International Research Journal of Biological Sciences ISSN 2278-3202
Vol. **4(3),** 76-83, March **(2015)** *Int. Res. J. Biological Sci.*

Phytoplankton Community Structure and Species Diversity of Nangal Wetland, Punjab, India

Brraich O.S. and Kaur R.*
Department of Zoology and Environmental Sciences, Punjabi University, Patiala, Punjab, INDIA

Available online at: www.isca.in, www.isca.me
Received 14th January 2015, revised 21st February 2015, accepted 4th March 2015

Abstract

The phytoplankton community structure and species diversity were studied at Nangal Wetland during February 2013 to January 2014.Phytoplankton samples were collected using phytoplankton net on monthly basis. The samples collected were preserved in 5% solution of formaldehyde on the spot, and then brought to the laboratory for further study. 49 genera belonging to three major classes i.e., dominated by Chlorophyceae (21 genera) followed by Bacillariophyceae (19 genera) and Cyanophyceae (13 genera) were reported. The range, mean and standard deviation for all 3 classes of phytoplankton were recorded. The most abundant genera include Navicula spp., Cymbella spp., Pinnularia spp., Gomphonema spp., Meridion spp., Fragillaria spp., Tabellaria spp., Spyrogyra spp. and Oedogonium spp. The maximum and minimum species richness (Menhinick index R_2) was found to be 0.05 for Chlorophyceae and 0.04 for Cyanophyceae. Maximum and minimum species diversity (Shannon-Weiner H') were found 2.94 for Chlorophyceae and 2.15 for Bacillariophyceae. Maximum species evenness was recorded for Cyanophyceae and minimum for Bacillariophyceae. Highest numerical abundance was observed in summer and lowest during winter season. Phytoplanktonic study is very important because they act as primary producers, food for variety of aquatic organisms and an efficient bio-indicator for water quality. Large population of phytoplankton is thriving in this wetland which enhances its productivity.

Keywords: Abundance, bio-indicator, freshwater, Menhinick index, Shannon-Weiner.

Introduction

Nangal Wetland is situated in the Shivalik foothills existing in the state of Punjab. This wetland has created in the downstream of Bhakhra reservoir for its strategic importance as balancing reservoir. During emergency situations surplus water is released into this wetland from Bhakhra reservoir and it absorb this water like a sponge and protect this area from the threats of flash floods. Nangal Wetland is a riverine and lacustrine type of aquatic ecosystem which supports valuable flora and fauna. It attracts thousands of migratory birds during the winter season every year because it provides suitable feeding and breeding grounds for birds and other aquatic organisms. The area adjoining this wetland is covered with thick submerged aquatic vegetation, green lands and forests. However, it is very important to document its various components of biodiversity and study on conservation and management due to its strategic importance.

Wetlands are combination of aquatic and terrestrial conditions, which are very important and complex aquatic ecosystems in the world. Wetlands are further defined as 'lands transitional between terrestrial and aquatic eco-system where the water table is usually at or near the surface or the land is covered by shallow water[1]. Wetland ecosystems are considered as most productive aquatic ecosystems on the earth that receives water from various sources like rivers, streams, precipitation, land over flow, infiltration from surface and sub-surface, potamon zone of streams and also from underground water as well. Theinput of water from different sources enhances the productivity of wetlands due to transportation of essential load of nutrients[2] and organic matter[3]. The occurrence of large amount of nutrients like nitrate, phosphate, silica and sulphate are essential to enhance the productivity by enhancing the diversity and abundance of phytoplankton in the water. The occurrence of phytoplankton and algal blooms in the shallow water are also helpful to increase the productivity of wetlands because large surface area of wetlands is exposed tosunlight for photosynthetic activity[4].

Phytoplanktonic study is the primary interest to exploit water resourcesfor any scientific utilization. Algal blooms present in water are autotrophic organisms and receives their essential nutrients from dissolved chemicals. Thus, these organisms excellently depict the present conditions of aquatic environment as believed by many workers. These are also widely used as bioindicators to monitor water quality, pollution and eutrophication in wetlands[5]. Plankton are microscopic organisms and float freely in the water from one place to another as they have small powers of locomotion. They drift in the water with the action of waves, current and other forms of water motion and equally distributed in the wetland ecosystems[6]. Phytoplankton constitutes the very basis of nutritional cycles of an aquatic ecosystem. They form a bulk of food for zooplankton, fishes and other aquatic organisms.

Phytoplankton are one of the initial biological components from which the energy is transferred to higher organisms through food chain[7-9].

In any aquatic environment, phytoplankton considered as the chief primary producers[10], which entrap solar energy by the process of photosynthesis and produce carbohydrates in the form of food by assimilating carbon dioxide, thus establish coordination between the abiotic and the bioticfactors in the aquatic ecosystem[11]. For the production of maximum amount of phytoplankton in the water, optimum level of physico-chemical factors are required[12-13]. It is further reported that phytoplankton are the autotrophic component of the plankton community that drifts in the water column of aquatic ecosystems[14]. It is also revealed that certain algae respond quickly to any change in the quality of water and assumes the rate like a "sensor" in evaluation of water pollution either by retarding and preventing algal growth while others stimulate growth resulting into their blooms[15].

