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Spatial and Temporal Distribution of Phytoplankton from Ropar Wetland (Ramsar Site) Punjab, India

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Abstract Wetlands are considered as important ecosystems on this earth because they provide refuge and food to variety of aquatic biodiversity. Spatial heterogeneity of the phytoplankton community and seasonal diversity has been observed. Sampling of phytoplankton was carried out from the Ropar wetland, of Punjab, India between October 2015 to September 2017 at four representative sites (S1, S2, S3 and S4). Correlation of physico-chemical variables with phytoplankton density was recorded by using Pearson Correlation analysis and seasonal variation as well as a high influence of these physico-chemical parameters was observed on phytoplankton productivity. It has been observed that when temperature and amount of nutrients were higher, the density of phytoplankton was higher. The phytoplankton diversity showed higher sensitivity in the water, the dissolved oxygen and free CO2 showed significant negative correlation with all the physio-chemical parameters at all the sites. A total of 28 phytoplankton genera belonging to Bacillariophyceae (14 genera) Chlorophyceae (9 genera), Cyanophyceae (4 genera) and Dinophyceae (1 genus) were recorded from four sampling sites. Bacillariophyceae dominated both in diversity and percentage composition while Dinophyceae had shown least expression. Phytoplankton population showed high diversity in the summer and low in monsoon period. Various diversity indices (Shannon-Wiener diversity index, Simpson's diversity index and Pielou evenness index) were used to found the seasonal variation of phytoplankton. The Shannon- Wiener diversity index was most useful in indicating the trophic status of the water as well as the pollution status, which in this case, depicted a moderate level of pollution in this wetland.

Keywords: *wetland, correlation coefficient, diversity indices, phytoplankton, seasonal variation*

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1. Introduction

Wetlands are major resource of fresh water and it was very essential part of human life, mainly for drinking and domestic purposes. The rapid increasing of human population and industrialization has created problems of disposal of waste water products. The undesirable and toxic substances are regularly discharged into the wetlands through surface run off that degrades the water quality [1]. The Environmental disturbance can induce changes in biological systems and it was reflecting the occurrence, distribution and diversity of biotic communities [2].

Phytoplankton is microscopic unicellular aquatic plants and they convert solar radient energy into biological energy through photosynthesis. This energy is transferred to higher organisms through food chain [3,4]. Phytoplankton are highly diverse group of photoautotrophic organisms with chlorophyll-a and unicellular reproductive structures, which are important for aquatic habitats [5,6]. They are important primary producers in the base of the food chain, constitute a vital link and an important biological indicator of the water quality [7]. Thus, study of phytoplankton is very useful tool for the assessment of water quality in any type of water body and also contributes to the understanding of basic nature and general economy of the lake [8]. Phytoplankton is the primary producer community and consists mainly of algae such as diatoms, dinoflagellates and a variety of forms from other divisions of the plant kingdom. These are very sensitive to the environment they live in and any alteration in the environment leads to the change in their communities in terms of tolerance, abundance, diversity and dominance in the habitat [9]. Water maintains an ecological balance between various group of living organism and their environment [10]. Phytoplankton study provides a relevant and convenient point of focus for research on the mechanism of eutrophication and its adverse impact on aquatic ecosystem [11].

Hence, monitoring of aquatic ecosystems from phytoplankton study point of view is very important to initiate conservation and management programs. This study provides fundamental information on the phytoplankton species diversity, abundance and the influence of physico-chemical parameters of water on phytoplankton population, species composition and community organization in Ropar wetland.

2. Materials and Methods

2.1. Study Area

Ropar Wetland is a manmade freshwater riverine as well as lacustrine wetland. It came into existence with the impoundment of water by constructing a barrage on the river Sutlej near Ropar town (Figure 1). It is situated at 30°58′-31°02′N latitude and 76°30′-76°33′E longitude. This important ecological zone is located in the Shivalik foothills of the Lower Himalayas and was created in 1952 on the Sutlej River, in the Punjab State of India, by building a head regulator to store and divert water for beneficial uses of irrigation through canals, drinking and industrial water supply. [12].

2.2. Collection, Preservation and Identification of Phytoplankton Samples

Four representative sampling sites i.e. S1, S2, S3, S4 were identified keeping in view of the variation in the microhabitat and hydrological features of the Ropar wetland (Figure 1). Sampling sites were recognized with an objective of obtaining Phytoplankton samples and physico-chemical parameters from the wetland. Samples were collected on monthly basis from October 2015 to September 2017 for a period of two years. Plankton net was made by using nylon bolting cloth having mesh size of (24 mesh/mm2) used for the collection of plankton samples. 100 litres of water was sieved every time through the net. Samples were collected and preserved in 5% formaldehyde solution in plastic sample bottles and transported to the Fish and Fisheries laboratory, Department of Zoology and Environmental Sciences, Punjabi University, Patiala, for identification and further analysis as per [13,14]. In the laboratory, plankton slides were prepared for identification. Identification and counting of phytoplankton were done by use of binocular light microscope. Sedgwick Rafter Counting Chamber was used to determine their density [15]. The plankton was identified to genus level as per the guidelines given by [14,16,17,18].

