Sukhna Lake is a man made lake which was created in the foothill of the Shivalik Himalayas in the year 1958 for maintaining ground water table of the future city which was supposed to be a green city with lots of gardens. It has a fascinating range of flora and fauna and has been declared as a protected national wetland by the Government of India.

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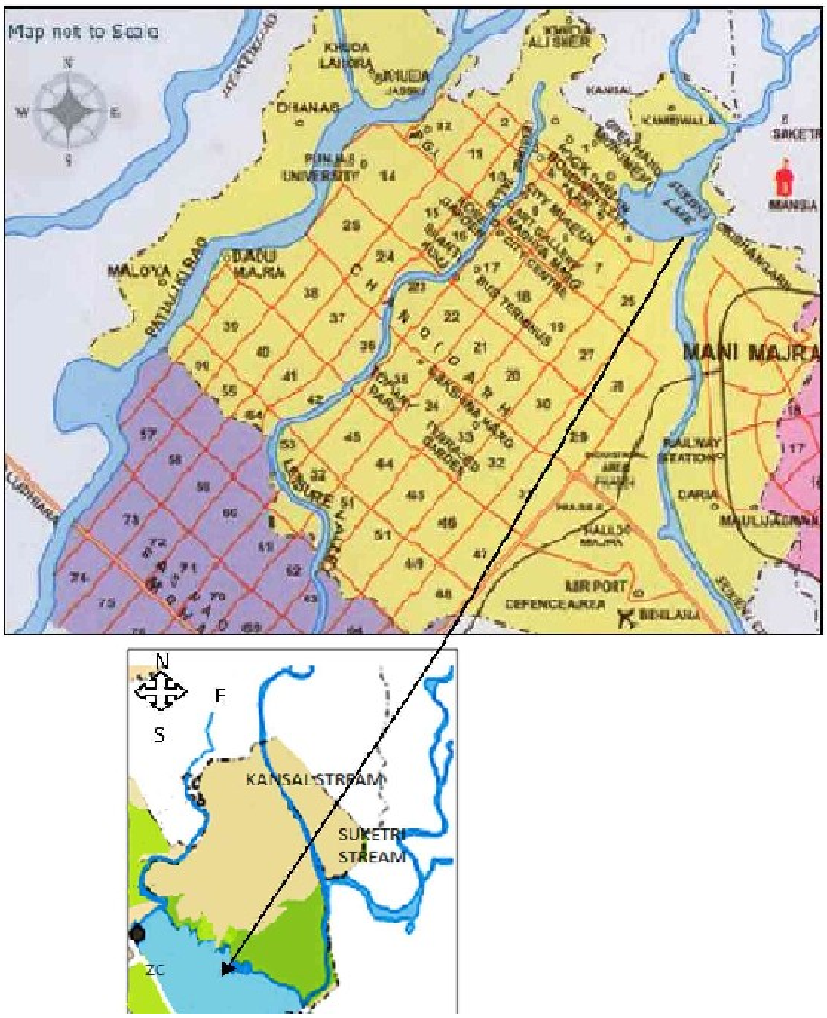
The water flowing into the lake is heavily loaded with silt. Due to higher run off, there is accelerated pace of erosion in the catchment areas, resulting in the higher rate of sedimentation in the reservoir Sukhna Lake and streambeds. The silt deposited year after year in the lake bed reduces the water storage capacity, depth, water spread area and submergence area at lake level.

Keeping in mind the above mentioned problem and other anthropogenic activities therein, the lake was divided into three zones for study: Zone A (Z_A) with least human activity, affected severely due to siltation); Zone B (Z_B) which supports angling activity; Zone C (Z_C) with maximum human activity (Figure 1).



LOCATION: chandigarh, India
LAKE TYPE: Artificial
SURFACE AREA: 3 square km
AVERAGE DEPTH: 8feet

Fig. 1: Outline map of Lake Sukhna showing the collection sites

METHODOLOGY

For the study of biotic and abiotic parameters, samples were collected from three substations (Z_A, Z_B and Z_C) of Sukhna Lake between late morning and early evening fortnightly from April 2009 to September 2009.

