Plant Archives Volume 21, No 1, 2021 pp. 1753-1765 *e-ISSN:2581-6063 (online), ISSN:0972-5210*

Plant Archives

Journal home page: www.plantarchives.org

DOI Url: https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no1.240

SPECIES DIVERSITY AND RICHNESS INDICES OF PHYTOPLANKTON SPECIES IN ANCHAR LAKE OF KASHMIR-INDIA

Muzamil Bashir[1], Sheema Zaffar[2], Javid Ahmad Malik[3] and Mohammad Farooq Mir[4]

[1]Department of Zoology, Central University of Kashmir, Ganderbal Jammu and Kashmir-India

[2]Department of Environmental Sciences, University of Kashmir, Srinagar J&K-India

[3]Department of Zoology, Guru Ghasidas University, Bilāspur, India

[4]Hydrobiology Research Laboratory S.P. College Srinagar, Cluster University, Srinagar-J&K-India

Email: bmuzamil99@gmail.com

(Date of Receiving-26-12-2020; Date of Acceptance-22-03-2021)

ABSTRACT

The most significant biotic constituent in a lake ecosystem is represented by phytoplankton in their diverse forms. phytoplankton because of their capacity to integrate environmental changes over periods of a few years, and reflect the cumulative effects of successive disturbances, are considered excellent biomass ecological state of water bodies Biodiversity to the aquatic ecosystem is quite varied starting from plankton (phytoplankton and zooplankton) to higher vertebrates like fishes. Study of plankton (phytoplankton and zooplankton) diversity and their ecology greatly contribute to an understanding of the basic nature and general economy of an aquatic habitat. In the present study overall, six broad groups of phytoplankton were observed during the present study, which include Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae, Dynophyceae and Cryptoceae.

Keywords: Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae, Dynophyceae and Cryptoceae

INTRODUCTION

In an aquatic ecosystem the life of aquatic biota is closely dependent on the physical, chemical and biological characteristics of water, each of which directly acts as a controlling factor. Therefore, for understanding the dynamics of an organism, a population or a community, knowledge of both the organism and its environment is required. In all aquatic ecosystems, there is a link between the producers and consumers which are two physiologically different groups of organisms.

Biodiversity to the aquatic ecosystem is quite varied starting from plankton (phytoplankton and zooplankton) to higher vertebrates like fishes. Study of plankton (phytoplankton and zooplankton) diversity and their ecology greatly contribute to an understanding of the basic nature and general economy of an aquatic habitat. Phytoplanktons are the primary source of energy driving large lentic ecosystems; and zooplankton are the central atrophic link between primary producers like phytoplankton and fish (Schriver *et al.,* 1995, Tatrai *et al*., 1997).

Phytoplankton's are one of the initial biological components from which the energy is transferred to higher organisms through food chain (Tiwari and Chauhan, 2006; Tas and Gonulal, 2007; Senthilkumar and Sivakumar, 2008). Earlier studies on lake phytoplankton diversity (Pongswat *et al*., 2004; Ganai *et al*., 2010) revealed the importance of phytoplanktonic study. Plankton plays a significant role in the dynamics of the ecosystem. When an aquatic system is considered, the planktons prove to be of great importance as the changes in the environment can potray an instantaneous response of the planktons. The planktonic organisms in an aquatic systems are essential link in the food chain and play an important role in the transformation of energy from one tropic level to the next highest, ultimately leading to the fish production, which is the final product of the aquatic environment. Phytoplanktonic organisms are sensitive indicators of environmental stresses (Hutchinson, 1967). Primary productivity of different water bodies have been studied by direct relationship on the biota of surface water governed by various environmental conditions. The primary production of organic matter is in the form of phytoplankton's which are more intense in reservoir, lake than in rivers and zooplankton support the economically important fish population. The abundance of phytoplankton and zooplankton in the freshwater bodies is greatly regulated by the physico-chemical factors (Muhlhauser *et al.,* 1995; Jersabek & Schabetsberger, 1996). The Anchar lake is fluviatile in its origin; shallow basined and is situated 12 kms to the northwest of Srinagar city within the geographical coordinates of 34° 20´-34° 26´ N latitude and 74°82´ and 74° 85´ E longitude at 1584 m.a.s.l. The lake is mono basined with its main catchment comprising Srinagar city and a number of bordering villages. A network of channels from the river Sind enters the lake on its western shore and serves as the main source of water. The littorals of the lake are surrounded by a thick canopy of trees, willows and popular trees providing the base material for the manufacture of baskets, cricket bats, wood carvings, wicker work, etc. Besides numerous values of the lake in meeting human needs for survival and socio-economic development. During the present investigation the lake was studied for a period of 18 months. The lake was divided into six collection sites on the basis of different types of substratum and ecology of the sites. As such the present lake was divided into six sites shown in map.

1. Sangam site,
2. Zinymar site,
3. Centre site,
4. Skims hospital site,
5. Eid-gah site,
6. Jinab shab shrine site.

MATERIALS AND METHODS

Quantitative analysis

Several methods known for the collection of plankton, the use of 'plankton net' is most common. Out of several methods used for quantitative enumerations the drop-method and Sedgwick Rafter cell method are used mostly but we used only Sedgwick Rafter method

Calculation

v =t x d x w X L
where,

v = volume of the sample 'observed' (mm^3)
t = number of 'observed' transects
d= depth of the cell cavity (mm)
w = width of the microscope field (mm)
L = length of the cell cavity (mm)

Organisms l^{-1} =n () 1/c x 10^3

Where n = total number of individuals in observed transects

V= Volume of the sample in counting cell (mm^3)
v = volume of 'observed' transects (mm^3)

Results : Express as organisms l^{-1} (species and phyla wise, and total plankton separately).

Shannon H

All biodiversity parameters were calculated through biodiversity calculator by Tanner M. Young (2017)

Shannon Entropy

All biodiversity parameters were calculated through biodiversity calculator by Tanner M. Young (2017)

Simpson 1-D
All biodiversity parameters were calculated through biodiversity calculator by Tanner M. Young (2017).

Gini Simpson's index

All biodiversity parameters were calculated through biodiversity calculator by Tanner M. Young (2017)

3.4.2.5 Evenness

All biodiversity parameters were calculated through biodiversity calculator by Tanner M. Young (2017)

3.4.2.6 Margalef

All biodiversity parameters were calculated through biodiversity calculator by Tanner M. Young (2017)

3.4.2.7 Berger Parker Index

All biodiversity parameters were calculated through biodiversity calculator by Tanner M. Young (2017)

Hill Numbers – True Diversity

All biodiversity parameters were calculated through biodiversity calculator by Tanner M. Young (2017)

Renyi Entropy

The Rényi entropy generalizes the Shannon entropy and quantifies the diversity, uncertainty, or randomness of a system. The Rényi entropy is important in ecology and statistics as indices of diversity. The Rényi entropy is also important in quantum information, where it can be used as a measure of entanglement.