Figure 1. Map of the study area (Ropar Wetland)

2.3. Determination of Biological Parameters

Statistical analysis of the data generated was made in Microsoft Excel and PAST software. The statistical calculations like range, statistical mean, standard deviation (S.D.) and Pearson correlation coefficient between different physico-chemical factors and phytoplankton diversity were determined.

2.4. Data Analysis

The percentage occurrence and relative numerical abundance of phytoplankton was subjected to diversity analysis using different indices like Shannon Diversity Index "H" [19], Pielou Evenness Index "J" [20] and Simpson Diversity Index"D" [21].

3. Results and Discussion

In any aquatic environments, the diversity, distribution, and variation in the biotic parameters provide a good indication of energy [22]. Phytoplankton is characterized as a major source of organic carbon and is situated at the bottom level within these environments [23]. The sensitivity and fluctuation in species composition are usually a suitable account to reveal the alteration within an ecosystem [24]. Species diversity responds to changes in environmental gradients and may characterize many interactions that can establish the complicated pattern of community structure. Normally, it is found that any slight alteration in environmental status can change diversity until there is no adaptation or gene flow from non adaptive sources. A high diversity count suggests a healthy ecosystem and the low diversity indicates a degraded environment. A study on phytoplankton of Ropar Wetland, Punjab was carried out for two years, from October, 2015 to September, 2017. Four representative sampling sites i.e. S1, S2, S3, S4 were identified keeping in view of the variation in the microhabitat and hydrological features of the Ropar wetland. A study area observed various seasons and widely divided into winter (December to February), summer (March to May), monsoon (June to August) and autumn (September to November). Phytoplankton population was composed of 4 major groups of algae namely Cyanophyceae (blue green algae), Chlorophyceae (green algae), Bacillariophyceae (diatoms) and Dinophyceae (Dinoflagellates) in fresh water ecosystem. At all the sites a total of 28 genera of phytoplankton were recorded belonging to 4 major classes, among these, Bacillariophyceae with 14 genera were found to be dominant followed by Chlorophyceae with 9 genera, Cyanophyceae with 4 genera and Dinophyceae with 1 genus (Table 1, Table 2, Table 3, Table 4). The overall class-wise representation of phytoplanktonic diversity and their order of dominance are as follows: **Bacillariophyceae> Chlorophyceae> Cyanophyceae> Dinophyceae.** Similar observations of occurrence of phytoplankton from lakes, ponds and wetlands were also studied by other scientists [3,25,26,27].

Table 1. Mean, S.D., range and seasonal variations of phytoplankton (ind/L) of Ropar Wetland at S1 site from October 2015 to September 2017

Phytoplankton(units/L)/ Month	Winter season	Summer season	Monsoon season	Autumn season	October 2015 to September 2017	
CYNOPHYCEAE	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Range**
Anabeana spp.	4441.66±548.33	5700±814.55	3425±548.17	4916.66±553.32	4620.83±1024.47	2900-7025
Merismopedia spp.	4533.33±548.78	6625±560.35	4416.66±552.41	5550±548.17	5281.25±1047	3825-7275
Oscillatoria spp.	7341.66±557.82	8525±548.17	6158.33±561.39	7550±548.17	7393.75±1002.93	5500-9050
Spirulina spp.	6450±548.17	7525±548.17	5450±548.17	6550±548.17	6493.75±907.88	4925-8050
CHLOROPHYCEAE						
Chlorella spp.	4450±548.17	5550±548.17	3425±548.17	5450±548.17	4718.75±1018.10	2900-6075
Cladophore spp.	6450±548.17	7850±548.17	5450±548.17	7450±548.17	6800±1080.05	4925-8375
Closterium spp.	7450±548.17	8750±548.17	6450±548.17	8450±548.17	7775±1055.31	5925-9275
Cosmarium spp.	5450±548.17	6750±548.17	4450±548.17	6450±548.17	5775±1055.31	3925-7275
Pediastrum spp.	7450±548.17	8750±548.17	6450±548.17	8450±548.17	7775±1055.31	5925-9275
Selenastrum spp.	7450±548.17	8825±548.17	6425±548.17	8450±548.17	7787.5±1081.94	5900-9350
Spirogyra spp.	7441.66±547.87	8525±548.17	6450±548.17	8450±548.17	7716.66±1005.11	5925-9050
Stigeoclonium spp.	6450±548.17	7658.33±547.87	5450±548.17	7433.33±548.78	6747.91±1030.90	4925-8175
Ulothrix spp.	6425±548.17	7950±548.17	5425±548.17	7150±718.67	6737.5±1100.46	4900-8475
BACILLARIOPHYCEAE						
Cymbella spp.	6450±548.17	7550±548.17	5425±548.17	7433.33±548.78	6714.58±1015.07	4900-8075
Denticula spp.	7433.33±548.78	8850±548.17	6450±548.17	8425±548.17	7789.58±1077.66	5925-9375
Fragilaria spp.	6466.66±547.87	7525±548.17	5450±548.17	7450±548.17	6722.91±1003.38	4925-8050
Gomphonema spp.	7450±548.17	8525±548.17	6450±548.17	8466.66±547.87	7722.91±1007.71	5925-9050
Gyrosigma spp.	6441.66±548.78	7766.66±652.81	5350±548.17	7425±548.17	6745.83±1101.52	4825-8725
Navicula spp.	7358.33±550.15	8791.66±548.33	6333.33±557.82	8366.66±555.12	7712.5±1100.07	5700-9325
Nitzschia spp.	6233.33±548.78	7575±549.54	5050±548.17	7033.33±547.87	6472.91±1097.10	4525-8125
Meridion spp.	6450±548.17	7833.33±547.87	5441.66±548.33	7450±548.17	6793.75±1078.55	4925-8350
Pinnularia spp.	7425±548.17	8550±548.17	6466.66±547.87	8416.66±547.87	7714.58±999.97	5950-9075
Pleurosigma spp.	7333.33±548.78	8816.66±547.87	6450±548.17	8216.66±547.87	7704.16±1048.28	5925-9325
Synedra spp.	6333.33±548.78	7725±548.17	5335±547.94	7233.33±548.78	6656.66±1062.53	4825-8250
Tabellaria spp.	6450±548.17	7825±548.17	5408.33±549.69	7441.66±548.78	6781.25±1086.33	4850-8350
Cocconeis spp.	7400±550.90	8925±547.72	6466.66±547.87	8325±549.54	7779.16±1081.30	5950-9425
Cyclotella spp.	7016.66±682.76	8866.66±547.87	6450±548.17	7866.66±613.32	7550±1087.17	5925-9375
DINOPHYCEAE						
Ceratium spp.	6016.66±587.50	7525±548.17	5458.33±548.33	7358.33±557.37	6589.58±1036.89	4925-8050
Total	**1104250**	**1329800**	**944460**	**1255250**		