Though, this wetland has created for its strategic importance, so the basic knowledge about various biotic components is very important to start sustainable conservation measures. Therefore, scientific documentation of phytoplankton diversity of Nangal Wetland is also very essential, because they are excellent bio-indicators, source of food which supports plankton feeder insects, fishes and birds.

Material and Methods

Nangal Wetland (figure-1), located in District Ropar, is a balancing reservoir situated over the Sutlej river at latitude 31°24'13.52"N and longitude 76°22'03.05"E with 1172 feet elevation. It spreads over an area of 700 acres covering land of adjoining six villages because this area is enriched with diverse flora, fauna and hydrology. This wetland is very important from socio-economic, ecological, hydrological and recreational considerations. Besides serving as an important refueling base for migratory avifauna, this lake supports diversity of species of local birds, fishes, reptiles, some important mammals and plants. Being a unique ecosystem, this wetland had been nominated to the Ministry of Environment and Forests, Govt. of India for inclusion under the National Lake Conservation Program[16]. Further, Ministry designated it as wetland of National importance in 2008.

Phytoplankton samples were collected using phytoplankton nylon net. 100 liters of water was filtered through a ring type (24 mesh/mm^2) net, fitted with a wide mouthed glass bottle. The samples collected were preserved in 5% solution of formaldehyde on the site. Identification and counting of phytoplankton were done with the help of binocular light microscope. Slides for qualitative and quantitative analyses were prepared. Sedgwick Rafter Counting Chamber[17] was used to determine their density. The phytoplankton were expressed as individuals per liter (individuals/liter) for the purpose of calculating diversity indices. Identification of phytoplankton was done following relevant books[18-20]. Three indices were used to obtain estimation of species diversity, species richness and species evenness.

Diversity index values were obtained by using the following equations:

$$H' = -\Sigma(\mathrm{Pi} \ln \mathrm{Pi}) \qquad \text{(Shannon's index)}^{21}$$
$$\lambda = -\Sigma \mathrm{ni}(\mathrm{ni}-1)/\mathrm{n}(\mathrm{n}-1) \qquad \text{(Simpson index)}^{22}$$

Where: Pi = Proportion of the first species. The proportions are given Pi=ni/n.

Species richness (R1 and R2) obtained using the following equation:

$$R1 = (S-1)\ln(n) \qquad \text{(Margalef index)}^{23}$$
$$R2 = \frac{S}{\sqrt{n}} \qquad \text{(Menhinick index)}^{24}$$

Where: R = Index of species richness, S = Total number of species, n = Total number of individuals,

Species evenness was determined by using the following expression.

Shannon's equitability (E) can be calculated by dividing H by Hmax (here Hmax= lnS). Equitability assumes a value between 0 and 1 with 1 being complete evenness.

$$E = \frac{H}{H\max} = \frac{H}{\ln S}$$

Where: H = Shannon diversity index, S= number of species in sample

Results and Discussion

The Bacillariophyceae (diatoms), Chlorophyceae (green algae) and Cyanophyceae (blue green algae) make up the three major groups of algae in fresh water ecosystems. In total 49 genera of phytoplankton were recorded belonging to 3classes (table 1). Chlorophyceae with 21 genera were found to be dominant in the wetland, followed by Bacillariophyceae, 19 genera and Cyanophyceae, 9 genera. Chlorophyceae (44%), Bacillariophyceae (43%) andCyanophyceae (13%) (figure 3). The classwise representation depicted following order of dominance in term of diversity of phytoplankton: Chlorophyceae>Bacillariophyceae>Cyanophyceae

The range, mean and standard deviation of phytoplankton has also been recorded (table 1). Out of 49 genera, 9 genera belong to class Cyanophyceae which includes.

Table-1
Phytoplankton composition at Nangal Wetland during February 2013 to January 2014