RESULTS AND DISCUSSION

Phytoplankton

During the present research work an analysis into species diversity was considered as the special help for the assessment of the shifts of aquatic inhabitants from favourable to unfavorable or resistant to tolerant group within the aquatic ecosystem. Phytoplankton plays a great part in assessment of the pollution status of the aquatic ecosystem. Overall, six broad groups of phytoplankton were observed during the present study, which include Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae, Dynophyceae and Cryptoceae. The Bacillariophyceae comprised of the dominant species with over 36 taxa at site 1, followed by Chlorophyceae, which constituted of 24 taxa. Cyanophyceae was more or less had same number of taxa (21) as chlorophyceae. However, Euglenophyceae, Dynophyceae and

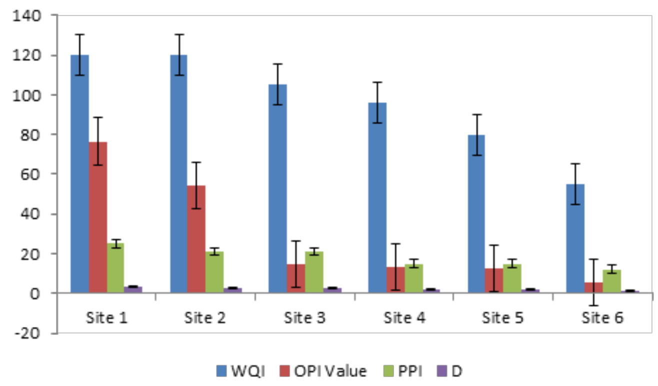

Fig. 1: Organic Pollution Index values of different sampling stations of Anchar Lake