Table 2. Mean, S.D., range and seasonal variations of phytoplankton (ind/L) of Ropar Wetland at S2 site from October 2015 to September 2017

Phytoplankton(units/L)/ Month	Winter season	Summer season	Monsoon season	Autumn season	October 2015 to September 2017	
CYNOPHYCEAE	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Range**
Anabeana spp.	5441.66±548.33	6866.66±748.44	4425±548.17	5916.66±553.32	5662.5±1061.3	3900-8025
Merismopedia spp.	5533.33±548.78	7625±560.35	5416.66±552.41	6550±548.17	6281.25±1047	4825-8275
Oscillatoria spp.	8341.66±557.82	9525±548.17	7158.33±561.39	8383.33±822.90	8352.08±1039.04	6500-10050
Spirulina spp.	7450±548.17	8525±548.17	6450±548.17	7550±548.17	7493.75±907.88	5925-9050
CHLOROPHYCEAE						
Chlorella spp.	5450±548.17	6550±548.17	4425±548.17	6450±548.17	5718.75±1018.10	3900-7075
Cladophore spp.	6450±548.17	7850±548.17	5450±548.17	7450±548.17	6800±1080.05	4925-8375
Closterium spp.	8450±548.17	9750±548.17	7450±548.17	9450±548.17	8775±1055.31	6925-10275
Cosmarium spp.	6450±548.17	7750±548.17	5450±548.17	7450±548.17	6775±1055.31	4925-8275
Pediastrum spp.	8450±548.17	9750±548.17	7450±548.17	9450±548.17	8775±1055.31	6925-10275
Selenastrum spp.	8450±548.17	9825±548.17	7425±548.17	9450±548.17	8787.5±1081.94	6900-10350
Spirogyra spp.	8441.66±547.87	9525±548.17	7450±548.17	9450±548.17	8716.66±1005.11	6925-10050
Stigeoclonium spp.	7450±548.17	8658.33±547.87	6450±548.17	8600±809.01	7789.58±1097.55	5925-9900
Ulothrix spp.	7425±548.17	8950±548.17	6425±548.17	8150±718.67	7737.5±1100.46	5900-9475
BACILLARIOPHYCEAE						
Cymbella spp.	7450±548.17	8550±548.17	6425±548.17	8433.33±548.78	7714.58±1015.07	5900-9075
Denticula spp.	8433.33±548.78	9850±548.17	7450±548.17	9425±548.17	8789.58±1077.66	6925-10375
Fragilaria spp.	7466.66±547.87	8525±548.17	6450±548.17	8450±548.17	7722.91±1003.38	5925-9050
Gomphonema spp.	8450±548.17	9525±548.17	7450±548.17	9466.66±547.87	8722.91±1007.71	6925-10050
Gyrosigma spp.	7441.66±548.78	8766.66±652.81	6350±548.17	8425±548.17	7745.83±1101.52	5825-9725
Navicula spp.	8358.33±550.15	9791.66±548.33	7333.33±557.82	9366.66±555.12	8712.5±1100.07	6700-10325
Nitzschia spp.	7233.33±548.78	8575±549.54	6050±548.17	8033.33±547.87	7472.91±1097.10	5525-9125
Meridion spp.	7450±548.17	8833.33±547.87	6441.66±548.33	8450±548.17	7793.75±1078.55	5925-9350
Pinnularia spp.	8425±548.17	9550±548.17	7466.66±547.87	9416.66±547.87	8714.58±999.97	6950-10075
Pleurosigma spp.	8333.33±548.78	9816.66±547.87	7450±548.17	9216.66±547.87	8704.16±1048.28	6925-10325
Synedra spp.	7333.33±548.78	8558.33±822.90	6335±547.94	8233.33±548.78	7615±1059.91	5825-9250
Tabellaria spp.	7450±548.17	8825±548.17	6408.33±549.69	8441.66±548.78	7781.25±1086.33	5850-9350
Cocconeis spp.	8400±550.90	9925±547.72	7466.66±547.87	9325±549.54	8779.16±1081.30	6950-10425
Cyclotella spp.	8016.66±682.76	9866.66±547.87	7450±548.17	8866.66±613.32	8550±1087.17	6925-10375
DINOPHYCEAE						
Ceratium spp.	7016.66±587.50	8525±548.17	6458.33±548.33	8358.33±557.37	7589.58±1036.89	5925-9050
Total	**1266250**	**1491800**	**1106460**	**1417250**		