Physico-Chemical Assessment

Samples were collected from each substation randomly from the bank over a length of 100mts.The physico-chemical parameters of water quality were analysed using standard methods given in APHA (American Public Health Association), 1998.

Assessment of Biotic Population

Plankton samples were collected by filtering 50L of water through plankton net (50 µm size) and then preserved in 4% buffered formalin solution. Quantification and identification of the plankton was done according to standard references (Prescott, 1954; Ward and Whipple, 1959; Needham and Needham, 1962; Anantani and Marathe, 1972; Gupta, 1972; Pandey *et al.,* 1993; Kumar and Singh 1995; APHA, 1998; Garg *et al.*, 2002). Species diversity index was calculated using Shannon and weaver diversity index (Shannon and Weaver, 1963) and Simpson diversity index (Simpson, 1949). Monthly mean and standard error was calculated for each physical, chemical and biological variable. Karl Pearson correlation coefficient was calculated by SPSS computer software version 11.5 for windows to see any correlation between various recorded parameters.

RESULTS

The changes in the hydrobiological (physico-chemical and biological) parameters of water are used as the direct and indirect indices of water quality (Reid, 1961). The absolute value and correlation of these factors enable to characterize the water quality.

PHYSICO-CHEMICAL PARAMETERS

The physico-chemical factors and their values that affect phytoplankton in the study area are presented in Table 1. The air and water temperature in Sukhna Lake during the study period was found to be more or less similar in all the zones. Surface water temperature, averaged over the entire study period was around 29.65˚C. The lowest and highest surface water temperature recorded during the study period were 24.60˚C (Z_A) in April and 34.60˚C (Z_C) in July respectively. pH in all the three zones was quite uniform among all stations and ranged from 6.90-9.35. No definite pattern of increase or decrease of conductivity and TDS was observed at any of the collection zone. Turbidity ranged from 5.60-71.50 mg/L in Z_A, 17.30-101.60 mg/L in Z_B and 7.40-105.40 mg/L in Z_C. Average dissolved oxygen concentration at all the zones ranged from 0.6 to 5.2 mg/L in Z_A to 4.6 to 6.6 mg/L in Z_B and 5.1 to 6.4 mg/L in Z_C. Free CO_2 ranged between 00-30 mg/L being, maximum at Z_B (30 mg/L). Orthophosphate varied from 0.007 - 2.153 mg/L. Highest peak was observed in the month of May and June at all collection zones. Low values of sulphate and chloride was observed in the study area. BOD at different zones of Sukhna Lake ranged from 00-3.60 mg/L.

PHYTOPLANKTON

Plankton samples from Sukhna Lake show the existence of a speciose and diverse phytoplankton biocoenosis some of them occur sporadically included 89 taxa (Table 2) and thus, reflect the overall environmental heterogeneity and habitat diversity of this national wetland. Taxonomic determination was done to genus level, and where possible also to species level.

Table1: Physico-chemical parameters of Sukhna Lake (April 2009 to September 2009)