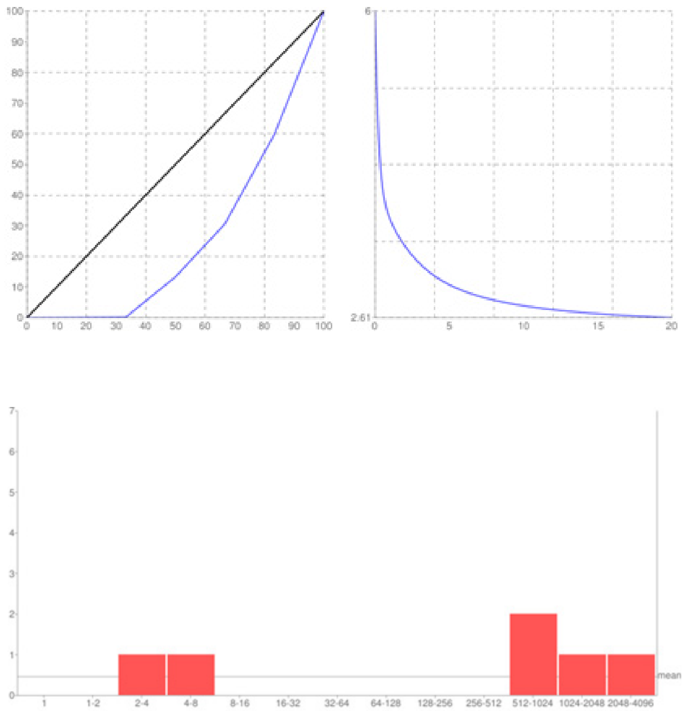

Fig. 2: Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 1 in Anchar Lake

Fig. 3: True Diversity of phytoplankton at site 1 in Anchar Lake

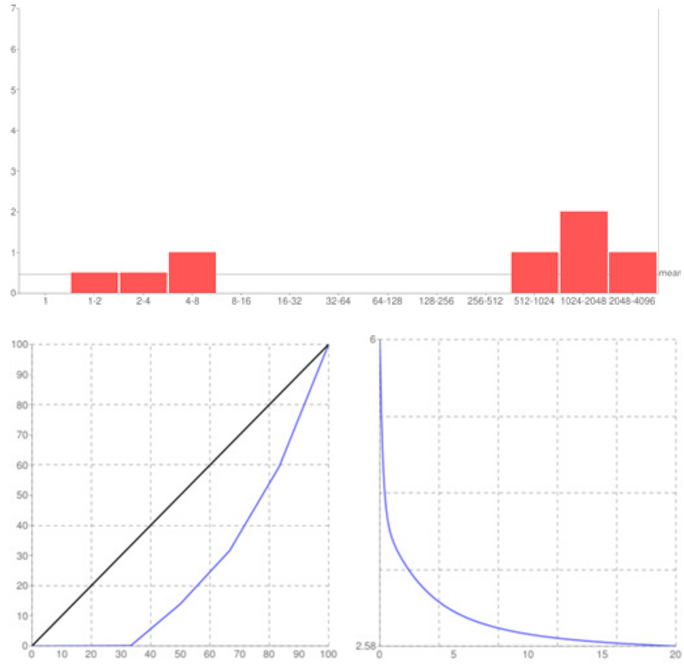

Fig. 4: Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 2 in Anchar Lake

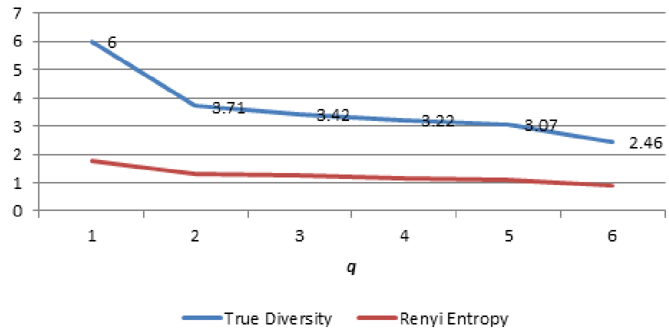

Fig. 5: True Diversity of phytoplankton at site 2 in Anchar Lake

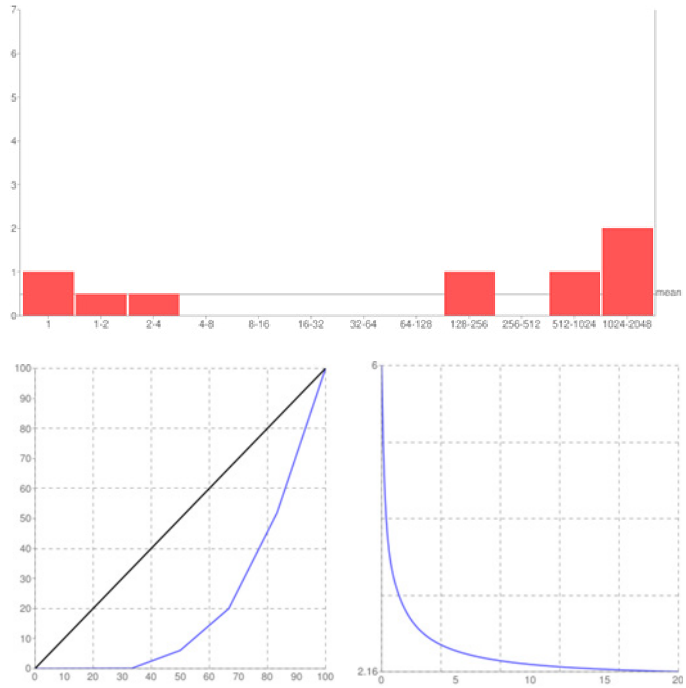

Fig. 6: Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 3 in Anchar Lake

Cryptophyceae were least populous with 2, 2 and 1 number of taxa respectively. Bacillariophyceae dominated the phytoplankton population at site 1, with abundance (%) of 40.21. The Shannon *H* was highest (1.3), with Evenness (e H/S) of 0.73 and Margalef Richness (*S*) of 4.56. While as Simpson's dominance (1-D) showed a value of 0.83, which was lesser than chlorophyceae.

Chlorophyceae followed the dominant phytoplankton population at site 1, with abundance (%) of 29.18. The Shannon *H* was (0.94), with Evenness (e H/S) of 0.52 and Margalef Richness (*S*) of 3.13. While as Simpson's dominance (1-D) showed a value of 0.91, which was higher than the dominant Bacillariophyceae. Cyanophyceae followed the two dominant phytoplankton population at site 1, with abundance (%) of 17.30. The Shannon *H* was (0.58), with Evenness (e H/S) of 0.32 and Margalef Richness (*S*) of 2.93. While as Simpson's dominance (1-D) showed a value of 0.97, which was higher than the dominant Bacillariophyceae and Chlorophyceae.

Euglenophyceae was among the least dominant phytoplankton population at site 1, with abundance (%) of 13.13. The Shannon *H* was (0.27), with Evenness (e H/S) of 0.15 and Margalef Richness (*S*) of 0.15. While as Simpson's dominance (1-D) showed a value of 0.98, which was higher than the other dominant phytoplankton species. Dynophyceae was yet among the least dominant phytoplankton population, with abundance (%) of 0.11. The Shannon *H* was (0.01), with Evenness (e H/S) of 0.006 and Margalef Richness (*S*) of 0.56. While as Simpson's dominance (1-D) showed a value of 1.00, which was higher than the other dominant phytoplankton species. On the other hand, Cryptophyceae was the least abundant phytoplankton population, with abundance (%) of 0.05. The Shannon *H* was (0.004), with Evenness (e H/S) of 0.002 and Margalef Richness (*S*) of 0.00. While as Simpson's dominance (1-D) showed a value of 1.00, which was higher than the other dominant phytoplankton species Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 1 in Anchar Lake is depicted in (fig. 2.)

At site 2, the number of taxa for six phytoplankton was same as site 1. Bacillariophyceae dominated the phytoplankton population, with abundance (%) of 40.50. The Shannon *H* was highest (1.31), with Evenness (e H/S) of 0.73 and Margalef Richness (*S*) of 9.84. While as Simpson's dominance (1-D) showed a value of 0.84, which was lesser than chlorophyceae. Chlorophyceae followed the dominant phytoplankton population Bacillariophyceae, with abundance (%) of 27.78. The Shannon *H* was (0.94), with Evenness (e H/S) of 0.52 and Margalef Richness (*S*) of 7.34. While as Simpson's dominance (1-D) showed a value of 0.92, which was higher than the dominant Bacillariophyceae. Cyanophyceae followed the two dominant phytoplankton population at site 2, with abundance (%) of 17.73. The Shannon *H* was (0.58), with Evenness (e H/S) of 0.32 and Margalef Richness (*S*) of 6.68. While as Simpson's dominance (1-D) showed a value of 0.97, which was higher than the dominant Bacillariophyceae and Chlorophyceae.

Euglenophyceae was among the least dominant phytoplankton population at site 2, with abundance (%) of 13.79. The Shannon *H* was (0.28), with Evenness (e H/S) of 0.15 and Margalef Richness (*S*) of 0.00. While as Simpson's dominance (1-D) showed a value of 0.98, which was higher than the other dominant phytoplankton species. Dynophyceae was yet among the least dominant phytoplankton population, with abundance (%) of 0.08. The Shannon *H* was (0.01), with Evenness (e H/S) and Margalef Richness (*S*) of 0.00 While as Simpson's dominance (1-D) showed a value of 0.98, which was higher than the other dominant phytoplankton species. On the other hand, Cryptophyceae was the least abundant phytoplankton population, with abundance (%) of 0.03. The Shannon *H*, Evenness (e H/S) and Margalef Richness (*S*) was 0.00. While as Simpson's dominance (1-D) showed a value of 1.00, which was higher than the other dominant phytoplankton species. Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 2 in Anchar Lake is depicted in (fig. 4.)

At site 3, the Bacillariophyceae comprised of the dominant species with over 28 taxa, followed by Chlorophyceae, which constituted of 19 taxa. Cyanophyceae was more or less had same number of taxa (16) as chlorophyceae. However, Euglenophyceae, Dynophyceae and Cryptophyceae were least populous with 2, 1 and 1 number of taxa respectively. Bacillariophyceae dominated the phytoplankton population, with abundance (%) of 48.05. The Shannon *H* was highest (1.16), with Evenness (e H/S) of 0.65 and Margalef Richness (*S*) of 8.19. While as Simpson's dominance (1-D) showed a value of 0.77, which was lesser than chlorophyceae. Chlorophyceae followed the dominant phytoplankton population Bacillariophyceae, with abundance (%) of 32.00. The Shannon *H* was (0.81), with Evenness (e H/S) of 0.45 and Margalef Richness (*S*) of 6.23. While as Simpson's dominance (1-D) showed a value of 0.90, which was higher than the dominant Bacillariophyceae. Cyanophyceae followed the two dominant phytoplankton population at site 3, with abundance (%) of 13.90. The Shannon *H* was (0.44), with Evenness (e H/S) of 0.25 and Margalef Richness (*S*) of 5.54. While as Simpson's dominance (1-D) showed a value of 0.98, which was higher than the dominant Bacillariophyceae and Chlorophyceae.