Cyanophyceae	Mean± Standard Deviation	Range
Microcystis spp.	6820.83±5003.35	3625-14175
Anabaena spp.	4562.5±2883.6	2250-10125
Oscillatoria spp.	5910.42±4510.36	2325-12350
Merismopedia spp.	4575±2622.93	2450-7775
Phormidium spp.	5318.75±2999.91	1250-10050
Cylindrospermum spp.	6312.5±3543.28	2050-11450
Chroococcus spp.	3395.83±2538.23	1850-8825
Asterionella spp.	4658.33±2756.12	2250-8775
Lyngbye spp.	2527.08±2245.61	1025-6875
Chlorophyceae		
Spirogyra spp.	15845.83±9582.60	9275-28775
Zygnema spp.	7552.08±5564.2	4350-16150
Cladophora spp.	11297.91±6337.64	6925-17575
Oedogonium spp.	16743.75±10448.91	8150-29900
Microspora spp.	4587.5±3700.63	4175-8875
Ulothrix spp.	7881.25±5607.14	5725-15225
*Pediastrum*spp.	7635.42±5052.58	7350-14300
Chlorella spp.	8693.75±6815.47	1425-19125
Cosmarium spp.	7060.41±4891.63	1825-15325
Oocystis spp.	3666.67±2654.29	1900-6850
Stigeoclonium spp.	8068.75±6112.04	9850-14250
Closterium spp.	6593.75±6018.67	4350-21775
Hydrodictyon spp.	6604.16±3315.74	3350-11225
Scenedesmus spp.	4208.33±3251.85	2325-8975
Actinastrum spp.	4000±3313.69	1250-9350
Wolffiella spp.	4302.08±2560.55	2250-7850
Anksitrodesmum spp.	6741.66±3250.88	3450-10075
Penium spp.	5772.91±3563.82	3850-11875
Pandorina spp.	5120.83±3259.51	2125-10025
Eudorina spp.	5418.75±4059.03	2550-11775
Selenastrum spp.	3862.5±3005.67	2175-8175
Bacillariophyceae		
Acnanthes spp.	3459.17±2703.53	2175-8450
Synedra spp.	11172.92±5183.76	5150-16825
Fragillaria spp.	13206.25±5581.66	7875-20325
Meridion spp.	6575±2217.11	2825-9175
Tabellaria spp.	20089.6±6116.34	7725-28550
Navicula spp.	12177.1±5447.17	5925-20675
Gyrosigma spp.	6781.25±4583.18	5400-12475
Pinnularia spp.	9595.83±4149.23	5625-14825
Nitzschia spp.	5277.08±3552.19	4650-10225
Stauroneis spp.	3710.41±2999.64	1525-8575
Cymbella spp.	15550±2438.51	11600-20300
Gomphonema ssp.	13562.5±2310.38	10475-17175
Cyclotella spp.	8066.67±5073.47	4475-13150
Anomoeoneis spp.	5262.5±4103.77	2750-11975
Stauroneis spp.	2743.75±2459.90	1550-6775
Surirella spp.	2993.75±3244.46	1250-9875
Melosira spp.	3556.25±2993.42	1125-8375
Phacus spp.	2464.58±2316.01	1325-6825
Cocconeis spp.	3427.08±2706.58	2175-7825

*Microcystis*spp. 3625-14175(6820.83±5003.35), *Anabaena* spp. 2250-10125(4562.5±2883.6), *Oscillatoria* spp. 2325-12350(5910.42±4510.36), *Merismopedia* spp. 2450-7775(4575±2622.93),*Phormidium* spp. 1250-10050(5318.75±2999.91), *Cylindrospermum* spp. 2050-11450(6312.5±3543.28), *Chrococcus* spp. 1850-8825(3395.83±2538.23), *Asterionella* spp. 2250-8775(4658.33±2756.12), *Lyngbye* spp. 1025-6875(2527.08±2245.61). Class Chlorophyceae consists of 21 genera which includes: *Spirogyra*spp. 9275-28775(15845.83±9582.60), *Zygnema*spp. 4350-16150(7552.08±5564.2), *Cladophora*spp. 6925-17575(11287.91±6337.64), *Oedogonium*spp. 8150-29900(16743.75±10448.91), *Microspora* spp. 4175-8875(4587.5±3700.63), *Ulothrix*spp. 5725-15225(7881.25±5607.14), *Pediastrum* spp. 7350-14300(7635.42±5052.58),*Chlorella* spp. 1425-19125(8693.75±6815.47), *Cosmarium*spp. 1825-15325(7060.41±4891.63), *Oocystis* spp. 1900-6850(3666.67±2654.29), *Stigeoclonium*spp. 9850-14250(8068.75±6112.04), *Closterium* spp. 4350-21775(6593.75±6018.67), *Hydrodictyon* spp. 3350-11225(6604.16±3315.74), *Scenedesmus* spp. 2325-8975(4208.33±3251.85), *Actinastrum* spp. 1250-9350(4000±3313.69), *Wolffiella* spp. 2250-7850(4302.08±2560.55), *Anksitrodesmus* spp. 3450-10075(6741.66±3250.88), *Penium* spp. 3850-11875(5772.91±3563.82), *Pandorina* spp. 2125-10025(5120.83±3259.51), *Eudorina* spp. 2550-11775(5418.75±4059.03), *Selenastrum* spp. 2175-8175(3862.5±3005.67) belong to Chlorophyceae.

Diatoms are a major group of algae and one of the most common types of phytoplankton, belong to member of Bacillariophyceae. Diatoms are microscopic single celled photosynthetic aquatic organisms contained within distinctive silica frustules that can remain preserved in sediments for thousands of years. Class Bacillariophyceae consists of 19 genera which include: *Acnanthes* spp. 2175-8450(3459.17±2703.53), *Synedra* spp. 5150-16825(11172.92±5183.76), *Fragillaria* spp. 7875-20325(13206.25±5581.66), *Meridion* spp. 2825-9175(6575±2217.11), *Tabellaria* spp. 7725-28550(20089.6±6116.34), *Navicula*spp. 5925-20675(12177.1±5447.17), *Gyrosigma*spp. 5400-12475(6781.25±4583.18), *Pinnularia* spp. 5625-14825(9595.83±4149.23), *Nitzschia*spp. 4650-10225(5277.08±3552.19), *Stauroneis*spp. 1525-8575(3710.41±2999.64), *Cymbella* spp. 11600-20300(15550±2438.51), *Gomphonema*spp. 10475-17175(13562.5±2310.38), *Cyclotella* spp. 4475-

13150(8066.67±5073.47), *Anomoeoneis* spp. 2750-11975(5262.5±4103.77), *Stauroneis* spp. 1550-6775(2743.75±2459.90), *Surirella* spp. 1250-9875(2993.75±3244.46), *Melosira* spp. 1125-8375(3556.25±2993.42), *Phacus* spp. 1325-6825(2464.58±2316.01), *Cocconeis*spp. 2175-7825(3427.08+2706.58).