S.No	PARAMETERS		Zone A	Zone B	Zone C
1.	Air Temp. (˚C)	Range	24.70 - 37.40	24.70 - 37.40	24.70 - 37.40
		Mean± SD	29.65 ± 8.27	29.65 ± 8.27	29.65 ± 8.27
2.	Water Temp. (˚C)	Range	24.60 - 32.40	25.60 - 32.00	25.50 - 34.60
		Mean± SD	29.78 ± 1.99	30.10 ± 2.20	30.31 ± 2.39
3.	pH	Range	6.90 - 9.35	7.20 - 8.50	6.90 - 9.10
		Mean± SD	7.76 ± 0.59	7.66 ± 0.31	7.73 ± 0.50
4.	Conductivity (µmhos/Cm)	Range	150.60 - 618.00	160.00 - 560.50	54.00 - 144.00
		Mean± SD	348.00 ± 123.53	296.44 ± 128.40	345.83 ± 178.40
5.	T.D.S. (mg/ L)	Range	73.20 - 342.00	94.00 - 210.00	110.00 - 210.00
		Mean± SD	168.98 ± 73.08	144.10 ± 56.32	154.92 ± 34.25
6.	Turbidity(mg /L)	Range	5.60 - 71.50	17.30 - 101.60	7.40 - 105.40
		Mean± SD	19.20 ± 19.17	48.47 ± 23.59	45.31 ± 32.69
7.	DO (mg/ L)	Range	00 - 8.40	3.60 - 8.40	4.80 - 6.60
		Mean± SD	4.20 ± 2.35	5.48 ± 1.26	5.55 ± 0.56
8.	Free CO2 (mg L)	Range	00 - 28.00	00 - 30.00	00 - 20.00
		Mean± SD	9.83 ± 8.69	7.83 ± 8.54	5.83 ± 6.83
9.	Chloride (mg/ L)	Range	9.94 - 38.77	9.94 - 32.80	9.94 - 24.85
		Mean± SD	21.41 ± 9.00	14.97 ± 7.70	16.58 ± 5.36
10.	Total Hardness (mg/ L)	Range	21.41 - 9.00	14.97 - 7.70	16.58 - 5.36
		Mean± SD	56.60 ± 18.75	72.33 ± 16.63	77.75 ± 24.30
11.	BOD (mg/ L)	Range	00 - 3.20	2.20 - 3.60	1.80 - 2.80
		Mean± SD	2.02 ± 1.13	2.80 ± 0.45	2.33 ± 0.26
12.	O-Phosphate (mg/ L)	Range	0.008 - 1.283	0.011 - 1.191	0.007 - 2.153
		Mean± SD	0.366 ± 0.438	0.358 ± 0.40	0.51 ± 0.69
13.	Sulphate (mg/ L)	Range	0.12 - 0.91	0.15 - 1.20	0.23 - 0.98
		Mean± SD	0.376 ± 0.22	0.42 ± 0.28	0.45 ± 0.20
14.	Alkalinity (mg/ L)	Range	72.00 - 230.00	66.00 - 150.00	54 - 144.00
		Mean± SD	145.33 ± 56.07	98.17 ± 30.53	107.50 ± 33.95

The assemblage was dominated, in descending order by chlorophyceae (37 taxa), cyanophyceae (26 taxa), bacillariophyceae (19 taxa), dinophyceae (2 taxa), euglenophyceae (2 taxa) and cryptophyceae (1 taxon). Z_A had maximum species richness (64 taxa) of which 40 per cent was constituted by chlorophyceae. *Closterium* spp. and *Spirogyra* spp. dominated over other chlorophyceae members. Bacillariophyceae and cyanophyceae respectively constituted 32 and 28 per cent. *Cyclotella* sp. and *Cymbella* spp. predominantly represented bacillariophycea whereas *Nodularia* spp. was found to be predominant group of cyanophyceae. Species richness was maximum is June and minimum in September (Table 3). Population density decreased from April to May, thereafter a sharp increase was recorded till July. After July again phytoplankton density decreased sharply in August (Figure 2).

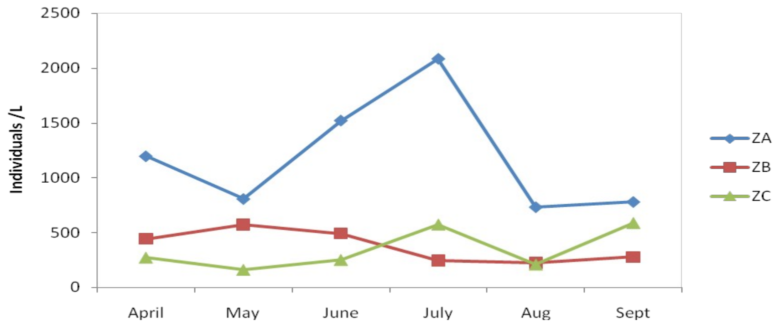


Fig 2: Monthly variation population density of phytoplankton at three zone during the study period.