Euglenophyceae was among the least dominant phytoplankton population at site 3, with abundance (%) of 5.95. The Shannon *H* was (0.17), with Evenness (e H/S) of 0.09 and Margalef Richness (*S*) of 0.00. While as Simpson's dominance (1-D) showed a value of 1.00, which was higher than the other dominant phytoplankton species. Dynophyceae was yet among the least dominant

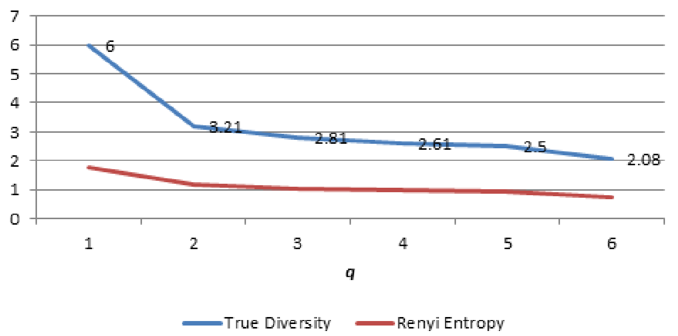

Fig. 7: True Diversity of phytoplankton at site 3 in Anchar Lake

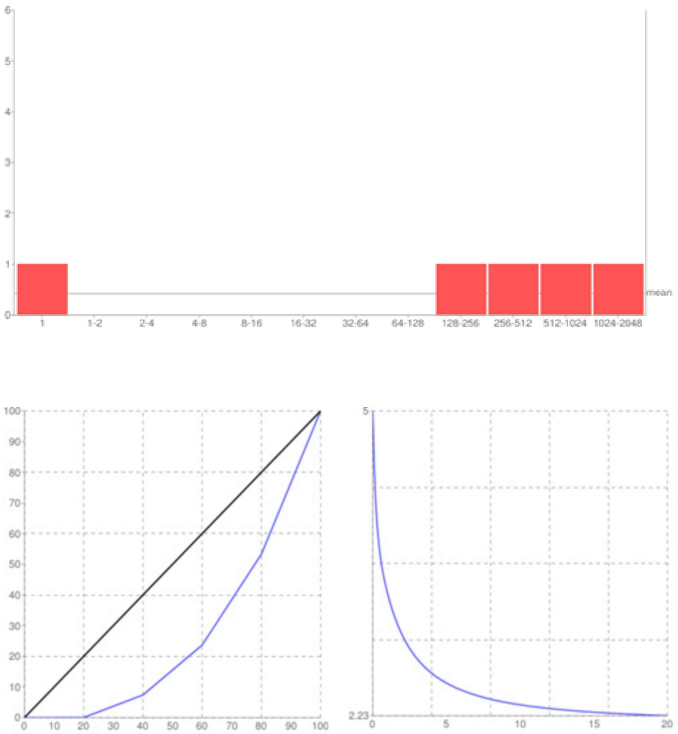

Fig. 8: Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 4 in Anchar Lake

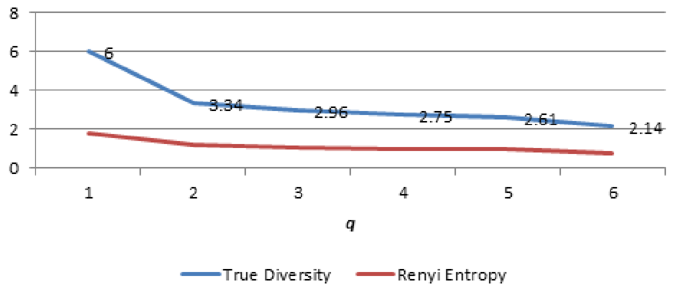

Fig. 9: True Diversity of phytoplankton at site 4 in Anchar Lake

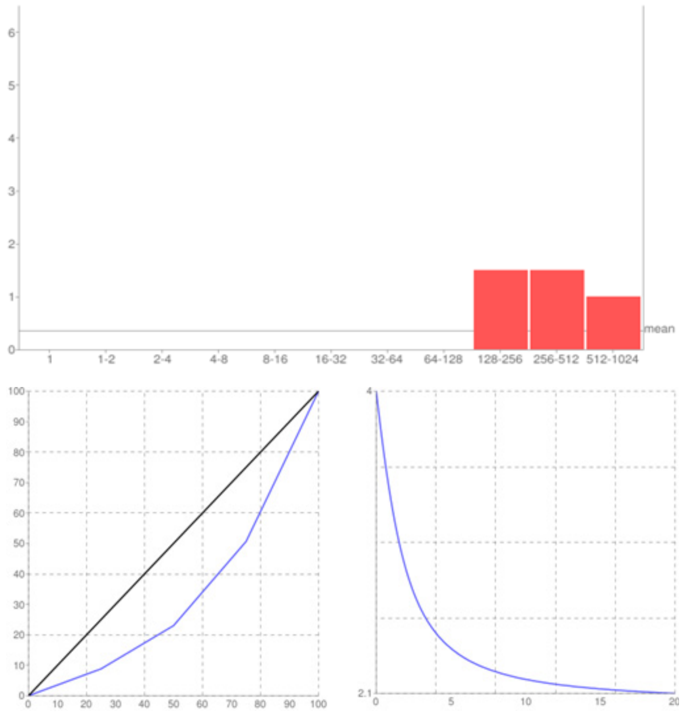

Fig. 10: Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 5 in Anchar Lake

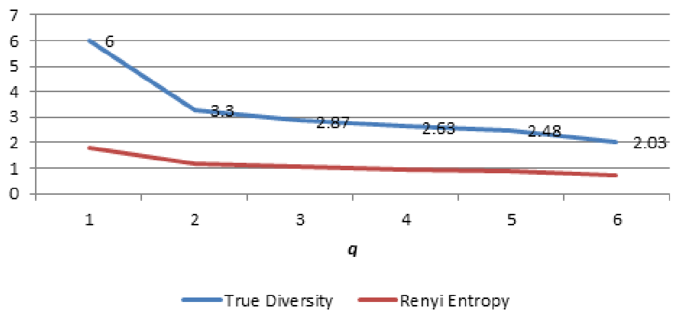

Fig. 11: True Diversity of phytoplankton at site 5 in Anchar Lake

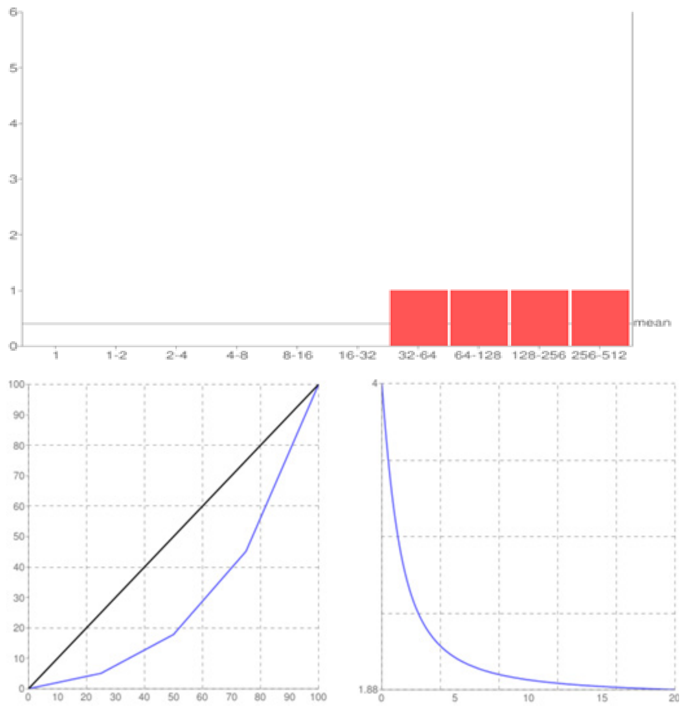

Fig. 12: Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 5 in Anchar Lake

phytoplankton population, with abundance (%) of 0.05. The Shannon *H* was (0.006), with Evenness (e H/S) and Margalef Richness (*S*) of 0.003 and 0.00 respectively, While as Simpson's dominance (1-D) showed a value of 1.00, which was higher than the other dominant phytoplankton species. On the other hand, Cryptophyceae was the least abundant phytoplankton population, with abundance (%) of 0.02. The Shannon *H*, Evenness (e H/S) and Margalef Richness (*S*) was 0.002, 0.001 and 0.00 respectively. While as Simpson's dominance (1-D) showed a value of 1.00, which was higher than the other dominant phytoplankton species. Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 3 in Anchar Lake is depicted in (fig.6).

At site 4, the Bacillariophyceae comprised of the dominant species with over 25 taxa, followed by Chlorophyceae, which constituted of 18 taxa. Cyanophyceae was more or less had same number of taxa (16) as chlorophyceae. However, Euglenophyceae, Dynophyceae and Cryptophyceae were least populous with 1, 1 and 0 number of taxa respectively. Bacillariophyceae dominated the phytoplankton population, with abundance (%) of 46.69. The Shannon *H* was highest (1.20), with Evenness (e H/S) of 0.67 and Margalef Richness (*S*) of 7.55. While as Simpson's dominance (1-D) showed a value of 0.78, which was lesser than chlorophyceae. Chlorophyceae followed the dominant phytoplankton population Bacillariophyceae, with abundance (%) of 29.63. The Shannon *H* was (0.85), with Evenness (e H/S) of 0.47 and Margalef Richness (*S*) of 6.00. While as Simpson's dominance (1-D) showed a value of 0.91, which was higher than the dominant Bacillariophyceae. Cyanophyceae followed the two dominant phytoplankton population at site 4, with abundance (%) of 16.28. The Shannon *H* was (0.49), with Evenness (e H/S) of 0.27 and Margalef Richness (*S*) of 5.54. While as Simpson's dominance (1-D) showed a value of 0.97, which was higher than the dominant Bacillariophyceae and Chlorophyceae.