Table 3. Mean, S.D., range and seasonal variations of phytoplankton (ind/L) of Ropar Wetland at S3 site from October 2015 to September 2017

Phytoplankton(units/L)/ Month	Winter season	Summer season	Monsoon season	Autumn season	October 2015 to September 2017	
CYNOPHYCEAE	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Range**
Anabeana spp.	3441.66±548.33	4533.33±547.87	2425±548.17	3916.66±553.32	3579.16±939.23	1900-5050
Merismopedia spp.	3533.33±548.78	5625±560.35	3416.66±552.41	4550±548.17	4281.25±1047	2825-6275
Oscillatoria spp.	6675±710.28	7525±548.17	5158.33±561.39	6550±548.17	6477.08±1029.85	4500-8050
Spirulina spp.	5450±548.17	6525±548.17	4450±548.17	5550±548.17	5493.75±907.88	3925-7050
CHLOROPHYCEAE						
Chlorella spp.	3450±548.17	4550±548.17	2425±548.17	4450±548.17	3718.75±1018.10	1900-5075
Cladophore spp.	5450±548.17	6850±548.17	4450±548.17	6450±548.17	5800±1080.05	3925-7375
Closterium spp.	6450±548.17	7750±548.17	5450±548.17	7450±548.17	6775±1055.31	4925-8275
Cosmarium spp.	4450±548.17	5750±548.17	3450±548.17	5450±548.17	4775±1055.31	2925-6275
Pediastrum spp.	6450±548.17	7750±548.17	5450±548.17	7450±548.17	6775±1055.31	4925-8275
Selenastrum spp.	6450±548.17	7825±548.17	5425±548.17	7450±548.17	6787.5±1081.94	4900-8350
Spirogyra spp.	6441.66±547.87	7525±548.17	5450±548.17	7450±548.17	6716.66±1005.11	4925-8050
Stigeoclonium spp.	4450±548.17	5658.33±547.87	3450±548.17	5433.33±548.78	4747.91±1030.90	2925-6175
Ulothrix spp.	4425±548.17	5950±548.17	3425±548.17	5150±718.67	4737.5±1100.46	2900-6475
BACILLARIOPHYCEAE						
Cymbella spp.	4450±548.17	5550±548.17	3591.66±822.90	5433.33±548.78	4756.25±1002.77	2900-6075
Denticula spp.	5433.33±548.78	6850±548.17	4450±548.17	6425±548.17	5789.58±1077.66	3925-7375
Fragilaria spp.	4466.66±547.87	5525±548.17	3450±548.17	5450±548.17	4722.91±1003.38	2925-6050
Gomphonema spp.	5450±548.17	6525±548.17	4450±548.17	6466.66±547.87	5722.91±1007.71	3925-7050
Gyrosigma spp.	5441.66±548.78	6766.66±652.81	4350±548.17	6425±548.17	5745.83±1101.52	3825-7725
Navicula spp.	6358.33±550.15	7791.66±548.33	5333.33±557.82	7366.66±555.12	6712.5±1100.07	4700-8325
Nitzschia spp.	5233.33±548.78	6575±549.54	4050±548.17	6033.33±547.87	5472.91±1097.10	3525-7125
Meridion spp.	5450±548.17	6833.33±547.87	4441.66±548.33	6450±548.17	5793.75±1078.55	3925-7350
Pinnularia spp.	6425±548.17	7550±548.17	5466.66±547.87	7416.66±547.87	6714.58±999.97	4950-8075
Pleurosigma spp.	6333.33±548.78	7816.66±547.87	5450±548.17	7216.66±547.87	6704.16±1048.28	4925-8325
Synedra spp.	5333.33±548.78	6725±548.17	4335±547.94	6233.33±548.78	5656.66±1062.53	3825-7250
Tabellaria spp.	5450±548.17	6825±548.17	4408.33±549.69	6441.66±548.78	5781.25±1086.33	3850-7350
Cocconeis spp.	6400±550.90	7925±547.72	5466.66±547.87	7325±549.54	6779.16±1081.30	4950-8425
Cyclotella spp.	6016.66±682.76	7866.66±547.87	5450±548.17	6866.66±613.32	6550±1087.17	4925-8375
DINOPHYCEAE						
Ceratium spp.	5016.66±587.50	6525±548.17	4458.33±548.33	6358.33±557.37	5589.58±1036.89	3925-7050
Total	**902250**	**1124800**	**741460**	**1051250**		