Table 2: List of Phytoplankton found in the preserved samples from Lake Sukhna

Species marked as 'r' were reported only once during the study period

CHLOROPHYCEAE

Pediastrum boryanum
Pediastrum duplex
Pediastrum simplex
Closterium acerosum
Closterium tumidum
Cosmarium bengalense
Cosmarium granatum
Cosmarium subtumidum
Cosmarium venustum
Cosmarium poritanium
Oocystis sp. *r*
Microspora sp.
Steioclonium sp. r
Closteriopsis sp.
Dicanthos sp
Apanochaeta sp
Chlorella sp.
Crucigenia sp.
Rhizoclonium sp.
Senedesmus bijugatus
Tetrasporidium sp.
Euastrum sp.
Hormidium flaccidium r
Ulothrix zonata
Oedogonium nodulosum
Mougeotia sp. r
Sirocladium sp.
Zygnema fanicum
Spirogyra spp
Pleurotaenium sp. r
Mesotaenium sp.
Netrium digitus r
Penium sp. r
Actinotaenium sp. r
Sphaerozosma sp.
Leptosira sp. r

BACILLARIOPHYCEAE

Stephanodiscus neoastraea
Meridion sp. r
Fragilaria sp.
Cymbella tumida
Cymbella cymbiformes
Epithemia sorex
Mastogloia sp.
Frustulia sp. r
Cyclotella sp.
Amphipleura sp.
Cocconeis cistula.
Phacus longicauda. *r*
Melosira sp. *r*
Synedra ulna
Tabellaria flocculosa.
Nitzschia sp.
Surirella brebissonii
Anomoneis sp. r
Neidium sp.
Pinnularia abaujensis
Navicula cryptocephala
Navicula sp.
Gomphonema sp
Stauroneis kriegeri

CYANOPHYCEAE

Chrococcus turgidus
Synechocystis sp.
Gloeocaspa sp.
Phormidium sp.
Lyngybya sp. r
Synechococcus sp.
Microcystis aeroginosa
Microcystis sp1
Aphanocaspa sp.
Merismopedia elegans
Gomphosphaeria sp.
Spirulina sp. r
Oscillatoria principles
Cylindrospermium majus
Nodularia muscorum
Nodularia spermigenia
Stichosiphon sp.
Rivularia sp.
Gloeotricha echinulata r
Coelosphaerium sp. r
Entophysalia sp. r
Gloeochaeta sp.
Anabaena sp.

EUGLENOPHYCEAE

Euglena sp.
Gymnozyga sp. r

DINOPHYCEAE

Cystodinium sp.
Kentosphaera sp

CRYPTOPHYCEAE

Cryptomonas sp. r

At Z_B, 45 taxa were identified of which chlorophyceae (16), cyanophyceae (14), bacillariophyceae (10), dinophyceae (3) eugeinophyceaea (1) and cryptophycea (1) represented respectively 36 %, 31%, 22%, 7%, 2% and 2% of the total species richness. *Nodularia* spp. was found to be abundant.

Z_C showed minimum species richness with 31 taxa, predominantly represented by chlorophyceae (15) which constituted 48 per cent. The other groups belonged to bacillariophyceae (8) and cyanophyceae (7) respectively constituted 26 and 23 percent. Only one species of Euglenophyceae was represented by one species only. *Sirocladium* sp. was found to be predominant. Population density at Z_B and Z_C was comparatively much less than Z_A. However, in July significant increase in population density was observed at Z_A and Z_C but Z_B showed decrease up to July and thereafter no significant variation was reported till September. Numerically maximum population of 2082 individuals/ L were observed during July at Z_A and minimum 164 individuals/ L during May at Z_C. A decrease in phytoplankton population was observed from Z_A to Z_C, in order of increase in anthropogenic activities therein. Seasonal variations showed an increase in phytoplankton population during summer (May to July). The population was maximum during July and declined in August. During the study year the monsoon was quite late during August. This might be the reason for significant decrease in phytoplankton population during August.