Table 2 and figure 2 shows the Monthly abundance of different classes of phytoplankton. Chlorophyceae comprises of highest phytoplankton abundance which ranges from maximum of 257800 (individuals/liter) in month of April and minimum of 15700 (individuals/liter) in month of July. Followed by Bacillariophyceae which ranges from maximum of 239550 (individuals/liter) in month of April and minimum of 76275 (individuals/liter) in month of July. Cyanophyceae ranges from maximum of 75950 (individuals/liter) in month of May and minimum of 17125 (individuals/liter) in month of June. The percentage composition (table 2 and Figure 3) of phytoplankton classes shows that Chlorophyceae (44%) contribute higher than Bacillariophyceae (43%) and Cyanophyceae (13%).

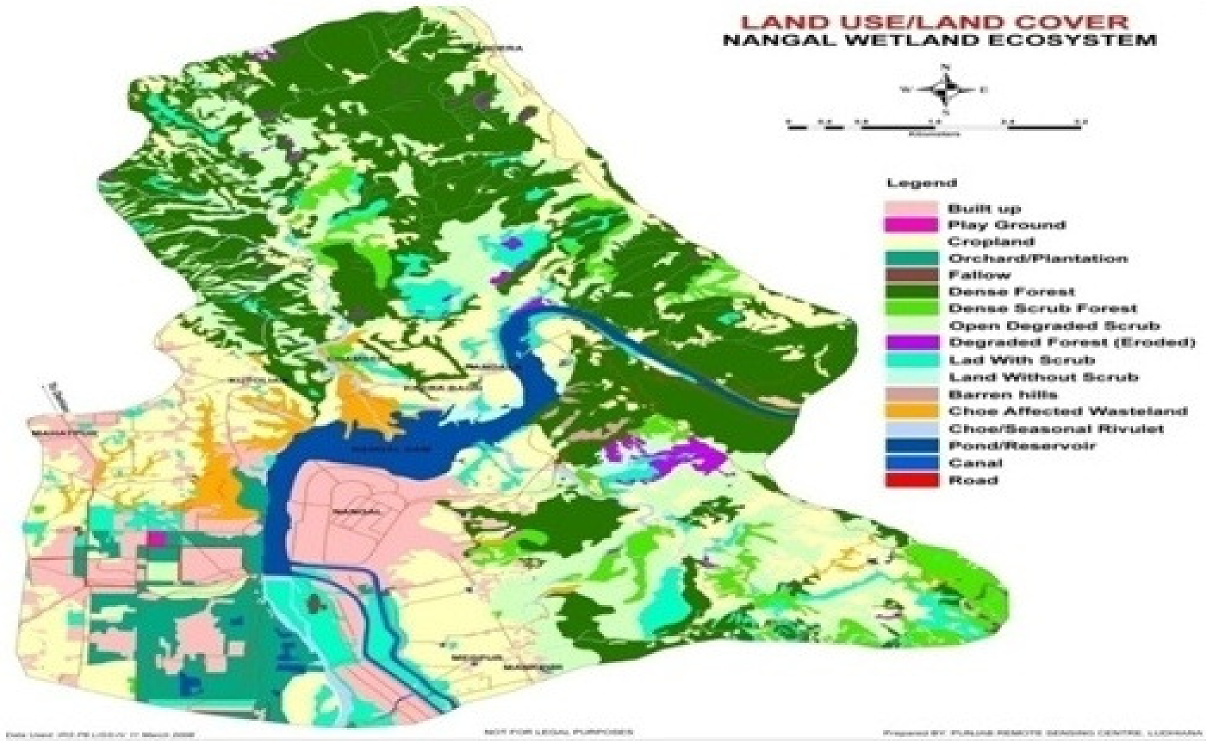

Figure-1
Map showing the Nangal Wetland

Table-2
Total monthly variations of phytoplankton (Individuals/L) at Nangal Wetland

Months/Classes	Cyanophyceae	Chlorophyceae	Bacillariophyceae	Total
February	54475	167975	119700	342150
March	73750	212700	226700	513150
April	74725	257800	239550	572075
May	75950	247550	221250	544750
June	17125	72075	87625	176825
July	18725	15700	76275	110700
August	30550	79950	119525	230025
September	42800	106675	159600	309075
October	41475	162150	157350	360975
November	46725	150450	152160	349335
December	24900	170950	133450	329300
January	27775	175925	102875	306575
Total	528975	1819900	1796060	4144935
Total Percentage	13%	44%	43%	