Table 4. Mean, S.D., range and seasonal variations of phytoplankton (ind/L) of Ropar Wetland at S4 site from October 2015 to September 2017

Phytoplankton(units/L)/ Month	Winter season	Summer season	Monsoon season	Autumn season	October 2015 to September 2017	
CYNOPHYCEAE	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Mean±S.D.**	**Range**
Anabeana spp.	6441.66±548.33	7700±814.55	5425±548.17	6916.66±553.32	3579.16±939.23	1900-5050
Merismopedia spp.	6533.33±548.78	8625±560.35	6416.66±552.41	7550±548.17	4281.25±1047	2825-6275
Oscillatoria spp.	9341.66±557.82	10525±548.17	8158.33±561.39	9550±548.17	6477.08±1029.85	4500-8050
Spirulina spp.	8450±548.17	9525±548.17	7450±548.17	8550±548.17	5493.75±907.88	3925-7050
CHLOROPHYCEAE						
Chlorella spp.	6450±548.17	7550±548.17	5425±548.17	7450±548.17	3718.75±1018.10	1900-5075
Cladophore spp.	7450±548.17	8850±548.17	6450±548.17	8450±548.17	5800±1080.05	3925-7375
Closterium spp.	9450±548.17	10750±548.17	8450±548.17	10450±548.17	6775±1055.31	4925-8275
Cosmarium spp.	7450±548.17	8750±548.17	6450±548.17	8450±548.17	4775±1055.31	2925-6275
Pediastrum spp.	9450±548.17	10750±548.17	8450±548.17	10450±548.17	6775±1055.31	4925-8275
Selenastrum spp.	9450±548.17	10825±548.17	8425±548.17	10450±548.17	6787.5±1081.94	4900-8350
Spirogyra spp.	9441.66±547.87	10525±548.17	8450±548.17	10450±548.17	6716.66±1005.11	4925-8050
Stigeoclonium spp.	8450±548.17	9658.33±547.87	7450±548.17	9433.33±548.78	4747.91±1030.90	2925-6175
Ulothrix spp.	8425±548.17	9950±548.17	7425±548.17	9150±718.67	4737.5±1100.46	2900-6475
BACILLARIOPHYCEAE						
Cymbella spp.	8450±548.17	9550±548.17	7425±548.17	9433.33±548.78	4756.25±1002.77	2900-6075
Denticula spp.	9433.33±548.78	10850±548.17	8450±548.17	10425±548.17	5789.58±1077.66	3925-7375
Fragilaria spp.	8466.66±547.87	9525±548.17	7450±548.17	9450±548.17	4722.91±1003.38	2925-6050
Gomphonema spp.	9450±548.17	10525±548.17	8450±548.17	10466.67±547.87	5722.91±1007.71	3925-7050
Gyrosigma spp.	8441.66±548.78	9766.66±652.81	7350±548.17	9425±548.17	5745.83±1101.52	3825-7725
Navicula spp.	9358.33±550.15	10791.67±548.33	8333.33±557.82	10366.67±555.12	6712.5±1100.07	4700-8325
Nitzschia spp.	8233.33±548.78	9575±549.54	7050±548.17	9033.33±547.87	5472.91±1097.10	3525-7125
Meridion spp.	8450±548.17	9833.33±547.87	7441.66±548.33	9450±548.17	5793.75±1078.55	3925-7350
Pinnularia spp.	9425±548.17	10550±548.17	8466.66±547.87	10416.67±547.87	6714.58±999.97	4950-8075
Pleurosigma spp.	9333.33±548.78	10816.67±547.87	8450±548.17	10216.67±547.87	6704.16±1048.28	4925-8325
Synedra spp.	8333.33±548.78	9725±548.17	7500.83±822.31	9233.33±548.78	5656.66±1062.53	3825-7250
Tabellaria spp.	8450±548.17	9825±548.17	7408.33±549.69	9441.66±548.78	5781.25±1086.33	3850-7350
Cocconeis spp.	9400±550.90	10925±547.72	8466.66±547.87	10325±549.54	6779.16±1081.30	4950-8425
Cyclotella spp.	9016.66±682.76	10866.67±547.87	8450±548.17	9866.66±613.32	6550±1087.17	4925-8375
DINOPHYCEAE						
Ceratium spp.	8016.66±587.50	9525±548.17	7458.33±548.33	9358.33±557.37	5589.58±1036.89	3925-7050
Total	**1434250**	**1659800**	**1275455**	**1585250**		