Species diversity

Shannon Weaver diversity index and Simpson's index of dominance was calculated to know the species diversity during different months (Table 3). The species diversity was comparatively more in summer months than during the monsoon. Z_A had highest species diversity which ranged between 0.928 to 2.628 being, minimum in August and maximum in May. A secondary peak was observed in September. Simpson index showed maximum (0.506) value in August and minimum (0.076) in September. At both Z_B and Z_C, diversity was maximum and Simpson index was minimum in June whereas minimum diversity and maximum value of Simpson index was found in September.

Table 3: Comparison of phytoplankton richness, density and diversity at three sampling zones

Months	Richness			Density (individuals/ L)			Shanon-Weaner Diversity index			Simpson's Dominance Index		
	ZA	ZB	ZC	ZA	ZB	ZC	ZA	ZB	ZC	ZA	ZB	ZC
April	23	14	12	1196	445	274	2.480	1.719	1.345	0.115	0.242	0.257
May	31	21	7	808	575	1 64	2.628	2.359	1.294	0.087	0.111	0.269
June	44	30	14	1521	493	254	2.453	2.627	2.319	0.147	0.068	0.067
July	32	14	12	2082	247	575	2.084	1.954	1.092	0.168	0.106	0.388
August	13	10	7	733	226	212	0.928	0.827	0.991	0.506	0.225	0.316
September	16	3	5	781	280	587	2.213	0.466	0.595	0.096	0.949	0.965

THE RELATIONSHIPS BETWEEN PHYTOPLANKTON AND SOME PHYSICO-CHEMICAL PARAMETERS

Statistical relationships between the composition of phytoplankton and the physico-chemical environment variables in the surface water at the sampling stations were explored. It indicated that several abiotic factors exert a considerable influence on phytoplankton abundance and diversity (Das *et al.*, 1996). Phytoplankton densities had significantly positive correlation with TDS (r= 0.669, significant at 0.05 level), chloride (r= 0.717, significant at 0.05 level) and significantly negative correlation with BOD (r= 0.623, significant at 0.05) in Z_A and significantly positive correlation with bicarbonate alkalinity (r= 0.728, significant at 0.01 level) and calcium hardness (r= 0.672, significant at 0.05 level) in Z_B (Table 4).

Table 4: Karl Pearson coefficient of correlation between different abiotic parameters and phytoplankton density

	WT	pH	TDS	DO	CO_2	CaAlk	BiAlk	CL^{-1}	TH	0-PO_4	BOD
Zone A	0.113	-0.196	0.669*	-0.449	0.059	-0.275	-0.018	0.707*	0.145	0.085	-0.623*
Zone B	0.025	-0.016	0.452	-0.039	0.397	-0.462	.728**	0.275	0.537	0.230	-0.564
Zone C	0.422	-0.192	0.293	0.039	0.039	0.018	0.322	0.585	0.033	0.117	0.539

****Correlation is significant at the 0.01level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).**

DISCUSSION

PHYSICO-CHEMICAL

Ecological factors estimated and characterised by this study reflect a typical tropical water quality characteristics which concurrent with lake's geographical location. Alkaline pH values recorded throughout the study were a reflection that lake is bicarbonate type (Wetzel, 1983; Joshi *et al.*, 1993). Surface water at all zones appeared well oxygenated. Low values of DO in the month of June was observed at Z_A could be attributed to the reduction of the collection zone to isolated pools and thus decrease in water level (Odum, 1971; Iqbal *et al.,* 2003). However in zone C, maximum value of DO was observed due to frequent turbulence caused by paddled boats which resulted in proper mixing of water. Alkalinity throughout the study period was mainly due to bicarbonates but high peak in the monsoon month (August) may be attributed to the presence of carbonates and absence of free CO_2 (Tucker, 1958; Chakrabarty *et al.,* 1959; Bisop, 1973; Flood, 1996; Shashtri and Pendse, 2001; Radhakrishnan *et al.,* 2007). Water bodies having total alkalinity above 50 mg/L can be considered productive (Moyle, 1946). Thus, the present findings showed that all the three zones of Sukhna Lake are productive in nature. Low value of chloride reflects that there was minimum amount of organic waste of animal origin (Pathak *et al.,* 2001; Shastri and Pendse, 2001; Pandey and Verma, 2004). Rise in orthophosphate concentration in May and June might be due to increased decomposition at higher temperature and low water level which was in accordance with the findings of Swaranlatha and Rao, 1998; Jha and Barat, 2003 ; Kumar *et al.,* 2005. Minimum concentration in the month of August and September was may be due to enhanced consumption as well as dilution due to rainfall (Joshi *et al.,* 1993). According to Lee *et al.,* 1981 classification based on orthophosphate concentration, it was found that lake is mesotrophic in nature. The nearly neutral and marginally hard waters of this manmade lake show moderate values for BOD and low concentration of sulphate.