Euglenophyceae was among the least dominant phytoplankton population at site 4, with abundance (%) of 7.34. The Shannon *H* was (0.19), with Evenness (e H/S) of 0.10 and Margalef Richness (*S*) of 0.00. While as Simpson's dominance (1-D) showed a value of 0.99, which was higher than the other dominant phytoplankton species. Dynophyceae was yet among the least dominant phytoplankton population, with abundance (%) of 0.03. The Shannon *H* was (0.002), with Evenness (e H/S) and Margalef Richness (*S*) of 0.001 and 0.00 respectively, While as Simpson's dominance (1-D) showed a value of 1.00, which was higher than the other dominant phytoplankton species. On the other hand, Cryptophyceae was completely absent from the said site. Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 4 in Anchar Lake is depicted in (fig. 8.)

At site 5, the Bacillariophyceae yet again comprised of the dominant species with over 21 taxa, followed by Chlorophyceae, which constituted of 15 taxa. Cyanophyceae was more or less had same number of taxa (10) as chlorophyceae. However, Euglenophyceae, Dynophyceae and Cryptophyceae were least populous with 1, 0 and 0 number of taxa respectively. Bacillariophyceae dominated the phytoplankton population, with abundance (%) of 49.36. The Shannon *H* was highest (1.19), with Evenness (e H/S) of 0.66 and Margalef Richness (*S*) of 7.55. While as Simpson's dominance (1-D) showed a value of -0.34, which was lesser than chlorophyceae. Chlorophyceae followed the dominant phytoplankton population Bacillariophyceae, with abundance (%) of 27.62. The Shannon *H* was (0.84), with Evenness (e H/S) of 0.47 and Margalef Richness (*S*) of 6.00. While as Simpson's dominance (1-D) showed a value of 0.58, which was higher than the dominant Bacillariophyceae. Cyanophyceae followed the two dominant phytoplankton population at site 5, with abundance (%) of 14.19. The Shannon *H* was (0.49), with Evenness (e H/S) of 0.27 and Margalef Richness (*S*) of 5.54. While as Simpson's dominance (1-D) showed a value of 0.89, which was higher than the dominant Bacillariophyceae and Chlorophyceae. Euglenophyceae was among the least dominant phytoplankton population at site 5, with abundance (%) of 8.81. The Shannon *H* was (0.21), with Evenness (e H/S) of 0.11 and Margalef Richness (*S*) of 0.00. While as Simpson's dominance (1-D) showed a value of 0.96, which was higher than the other dominant phytoplankton species. Dynophyceae and Cryptophyceae were completely absent from the said site. Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 5 in Anchar Lake is depicted in (fig. 10).