Monthly variations in total count (ind/L) of phytoplankton from October, 2015 to September, 2017 are presented with bar graphs at all the sites (Figure 2). Maximum phytoplankton diversity was observed in the month of April 2017 at S2 and S4 site (263800 ind/L and 291800 ind/L) and minimum in the month of August 2016 at S1 and S3 site (143130 ind/L and 109130 ind/L). During the present investigations it was observed that the phytoplankton fluctuates in different seasons (Table 1, Table 2, Table 3, Table 4) due to the changes in physico-chemical nature of water. The seasonal variation in phytoplankton from October 2015 to September 2017 is shown in Figure 3. At all the sites maximum diversity of phytoplankton was observed in summer season (March to May) and minimum in monsoon season (June to August). At S1, S2, S3 and S4 site maximum density has been reported during summer season i.e. 1329800, 1491800, 1124800 and 1659800 ind/L and minimum diversity was found during monsoon season i.e. 944460, 1106460, 741460 and 1275455 ind/L. Among all the sites the highest diversity was found to be at S2 and S4 site and lowest diversity was reported at S1 and S3 site. The maximum count of phytoplankton density during the summer season was due to the high temperature and minimum during the monsoon season due to the dilution and addition of slit in water. The maximum count in summer months may be attributed due to increasing trend of temperature from spring season to summer season along with high amount of dissolved nutrients in the water. The minimum diversity in monsoon months was due to the dilution of wetland water and mixing of slit. Phytoplankton count was less during winter months may be attributed due to the low water as well as ambient temperature in the wetland. Our results are in conformity with the workers who reported during summer, increase in temperature enhanced the rate of decomposition followed by evaporation, increase in nutrient concentration and abundant food present in the form of photosynthesis and low abundance during monsoon season is attributed to dilution by heavy rain, fresh water inflow and siltation [28,29]. Similarly it was observed by other worker and observed that variation in phytoplankton distribution and abundance were mostly influenced by the seasonal changes in environmental parameters (DO, salinity, temperature, nitrate, silicate). It is of paramount importance to study the hydro-chemical parameters to distinguish the difference in phytoplankton diversity on a seasonal scale in marine ecosystem [30]. Other researchers also observed similar seasonal observation viz. minimum density of phytoplankton during monsoon and maximum during summer in Chatla Lake Assam [26]. Bioindication showed a low diverse community in the monsoon period with better water quality than in preand post-monsoon [31]. Further the phytoplankton species also showed significant changes according to seasonal variations as well as the nutrient availability. Phytoplankton attained their maximum population density during premonsoon; whereas minimum population was observed during monsoon [32]. Some species of phytoplankton were found to be more frequent, most abundant and were reported almost throughout the year and these species are *Navicula spp.*, *Synedra spp.*, *Fragilaria spp.*, *Tabellaria spp.*, *Nitzschia spp.*, *Pinnularia spp.*, *Cymbella spp.*, *Gomphonema spp.*, *Spirogyra spp.*, *Cladophora spp.*, *Gomphonema spp.*, *Meridion spp.* and *Denticula spp*. Rest of the species shows asymmetrical distribution but was present in adequate numbers. The existance of some genera like *Spirogyra spp.*, *Closterium spp.*, *Cosmarium spp*. and *Staurastrum spp*. indicate a good quality of this wetland because they are the resident of unpolluted water. The genera like *Oscillatoria spp.*, *Microcystis spp.*, *Navicula spp.*, *Synedra spp.*, *Cyclotella spp.*, *Cymbella spp.*, *Gomphonema spp*. and *Merismopodia spp*. are the indicators of polluted water and maximum numbers of these polluted species are observed at S1 and S3 sites and minimum numbers at S2 and S4 sites.