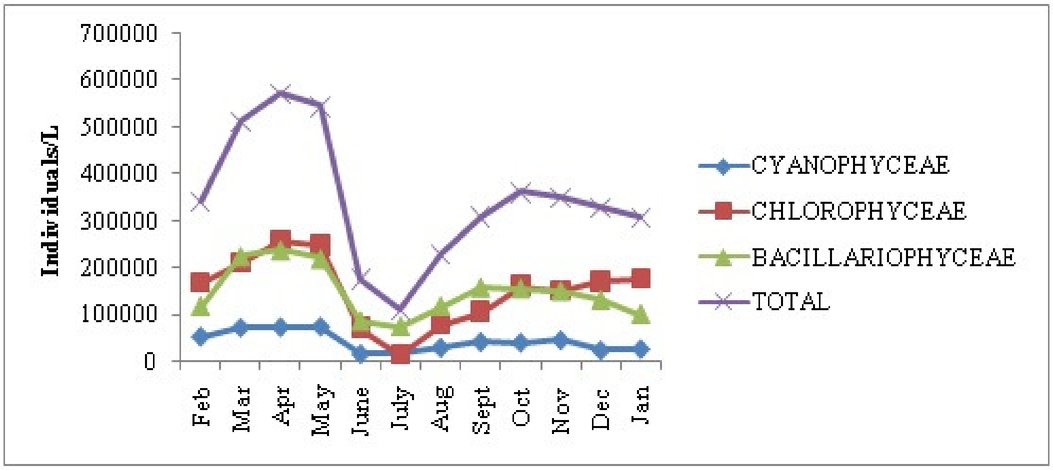

Figure-2
Monthly variation in total count (individuals L^{-1}) of different groups of phytoplankton

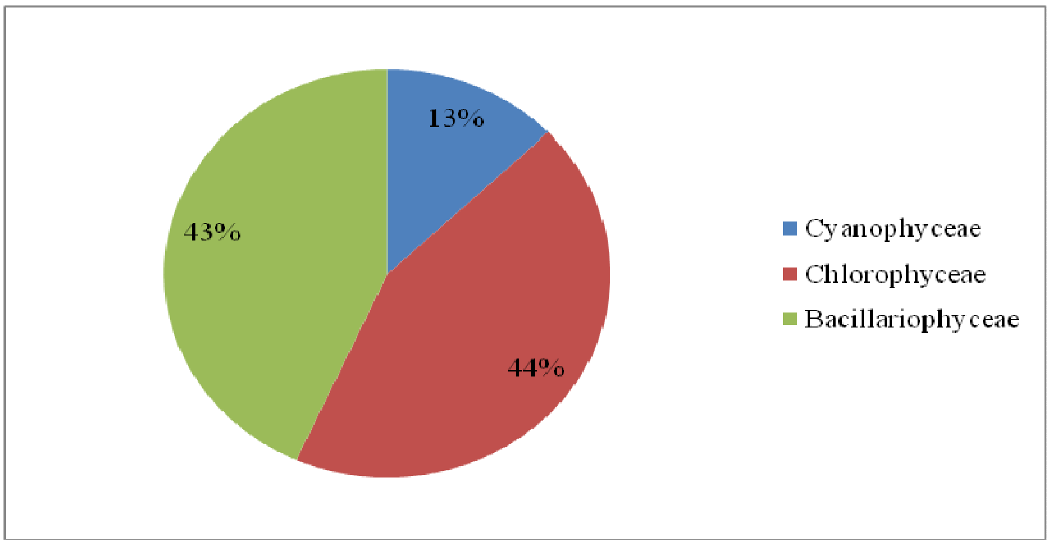

Figure-3
Percentage contribution of different groups of phytoplankton

Table 3 shows phytoplankton diversity indices of Nangal Wetland during the course ofpresentstudy period. Maximum species richness was recorded 1.67 Margalef's index (R1) and 0.05 Menhinick index (R2) for Chlorophyceae; minimum species richness was recorded 0.74 Margalef's index (R1) for Cyanophyceae and 0.04 Menhinick index (R2) for Cyanophyceae and Bacillariophyceae. Maximum species diversity was recorded 0.94 Simpson's index (λ) and 2.94 Shannon-Weiner index (H') for Chlorophyceae; minimum species diversity 0.88 Simpson's index (λ) for Cyanophyceae and 2.15 Shannon-Weiner index (H') for Bacillariophyceae. Species evenness of phytoplankton ranges 0.82-0.96. Maximum species evenness was recorded for Cyanophyceae; minimum species evenness was recorded for Bacillariophyceae. In the present study, the highest dominance index of phytoplankton was found for the class Cyanophyceae (0.11) and least for the class Chlorophyceae (0.05).