At site 6, the Bacillariophyceae yet again comprised of the dominant species with over 19 taxa, followed by Chlorophyceae, which constituted of 11 taxa and Cyanophyceae with 7 taxa. However, Euglenophyceae, Dynophyceae and Cryptophyceae were least populous with 1, 0 and 0 number of taxa respectively. Bacillariophyceae dominated the phytoplankton population, with abundance (%) of 54.81. The Shannon *H* was highest (1.09), with Evenness (e H/S) of 0.61 and Margalef Richness (*S*) of 6.23. While as Simpson's dominance (1-D) showed a value of 0.70, which was lesser than chlorophyceae. Chlorophyceae followed the dominant phytoplankton population Bacillariophyceae, with abundance (%) of 27.35. The Shannon *H* was (0.76), with Evenness (e H/S) of 0.42 and Margalef Richness (*S*) of 4.34. While as Simpson's dominance (1-D) showed a value of 0.93, which was higher than the dominant Bacillariophyceae. Cyanophyceae followed the two dominant phytoplankton population at site 6, with abundance (%) of 12.76. The Shannon *H* was (0.41), with Evenness (e H/S) of 0.23 and Margalef Richness (*S*) of 3.35. While as Simpson's dominance (1-D) showed a value of 0.98, which was higher than the dominant Bacillariophyceae and Chlorophyceae. Euglenophyceae was among the least dominant phytoplankton population at site 6, with abundance (%) of 5.00. The Shannon *H* was (0.15), with Evenness (e

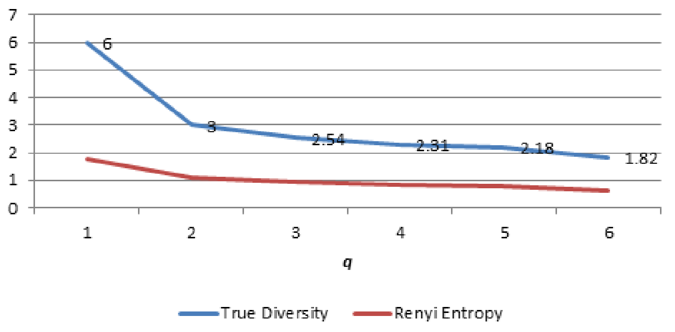

Fig. 13: True Diversity of phytoplankton at site 6 in Anchar Lake

H/S) of 0.08 and Margalef Richness (*S*) of 0.00. While as Simpson's dominance (1-D) showed a value of 1.00, which was higher than the other dominant phytoplankton species. Dynophyceae and Cryptophyceae were completely absent from the said site. Preston diagram, Lorenz graph and Renyi/Hill graph for phytoplankton diversity at site 6 in Anchar Lake is depicted in (fig. 12).

The sudy depicts the site wise phytoplankton diversity indices of Anchar Lake, studied during the present research work. It is clear from the study that the species richness was 6 for site 1-3, 5 for site 4 and 4 for sites 5 and 6. The sites 1 to 4 were dominated by the phytoplankton, which justified its status as nutrient rich. The Shannon Entropy (*H'*) was highest for site 2, followed by site 1. The Shannon equitability (H'/H_{max}) was 73.1% for site 2, followed by site 1 (73.0%). Site 4 and 5 showed higher values for both Shannon Entropy (*H'*) and Shannon equitability index (H'/H_{max}) as compared to site 3. Similar results were observed for Gini-Simpson Index (*1-l*), with 70.8% for site 2 and 70.6% for site 1, followed by other sites. Gini equitability ($l/(1\text{-}l_{max})$) and predicted equitability for unbiased finite samples lent the same results. However, Berger Parker Index (max(p_i)) showed highest value of 54.8% for site 6, which was followed by other sites in hierarcheal manner with increasing biodiversity. The three dominant sites showed the Berger Parker Index values of 40.2 (site 1), 40.6 (site 2) and 48.1 (site 3).

Phytoplankton true diversity (^qD) and Renyi Entropy (^qH) calculated during the present research work. The generalized mean for infinite orders (*q*) was calculated using species diversity calculator. The true diversity (^qD) and Renyi Entropy (^qH) at all the sites for $q = 0$ (harm) was 6.00 and 1.79 respectively, which showed lower values for infinite samples, as depicted by fig, 3 (site 1), fig.5 (site 2), fig.7 (site 3), fig.9 (site 4), fig.11 (site 5) and fig.13 (site 6).

Correlations were calculated between the physic chemical parameters and the phytoplankton species abundance at various study sites during the present research period. At site 1, bacillariophyceae showed positive correlations with water temperature (r = 0.22), pH (r = 0.23), nitrate nitrogen (r = 0.91) and COD (r = 0.433), while as other parameters showed negative correlations. On the other hand Chlorophyceae showed positive correlation with nitrate nitrogen (r = 0.38) and COD (r = 0.65). Cyanophyceae showed positive correlation with pH (r = 0.11), alkalinity (r = 0.28), Ammonical nitrogen (r = 0.19) and BOD (r = 0.67). Euglenophyceae showed positive correlations with pH (r = 0.09), alkalinity (r = 0.30), total hardness (r = 0.36), Ammonical nitrogen (r = 0.42), phosphate (r = 0.47) and BOD (0.27). Similarly Dynophyceae showed positive correlation with alkalinity (r = 0.33), total hardness (r = 0.59), phosphate (r = 0.89), COD (r = 0.07). Cryptophyceae, on the other hand showed positive correlation with water temperature (r = 0.53), total hardness (r = 0.76), Ammonical nitrogen (r = 0.68), nitrate nitrogen (r = 0.27), BOD (r = 0.25) and COD (r = 0.57).

At site 2, bacillariophyceae showed positive correlations with alkalinity (r = 0.14), phosphate (r = 0.20), and COD (r = 0.15), while as other parameters showed negative correlations. On the other hand Chlorophyceae showed positive correlation with pH (r = 0.53), total hardness (r = 0.56), nitrate nitrogen (r = 0.47), BOD (r = 0.71) and COD (r = 0.72). Cyanophyceae showed positive correlation with pH (r = 0.03), alkalinity (r = 0.22), total hardness (r = 0.06), Ammonical nitrogen (r = 0.32), nitrate nitrogen (r = 0.03) and phosphate (r = 0.20). Euglenophyceae showed positive correlations with pH (r = 0.35), total hardness (r = 0.62), nitrate nitrogen (r = 0.30), phosphate (r = 0.22) and COD (0.39). Similarly Dynophyceae showed positive correlation with water temperature (r = 0.61), pH (r = 0.53), alkalinity (r = 0.12), Ammonical nitrogen (r = 0.58), BOD (r = 0.78), COD (r = 0.06). Cryptophyceae, on the other hand showed positive correlation with nitrate nitrogen (r = 0.13) and phosphate (r = 0.11).