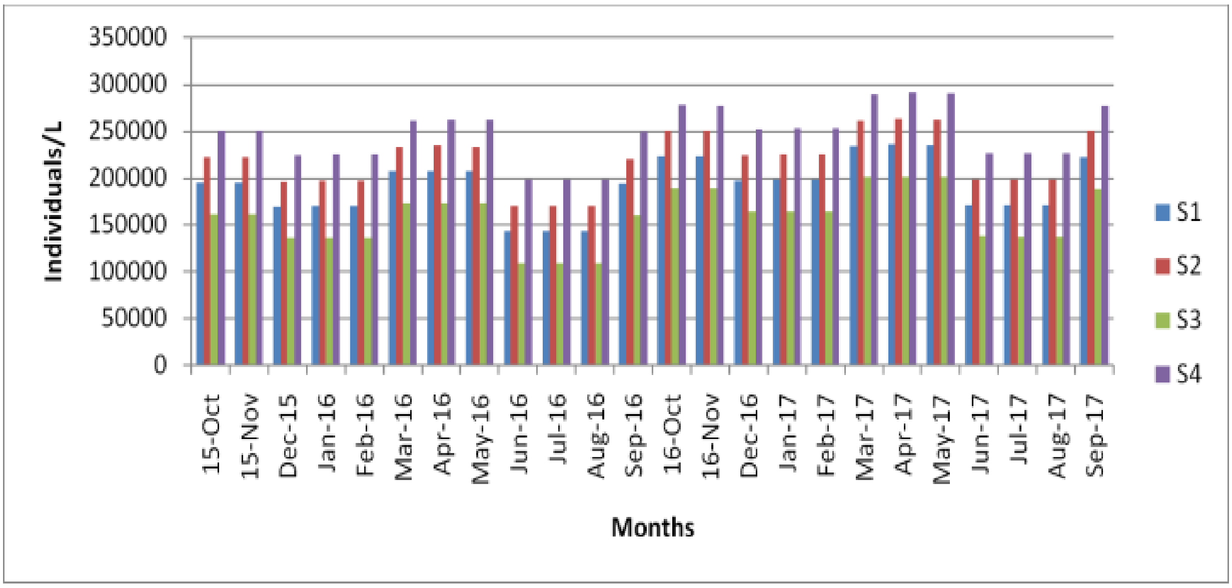

Figure 2. Monthly variation in total count (ind/L) of phytoplankton at all the sites

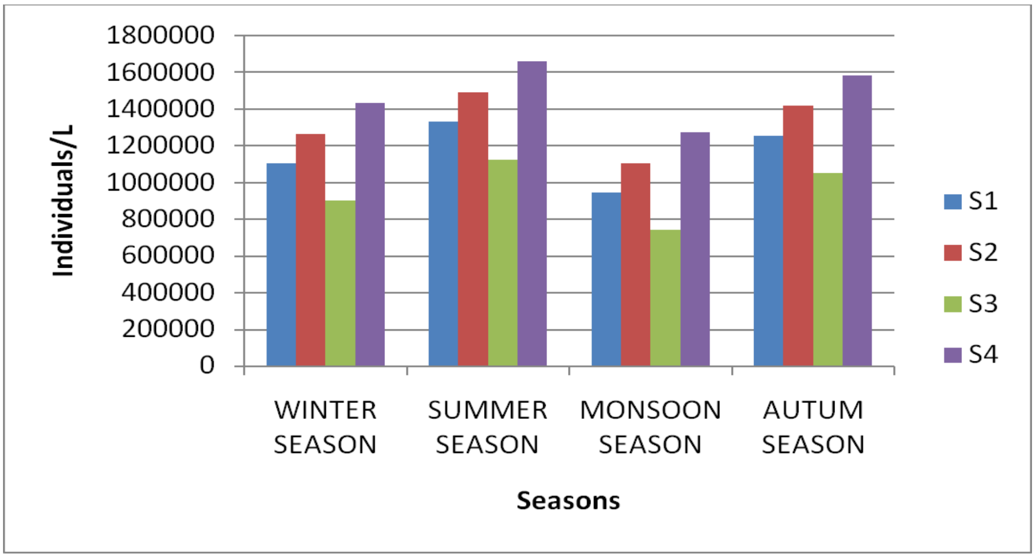

Figure 3. Seasonal variation in total count (ind/L) of phytoplankton at all the sites

3.1. Diversity Indices

Phytoplankton diversity indices of the Ropar wetland during the present investigations from October 2015 to September 2017 at all sites (S1, S2, S3 and S4) were shown in Table 5, Table 6, Table 7, Table 8. At all the sites maximum species diversity and species evenness was recorded during summer season and minimum species diversity during monsoon season. Phytoplankton species diversity index, Simpson's index (λ) which varied from 0 to 1, gives the probability that two individuals drawn at random from a population belong to the same species. Simply stated, if the probability was high that both individuals belong to the same species, then the diversity of the community sample was low. 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. Equitability (evenness) was relatively high during the raining season indicating a reduction in the plankton diversity at this period [33]. Evenness indices indicate whether all species in a sample are equally abundant. This means that species evenness decreased with increasing size of the plankton population. The species richness index (SR) was highest during the pre-monsoon period, which correlated with a maximal species richness of the phytoplankton community [34]. The evenness index (J/) revealed a maximum value in the monsoon season. The study by another worker observed that the Shannon & Wiener diversity index was found to be higher during postmonsoon and lower during monsoon season which is in accordance with present study [32]. The result of present investigations of diversity indices indicates that the wetland is moderately polluted

Table 5. Seasonal variations in Phytoplankton diversity indices at S1 site of Ropar Wetland

Indices	Winter season	Summer season	Monsoon season	Autumn season
Taxa_S	28	28	28	28
Individuals	184035	221630	157406	209202
Simpson_1-D	0.9636	0.9638	0.9634	0.9637
Shannon_H	3.322	3.325	3.32	3.324
Evenness_e^H/S	0.9899	0.9933	0.9874	0.9914

Table 6. Seasonal variations in Phytoplankton diversity indices at S2 site of Ropar Wetland

Indices	Winter season	Summer season	Monsoon season	Autumn season
Taxa_S	28	28	28	28
Individuals	211035	248629	184406	236202
Simpson_1-D	0.9637	0.9639	0.9636	0.9638
Shannon_H	3.324	3.327	3.323	3.325
Evenness_e^H/S	0.992	0.9946	0.9904	0.9931