Table-3
Annual variations of phytoplankton biodiversity indices at Nangal Wetland

Indices	**Index**	**Cyano phyceae**	**Chloro phyceae**	**Bacillario phyceae**
	N_0	9	21	19
Species Richness	R_1	0.74	1.67	1.51
	R_2	0.04	0.05	0.04
Species Diversity	Λ	0.88	0.94	0.92
	H'	2.16	2.94	2.15
Species Evenness	E	0.96	0.90	0.82
Dominance	D	0.11	0.05	0.07

(N_0): No. of all species/genera, (R_1): Margalef's index, (R_2): Menhinick index, (λ): Simpson's index, (H'): Shannon-Weiner index, E: Evenness index

Discussion: It is observed that phytoplankton density varies with different seasons (table 2 and figure 2). It shows maximum count in spring, summer and monsoonal months which may be attributed to the increasing trend of temperature from spring season to summer season along with high amount of dissolved nutrients in the wetland water. With the onset of monsoon from the month of June onwards, phytoplankton density was reported to be decreased with the dilution of wetland waterand mixing of silt. Phytoplankton count was minimum in winter months which may be attributed to low water as well as ambient temperature in the wetland. The present results are also in conformity with results of other workers, who studied phytoplankton on some tropical freshwater bodies in India[25,26]. Some workers also studied that during summer, rise of temperature enhanced the rate of decomposition followed by evaporation, increase in nutrient concentration and presence of abundant food in the form of photosynthesis increases the phytoplankton density[27].

Some workers analyzed the qualitative and quantitative concepts of phytoplankton and recorded 43 species, of which 18 were from Chlorophyceae, 10 from Bacillariophyceae, 10 from Cyanophyceae and 5 from Euglenophyceae[28]. Another worker studied phytoplankton composition in relation to hydrochemical properties of Tropical Community Wetland, Kanewal, Gurarat, India, and recorded 45 species of phytoplankton represented by three classes of algae viz. Cyanophycceae, Chlorophyceae and Bacillariophyceae which includes 18, 17 and 9 taxa respectively[29].In a study of phytoplankton diversity on Wadhvana Wetland at Dabhoi Tahuka (Gujarat) India. Total 31 species belonging to 17 families of phytoplankton were recorded which included both algae as well as diatoms[30]. Some other workers studied seasonality in abundance, biomass and production of the phytoplankton of Welala and Shesher Wetlands, Lake Tana Sub-Basin (Ethiopia) and recorded 36 genera/species, belonging to 7 taxonomic groups. In their study, four genera of Cyanophyceae (blue green algae), 18 genera of Chlorophyceae (green algae), 10 genera of Bacillariophyceae (diatoms) and Chrysophyceae, Euglenophyceae, Desmidiaceae and Dinophyceae with one or two diatoms were observed[31]. During present course of work, total 49 genera of phytoplankton were recorded belonging to 3 classes viz.,Chlorophyceae with 21 genera were found to be dominant in the wetland, followed by Bacillariophyceae, 19 genera and Cyanophyceae, 9 genera. Similar observations of occurrence of phytoplankton from Lakes, Ponds and wetlands were made other scientists[9, 32-34].

Due to the action of photosynthesis, algae releases oxygen as by-product into the water that can be used by fishes and other aquatic animals which is a basic requirement for their propagation[35]. Qualitative and quantitative dominance of diatoms in an aquatic ecosystem is a major indicator of water quality and environmental condition as they are adapted to a wide range of physico-chemical parameters[36-38]. Algae are tiny aquatic plants that are found as single cells or in colonies of various sizes. They make a primary link in the aquatic food chain, acting as food for zooplankton, aquatic insects, fishes, birds and other aquatic animals[39]. In the present course of study, the order of dominance in term of diversity of phytoplankton is: Chlorophyceae>Bacillariophyceae>Cyanophyceae. They are excellent bio-indicators for water quality and source of food for plankton feeder insects, fishes, birds and other aquatic organisms.

The Simpsons index is often used to quantify the biodiversity of habitats. It takes into account the number of species present as well as the abundance of species. The greater the value greater is the sample diversity. According to the Simpson's index, in the present study the value ranges from 0.88-0.94, shows that species are not evenly distributed. Shannon's index (H′) encompasses species richness and spices evenness components as overall index of diversity. The higher values of Shannon's Index (H′), indicated the greater species diversity. This index also determines the pollution status of a water body. A scientist concluded that the normal values range from 0-4. The values of the index greater than 3 indicate clean water; 1-3 indicate moderate pollution and value less than 1 are characterized as heavily polluted[40]. In the present study, Shannon-Weiner diversity index ranges 2.15-2.94, it is clear that the wetland water show moderate pollutionlevel. The diversity index of Chlorophyceae, Cyanophyceae and Bacillariophyceae is 2.94, 2.16 and 2.15 respectively. According to this, Chlorophyceae shows higher diversity as compared to Cyanophyceae and Bacillariophyceae.