At site 3, bacillariophyceae showed positive correlations with water temperature (r = 0.52), pH (r = 0.65), total hardness (r = 0.96), ammonical nitrogen (r = 0.07), BOD (r = 0.39), while as other parameters showed negative correlations. On the other hand Chlorophyceae showed positive correlation with pH (r = 0.71), alkalinity (r = 0.13), total hardness (r = 0.06), Ammonical nitrogen (r = 0.92), nitrate nitrogen (r = 0.12), phosphate (r = 0.30) and BOD (r = 0.48). Cyanophyceae showed positive correlation with alkalinity (r = 0.82), Ammonical nitrogen (r = 0.10), nitrate nitrogen (r = 0.15), phosphate (r = 0.46) and COD (r = 0.55). Euglenophyceae showed positive correlations with water temperature (r = 0.09), pH (r = 0.04), and total hardness (r = 0.47). Similarly Dynophyceae showed positive correlation with alkalinity (r = 0.18) and COD (r = 0.15). Cryptophyceae, on the other hand showed positive correlation with water temperature (r = 0.25), pH (r = 0.27), alkalinity (r = 0.23), nitrate nitrogen (r = 0.39), BOD (r = 0.34) and COD (r = 0.38).

At site 4, bacillariophyceae showed positive correlations with total hardness (r = 0.41), phosphate (r = 0.40), and COD (r = 0.18), while as other parameters showed negative correlations. On the other hand Chlorophyceae showed positive correlation with water temperature (r = 0.31), total hardness (r = 0.43), phosphate (r = 0.65) and BOD (r = 0.29). Cyanophyceae showed positive correlation with water temperature (r = 0.52), pH (r = 0.30), total hardness (r = 0.14), Ammonical nitrogen (r = 0.25), nitrate nitrogen (r = 0.78), phosphate (r = 0.39) and BOD (r = 0.48). Euglenophyceae showed positive correlations with COD (r = 0.86). Similarly Dynophyceae showed positive correlation with pH (r = 0.48), alkalinity (r = 0.40), nitrate nitrogen (r = 0.88), phosphate (r = 0.13) and BOD (r = 0.27).

At site 5, bacillariophyceae showed positive correlations with water temperature (r = 0.10), total hardness (r = 0.58) and nitrate nitrogen (r = 0.27), while as other parameters showed negative correlations. On the other hand Chlorophyceae showed positive correlation with water temperature (r = 0.57), total hardness (r = 0.43), ammonical nitrogen (r = 0.25), phosphate (r = 0.13) and COD (r = 0.38). Cyanophyceae showed positive correlation with alkalinity (r = 0.17), total hardness (r = 0.34), nitrate nitrogen (r = 0.08) and COD (r = 0.01). Euglenophyceae showed positive correlations with water temperature (r = 0.58), pH (r = 0.14), total hardness (r = 0.39), Ammonical nitrogen (r = 0.23), BOD (r = 0.44) and COD (r = 0.08).

At site 6, bacillariophyceae showed positive correlations with alkalinity (r = 0.55) and BOD (r = 0.20), while as other parameters showed negative correlations. On the other hand Chlorophyceae showed positive correlation with alkalinity (r = 0.70) and BOD (r = 0.62). Cyanophyceae showed positive correlation with water temperature (r = 0.13), pH (r = 0.43), total alkalinity (r = 0.70), total hardness (r = 0.52) and BOD (r = 0.83). Euglenophyceae showed positive correlations with water temperature (r = 0.01), pH (r = 0.40), total alkalinity (r = 0.22), and BOD (r = 0.37).

Discussion

During the last several years, a tremendous amount of study has been done on chemical and biological evaluation of water pollution both in India and abroad. Zutshi *et. al.,* (1980) made a comparative limnological study on nine lakes of Jammu and Kashmir and observed that the trophic evolution of lakes occurred due to human interference. Gunale (1981) assessed the water quality of the Pavana, Mula and Muthe rivers flowing through the Poona city. These rivers, unpolluted at the point of entrance into the city, get progressively polluted due to wastes from industries and city sewage. As a result of pollution, deterioration of water quality affecting the composition of algal flora took place. He also reported that as a major element in aquatic biota, the algal community often exhibits dramatic changes in response to changes in physico-chemical properties of the aquatic environment. Hence algal flora or algal association is the best tool in the assessment of water pollution. In the present scenario, the phytoplankton abundance was more in sites 1 to 4, than other two sites, owing to highest pollution indicators, more organic load, macrophytic abundance and zooplanktonic abundance as well, which are indicative of the pollution status of Anchar Lake.

Venkateswarlu and Sampat Kumar (1982) studied on chemical and biological assessment of pollution in the river Moosi, Hyderabad. They not only discussed the physico-chemical parameters but also emphasized on indicator organisms. Baruah and Das (1983) studied the water quality and phytoplanktonic bloom of temple tank of Kamakhya, Assam and observed a permanent algal bloom, predominantly of Microcystis (=Polycytis). They reported that the enriched quantity of both organic and inorganic constituents of water is responsible for the permanent algal bloom. The detailed analysis of phytoplankton dominance, species diversity, Nygaard indices, Palmer indices confirmed that few lakes have already gone eutrophic and the rest were leading towards it.

Kar *et al.,* (1987) studied the biological quality of river and observed higher phytoplanktonic population in the downstream water with species of Bacillariophyceae dominating the population. He also followed the Czechanovski's index of similarity between the upstream and downstream of river by using phytoplankton population. Venkateswarlu and Reddy (1987) studied for the assessment of water quality and pollution in the river Tungabhadra near Kurnool (Andhra Pradesh) with the help of physico-chemical, heavy metals, and phycological analysis. After the investigation, they reported that the biological factors, especially the algae can be used as good indicator in assessing the quality of water. Valecha *et al.,* (1987) made an attempt to classify the lower lake of Bhopal with regard to its trophic status on the basis of compound quotient of Nygaard i.e. sum total of Myxophyceae, Chlorophyceae, Bacillariophyceae and Englenophyceae and their total is divided by the total of desmides. The high range of compound quotient recorded indicated the highly eutrophic nature of the lake. Occurance of few desmid species and physico-chemical data also confirm the above classification.

Khan (1991) while studying species diversity recorded that severe organic load causes low diversity by reducing the number of species and suggested that the change of water quality correspondingly changes the species diversity. Rajkumar *et al.,* (1994) studied the plankton species and environment relationship in urban aquatic eco-system and observed that in urban areas, species association was related to physico-chemical aspects of environments whereas in rural areas related to nutrient availability. Ragothaman and Patil (1995) had conducted a hydrobiological study in Narmada estuary for a period of one year. They recorded the phytoplankton count varied from 60 ml to 18000 /ml. They reported that the wide variation of phytoplankton density was due to agricultural runoff, common pollutant arising from municipal and domestic sewage.