PHYTOPLANKTON

The variations in phytoplankton are related to a variety of environmental factors in aquatic environments (Washington, 1984; Boney, 1989; Wu and Chou, 1999) the approach adopted in the present investigation, is to relate temporal changes in diversity to temporal changes in environmental conditions. It is a well established fact that phytoplankton grow and multiply best during summer when temperature is high (Richardson *et al.*, 2000; Izaguirre *et al.*, 2001; Susanne *et al.*, 2005; Farahani *et al.*, 2006 ; Chowdhury *et al.*, 2007) and longer photoperiod (Polli and Simon, 1992; Salmaso and Naselli, 1999 ; Brizzio *et al.*, 2001). Therefore the present study was planned in summer and the monsoon seasons. The species richness displayed a fair variety of algal species (89 taxa). The community was predominantly constituted by the members of chlorophyceae, bacillariophyceae, and cyanophyceae. Three members of dinophyceae, and one each of euglenophyceae and cryptophyceae also contributed to the community structure.

The results of seasonal variation in phytoplankton population revealed highest species diversity during May and June when days are longer and the water level is at its minimal. The three zone studied in Lake Sukhna differ in the physical structure as well as in utilization for human activities. As expected, the phytoplankton samples taken from Z_B and Z_C were less dense and less diverse than those taken from Z_A. The result supports the hypothesis that recreational boating and removal of riparian area has negative effect on the density and diversity of the planktons. Phytoplankton abundance and taxonomic diversity depends on the supply of the nutrients in natural water. In the present study highest plankton density and species diversity was found during the summer season toward the wild area (Z_A) where there was no anthropogenic activity. The area with maximum disturbance in water column (Z_C) showed minimum plankton density and species diversity. Less phytoplankton density and diversity at Z_C could be because the boating activity does not allow phytoplankton especially the filamentous algae to colonize. The results goes in confirmation to Stolpe and Moore, 1997; Asplund, 2000. According to them the turbulence created by propellers disrupts phytoplankton communities living just beneath the surface of the water, which results in a redistribution of the organisms (Harris, 1978, 1980, 1983, 1986; Reynold and Walsby, 1978; Pearl, 1995). This turbulence also decreases light penetration, which can reduce the photosynthetic rates of submerged aquatic vegetation, thereby slowing down primary production rates (Stolpe and Moore, 1997). On the contrary comparatively high phytoplankton density and diversity at Z_A can be attributed to release of nutrients in the water through riparian vegetation and thus promoting algal growth (Liddle and Scorgie, 1980; Backhurst and Cole, 2000).

The assemblage of phytoplankton in Sukhna Lake were indicative of the lake's richness based on species abundance and diversity. The analysis of physicochemical parameter of lake was an indicator of how healthy the lake was and the number of species found there was dependent on the physicochemical parameters of lake. These complementary analyses provide a better understanding of the lake's present condition (Arfi *et al.*, 2003) and their information can be used to mitigate negative effects.

ACKNOWLEDGEMENTS

The authors are thankful to Department of Zoology, Kurukshetra University for providing all necessary facility for the study. We are also grateful to the Chandigarh administration for granting permission to take samples from Lake Sukhna.

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