Both the Menhinick's and Margalef's indices measures richness of species in an ecosystem. In the present study, maximum and minimum species richness (Menhinick index R2) was found to be 0.05 for Chlorophyceae and 0.04 for both Cyanophyceae and Bacillariophyceae. Maximum and minimum species richness (Margalef's index R1) was found to be 1.67 for Chlorophyceae and 0.74 for Cyanophyceae. A related study of preliminary survey of plankton in Irrukkangudi reservoir, Virudhunagar District, Tamil Nadu, India reported monthly variations of the diversity indices for the phytoplankton. The Margalef index (R1) of phytoplankton was minimum (0.528) during October 2005 and maximum (3.235) during January 2006. An increasing trend was observed from October 2005 to January 2006 (0.528, 2.024, 2.962, 3.235). In the remaining period fluctuations were observed. The Menhinickindex (R2) was maximum (2.345) during January 2006 and minimum 0.452 in October 2005. An increasing trend was observed from October 2005 to January 2006 (0.452, 1.248, 1.874, 2.345)[41].

The evenness index is a measure of the evenness with which individuals are divided among the taxa present. In the present study, the value ranges from 0.82-0.96, which indicates that the individuals of the community were not evenly distributed. The evenness value of Cyanophyceae, Chlorophyceae and Bacillariophyceae is 0.96, 0.90 and 0.82 respectively. And the highest dominance index of phytoplankton was found for the class Cyanophyceae (0.11) and least for the class Chlorophyceae (0.05) (table 3). Some other workers recorded similar results in which they findmaximum evenness values for species poor and evenly distributed Euglenophyceae (0.9302), against the minimum for Cyanophyceae (0.6054).Highest values for species dominance were recorded for Cyanophyceae (0.2485) and lowest for Baccilariophyceae (0.04154)[42].

Conclusion

From the above results, it could be concluded that the Chlorophyceae were identified as seasonally dominated followed by Bacillariophyceae and Cyanophyceae. Shannon-Weiner diversity index ranges 2.15-2.94, it is clear that the wetland water show moderate pollution level. So, phytoplankton study is very important because they act as primary producers and an efficient bio-indicator for water quality.

Acknowledgements

Authors are very thankful to the Head, Department of Zoology & Environmental Sciences, Punjabi University, Patiala for providing necessary laboratory facilities.

References

1. Mitsch W.J. and Gosselink, I.G., Wetlands, *Van Nostrand Reinhold, New York*, **(1986)**

2. Stanley E.H. and Ward A.K., Inorganic nitrogen regimes in an Albamawetland, *J. N. Am. Benthol. Soc.*, **16**, 820-832 **(1997)**

3. Mann C.J. and Wetzel R.G., Dissolved organic carbon and its utilization in a riverine wetland ecosystem, *Biogeochemistry*, **31**, 99-120 **(1995)**

4. Mustapha M.K., Seasonal influence of limnological variables on plankton dynamics of a small shallow, Tropical African Reservoir, *Asian J. Exp. Biol. Sci.,***1**, 60-79 **(2010)**

5. Round F.E., The ecology of algae, *Cambridge University Press, Cambridge*, **(1984)**

6. Gandhi H.P., Fresh water diatoms of Central Gurarat, *ISBN*, 324, **(1998)**

7. Rajesh K.M., Gowda G. and Mendon R.M., Primary Productivity of the concentrations of cadmium, lead and mercury in view of health effect on brackish water impoundments along Nethravathi estuary, Mangalore in relation to characteristics of nutrient and phytoplankton dynamics in the York River Englewood Cliffs, New Jersey, **(2002)**

8. Ananthan G., Sampathkumar P., Soundarapandian P., and Kannan L., Observation on environmental characteristics of Ariyankuppam estuary and Verampattinam coast of Pondicherry, *J. Aquat. Biol.*, **19**, 67-72 **(2004)**

9. Tiwari A. and Chauhan S.V.S., Seasonal phytoplankton diversity of Kitham lake, Agra, *J. Environ. Biol.*, **27**, 35-38 **(2006)**

10. Wetzel R.G., In: River Ecology (Edition BA Whitton), Blackwell scientific Publication Oxford, 230-245 **(1975)**

11. Saha B.B. and Choudhary A.B., Photosysnthetic activity in relation to hydrological characterstics of a brakish water tidal ecosystem of sundarbans in West Bengal India, *J. Environ. Biol.*, **21**, 9-14 **(2000)**

12. Sinha V.R.P. and Srivastava H.C., Aquaculture Productivity Oxford and IHB Publishing Co. Pvt. Ltd. New Delhi. – In: Muhammad A, Abdus S, Sumayya I, Tasveer ZB, Kamran AQ (eds) (2005). Studies on monthly variations in biological and physico-chemical parameters of brackish water fish Pond, Muzaffar Garh, Bahauddin Zakariya University, Multan, Pakistan, *J. Sci. Res.*, **16**, 27-38 **(1991)**

13. Muhammad A., Abdus S., Sumayya I., Tasveer Z.B. and Kamran A.Q., Studies on monthly variations in biological and physico-chemical parameters of brackish water fish Pond, Muzaffar Garh, Bahauddin Zakariya University, Multan, Pakistan, *J. Sci. Res.*, **16**, 27-38 **(2005)**

14. Thurman H.V., Introductory Oceanography, Prentice Hall New Jersey, USA, **(1997)**

15. Krishna G. and Sinha R., Algal Spectrum of a Wetland and its Correlation with the Physico-Chemical Parameters, *Int. Res. J. Environ. Sci.*, **3**, 27-30 **(2014)**