Table 7. Seasonal variations in Phytoplankton diversity indices at S3 site of Ropar Wetland

Indices	Winter season	Summer season	Monsoon season	Autumn season
Taxa_S	28	28	28	28
Individuals	150369	187463	123572	175202
Simpson_1-D	0.9631	0.9635	0.9627	0.9634
Shannon_H	3.315	3.321	3.309	3.319
Evenness_e^H/S	0.9833	0.989	0.9775	0.9872

Table 8. Seasonal variations in Phytoplankton diversity indices at S4 site of Ropar Wetland

Indices	Winter season	Summer season	Monsoon season	Autumn season
Taxa_S	28	28	28	28
Individuals	239035	276630	212571	264202
Simpson_1-D	0.9639	0.964	0.9638	0.9639
Shannon_H	3.326	3.328	3.325	3.327
Evenness_e^H/S	0.9938	0.9955	0.9928	0.9945

3.2. Correlation Matrix Between Phytoplankton and Physico-Chemical Parameters

Correlation matrix between phytoplankton and different physico-chemical parameters was calculated at all the sites (S1, S2, S3 and S4) and were shown in Table 9. Phytoplankton population showed negative correlation with dissolved oxygen (DO) and free CO_2 at all the sites and also with total dissolved solids (TDS) at S3 site. DO at S1 (r = -0.08489), S2 (r = -0.34034), S3 (r = -0.01619) and at S4 (r = -0.32892). Free CO_2 at S1 site (r = - 0.03437), S2 (r = -0.03191), S3 (r = -0.28553), S4 (r = - 0.03233) and at S3 with TDS (r = - 0.09278) and phytoplankton population showed positive correlation with the rest of all the parameters at all the sites. The results found to be agreed with investigations carried out by the workers who recorded high population during summer and suggested that this might be due to physical rather than chemical conditions in which the water temperature and transparency had a direct relationship with phytoplankton population [28,35,36].

Table 9. Correlation matrix among physico-chemical parameters and density of phytoplankton at all the sites

Physico-chemical Parameters	Density of phytoplankton			
	S1-site	**S2-site**	**S3-site**	**S4-site**
Air Temperature(°C)	0.076354	0.17106	0.031586	0.03795
Water temperature(°C)	0.10537	0.21704	0.033906	0.095932
Conductivity(µS/cm)	0.31414	0.29288	0.31933	0.22525
TDS(mg/l)	0.3576	0.69335	-0.09278	0.28588
Turbidity(NTU)	0.6208	0.32045	0.45841	0.38018
Dissolved oxygen(mg/l)	-0.08489	-0.34034	-0.01619	-0.32892
Free CO_2(mg/l)	-0.03437	-0.03191	-0.28553	-0.03233
pH	0.32133	0.44213	0.29517	0.42752
Alkalinity(mg/l)	0.26106	0.28865	0.17365	0.28745
Salinity(mg/l)	0.3117	0.42667	0.22049	0.33403
Chlorides(mg/l)	0.45068	0.59851	0.38702	0.52993
Total Hardness(mg/l)	0.32302	0.53328	0.27989	0.41504
Ca^{++}Hardness(mg/l)	0.50102	0.42013	0.32319	0.41515
Mg^{++}Hardness(mg/l)	0.1934	0.059031	0.11946	0.070739
Phosphates(mg/l)	0.73699	0.50825	0.55614	0.46335
Sulphates(mg/l)	0.63296	0.54049	0.71045	0.6198
Nitrates(mg/l)	0.81403	0.79691	0.84966	0.7392
Nitrites(mg/l)	0.85487	0.80929	0.84182	0.81836
Silicates(mg/l)	0.75573	0.26798	0.60643	0.64975

4. Conclusion

The monthly and seasonal variations of physico-chemical parameters and their influences on phytoplankton community of Ropar wetland was conducted for two years during the present study. Further it was observed that this wetland is one of the productive riverine systems of North India, Punjab with affluent variety of phytoplankton. However, the present study showed less diverse forms of phytoplankton at the more polluted sites (S1 and S3) after the confluence of pollution from various sources i.e. ash from thermal plant, slit from cement plant, domestic sewage, surface run-off from agricultural fields and the effluents from various industries viz. National Fertilizer Limit (NFL) Nangal and anthropogenic activities are adversely affecting the ecology of both the systems as signifying the low species diversity and percentage distribution of phytoplankton. Low diversity in polluted water might be due to the fact that many pollution sensitive species were eradicate from the community and only a few pollution tolerant organisms thrive in the absence of competition and in the presence of abundant food supply. It was revealed that organic pollution during the monsoon period was increased as compared to the other seasons. The monsoon rainfall was found to impact the phytoplankton community and therefore the species dynamic must be examined for both human and climatic effects. Thus, overall present study revealed that the extent of pollution in the river which is directly affecting the flora and fauna. Hence, this study suggests that regular bio-monitoring of this water body should be carried out to keep its flora and fauna intact for the years to come.

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