16. Punjab State Council for Science and Technology, Nangal Reservoir-The Lake of National Importance, Punjab State Council for Science and Technology, Chandigarh, **(1994)**

17. Welch P.S., Limnological methods, McGraw Hill, New York, USA, **(1948)**

18. Needham G.T. and Needham P.R., A Guide to Freshwater Biology, 5th Edition, Holden Day Inc Sanfransisco, 108 **(1966)**

19. Edmondson W.T., Ward and Whipple's Freshwater Biology, 2nd (ed.), Wiley J and Sons, New York, 1248 **(1992)**

20. American Public Health Association, Standard methods for the examination of water and waste water, 21sted., American Public Health Association, American Water Works Association and Water Environment Federation, New York **(2012)**

21. Shannon C.E. and Weaver W., The mathematical theory of communication, University of Illinois Press, Urbana, **(1949)**

22. Simpson E.H., Measurement of diversity, *Nature*, **163**, 688 **(1949)**

23. Margalef R., Information theory in ecology, *General Sys-*

thematic, **3**, 36-71 **(1958)**

24. Menhinick E.P., A Comparison of some species - Individuals diversity indices applied to samples of field insects, *Ecol.*, **45**, 859-881 **(1964)**

25. Sreenivasan R., Sounder R. and Franklin T., Dirunal and seasonal changes in a productive shallow tropical pond, *J. Phycol. Soc.*, **86**, 103 **(1974)**

26. Hujare M.S., 2008. Seasonal variation of phytoplankton in the freshwater tank of Talsande, Maharastra, *Nat. Environ. Poll. Tech.*, **7**, 253-256 **(2008)**

27. Santhanam P. and Perumal P., Diversity of zooplankton in Parangipettai coastal waters south east coast of India, *J. Mar. Biol. Assoc.*, **45**, 144-151 **(2003)**

28. Pulle J.S. and Khan A.M., Phytoplanktonic study of Isapur dam water, *Ecol. Environ. Conserv.*, **9**, 403-406 **(2003)**

29. Nirmal Kumar J.I., Phytoplankton Composition in Relation to Hydrochemical Properties of Tropical Community Wetland, Kanewal, Gujarat, India, *Appl. Ecol. Environ. Res.*, **9**, 279-292 **(2011)**

30. Dabgar P.J., Phytoplankton diversity on Wadhvana Wetland at DabhoiTaluka (Gujarat) India, *Plant Sci. Feed*, **2**, 85-87 **(2012)**

31. Wondmagegne T., Wondie A., Mingist M. and Vijverberg J., Seasonality in Abundance, Biomass and Production of the phytoplankton of Welala and Shesher Wetlands, Lake Tana Sub-Basin (Ethiopia),*J. Water Res. Prot.*,**4**, 877-884 **(2012)**

32. Balasingh G.S.R. and Shamal V.P.S., Phytoplankton diversity of a perennial pond in Kanyakumari District, *J. Basic Appl. Biol.*, **1**, 23-26 **(2007)**

33. Laskar H.S. and Gupta S., Phytoplankton diversity and dynamics of Chatla floodplain lake, Barak Valley, Assam, Northeast India - A seasonal study, *J. Environ. Biol.,* **30**, 1007-1012 **(2009)**

34. Adesalu T.A., Phytoplankton dynamics of river Oli in Kainjii lake National Park, Nigeria during dry season, *Int. J. Bot.*,**6**, 112-116**(2010)**

35. Battish S.K., Freshwater Zooplankton of India, *Oxford and IBM Publications*,**(1992)**

36. Wackstrom J., Korhola A. and Blom T., Diatoms as quantitative indicators of pH and water temperature in subarticfennoscandianlakes, *Hydrobiol.*, **347**, 171-184 **(1997)**

37. Kelly M.G., Use of the trophic diatom index to monitor eutrophication in rivers, *Water Resour.*, **32**, 236-242 **(1998)**

38. Ajuonu N., Ukaonu S.U., Oluwajoba E.O., Mbawuike B.E., Williams A.B., Myade E.F., The abundance and distribution of plankton species in the Bonny Estuary, Nigeria, *Agr. Biol. J. N. Am.*, **2**, 1032-1037 **(2011)**

39. Baghela B.S., Studies on Biodiversity, Survival and Density of Freshwater Zooplankton in Relation to Salinity changes, Thesis M.L. Sukhadia University, Udaipur, **(2006)**

40. Wilham J.L. and Dorris T.C., Biological parameters of water quality criteria, *Bioscience*, 18, 447-481 **(1968)**

41. Kanagasabapathi V. and Rajan M.K., A preliminary survey of plankton in Irrukkangudi reservoir, Virudhunagar District, T.N., India, *J. Phytol.,* **2**, 63–72 **(2010)**

42. Baba A.I. and Pandit A.K., Species composition, diversity and population dynamics of phytoplankton at Saderkot in Wular Lake, Kashmir, *Ecosystem and Ecography*, **4**,142. Doi: 10.4172/2157-725.1000142 **(2014)**