Phytoplankton is the base of most lake food webs and fish production is linked to phytoplankton primary production (Ryder *et al.*, 1974). Phytoplankton assemblages respond rapidly to changes in their environment with concomitant changes in overall abundance, growth rates and species composition, changes in physical and chemical water quality can thus have a rapidly changed species composition (Dixit *et al.,* 1992). Chlorophyceae dominance has been attributed to eutrophic nature of the lake. These lakes are highly enriched and productive water bodies. Palmer (1980) and Mishra & Saksena (1993) have also reported these genera as the bioindicator of organic pollution. Bacillariophyceae were found to be present. Diatoms are usually abundant in alkaline waters having pH > 8 (Kamat 1965; Round, 1981).

Cyanophyceae are more efficient in utilizing CO_2 at high pH level and thus their abundance indicates the eutrophic nature of the studied water bodies. Cyanophyceae considered to be highly adaptive and colonized even in polluted waters at higher temperature. Temperature has found to play a key role in the periodicity of this group. This statement has also been supported by Mishra and Saksena (1993), Unni (1984) and Wanganeo (1980). Euglenophyceae, algal species belonging to this group show higher tolerance to organically polluted areas Palmer, (1969), thus can be used as biological indicator of organic pollution.

Bhat *et al.,* (2012) worked on phytoplankton biodiversity in Upper and Lower lake of Bhopal and identified 5 classes of phytoplankton. The relative number of classes in decreasing number in their study was Chlorophyceae (51.08%), Cyanophyceae (29.89%), Bacillariophyceae (10.32%), Euglenophyceae (5.97%) and Pyrophyceae (2.71%). The class wise representation depicted following order of dominance: Chlorophyceae > Cyanophyceae > Bacillariophyceae > Euglenophyceae > Pyrophyceae.

Phytoplanktons are primary producers in the base of the food chain and constitute a vital link and an important biological indicator of the water quality (Laskar and Gupta, 2013). Upadhyay *et al.,* (2011) used palmer and tropic state index to assess the planktonic diversity in Upper lake, Bhopal and reported total 87 phytoplankton species, in which 45 species belonged to Chlorophyceae, 24 species belong to Bacillariophyceae, 15 belonged to Cyanophyceae while 3 species belonged to Euglenophyceae. Out of 5 classes, Chlorophyceae was found to be dominant. Pani *et al.,* (2014) investigated the phytoplanktonic diversity of the lower & Upper lake, Bhopal and stated that the lakes are traditionally polluted water bodies due to influx of domestic sewage from its highly urbanized catchment. The lake continues to be enriched with high influx of sewage and autochthonous generation of organic matters which resulted in formation of algal blooms and a shift in dominance of species from Bacillariophyceae and Oligophyceae to Cyanophyceae.

While working on the phytoplanktonic diversity and its relation to physico-chemical parameters of water at Dogarwada Ghat of River Narmada, Jyoti *et al.,* (2015) revealed presence of total 27 taxa of phytoplanktons belonging to 4 families in order of *Chlorophyceae* (47%) >*Cyanophyceae* (27%) >*Bacillariophyceae* (23%)>*Euglenophyceae* (3%). The authors reported Diversity parameters Shannon index range from 1.092-0.37, Simpson index from 0.6622-0.6202, evenness diversity index from 0.9932 -0.7288and Margelef index between 0.5459-0.2951. The authors established a positive correlation between physico-chemical parameters of water and diversity and distribution of Phytoplankton. More or less similar results were observed by Arumugam *et al.,* (2015), while working on phytoplanktonic diversity in Tropical Lake of South India Murulidhar and Murthy (2015) revealed that, Bacillariophyceae was found to be the dominant group of phytoplankton (39.13 %) followed by Chlorococcales and Cyanophyceae each with (21.74 %), desmids (13.04 %) and Euglenoids (4.35 %) in Teetha wetland. Shweta and Shammi (2015) reported Bacillariophyceae as one of the most dominant phytoplankton species in Lower and Upper Lake of Bhopal.

An ecological study using phytoplankton community of Lake Baskandi anua, Cachar was carried out by Devi *et al.,* (2016) who reported that the Chlorophyceae was found to be highest in winter, Cyanobacteria and Euglena in monsoon and Bacillariophyceae in pre monsoon. Nissa and Bhat (2016), on the other hand carried out the pilot assessement of phytoplankton community in Nigeen Lake in Kashmir to correlated it with the sewage input and reported Chlorophyceae and Bacillariophyceae as the most dominant groups, which lends support to our observations. Navatha and Reddy (2016) reported special species richness in the genus *Pediastrum* in Dal Lake, Kashmir as the most dominant phytoplankton species belonging to Chlorophyceae, which dominated the lake ecosystem.

Summary

Overall, six broad groups of phytoplankton were observed during the present study, which include Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae, Dynophyceae and Cryptoceae.

- The Bacillariophyceae comprised of the dominant species with over 36 taxa at site 1, followed by Chlorophyceae, which constituted of 24 taxa. Cyanophyceae was more or less had same number of taxa (21) as chlorophyceae. However, Euglenophyceae, Dynophyceae and Cryptophyceae were least populous with 2, 2 and 1 number of taxa respectively.

- At Site 1, Bacillariophyceae (40.21)>Chlorophyceae (29.18)>Cyanophyceae (17.30)>Euglenophyceae (13.13)>Dynophyceae (0.11)>Cryptophyceae (0.05).
- At site 2, Bacillariophyceae (40.50)>Chlorophyceae (27.78)>Cyanophyceae (17.73)>Euglenophyceae (13.79)>Dynophyceae (0.08)>Cryptophyceae (0.03).
- At site 3, Bacillariophyceae (48.05)>Chlorophyceae (32.00)>Cyanophyceae (13.90)>Euglenophyceae (5.95)>Dynophyceae (0.05)>Cryptophyceae (0.02).
- At site 4, Bacillariophyceae (46.69)>Chlorophyceae (29.63)>Cyanophyceae (16.28)>Euglenophyceae (7.34)>Dynophyceae (0.03)>Cryptophyceae (Absent).
- At site 5, Bacillariophyceae (49.36)>Chlorophyceae (27.62)>Cyanophyceae (14.19)>Euglenophyceae (8.81)>Dynophyceae (Absent)>Cryptophyceae (Absent).
- At site 6, Bacillariophyceae (54.81)>Chlorophyceae (27.35)>Cyanophyceae (12.76)>Euglenophyceae (5.00)>Dynophyceae (Absent)>Cryptophyceae (Absent).
- The sites 1 to 4 were dominated by the phytoplankton, which justified its status as nutrient rich.
- Correlations were calculated between the physico chemical parameters and the phytoplankton species abundance at various study sites.

Positive correlations were mostly established between Ammonical nitrogen, phosphate, nitrate, BOD and COD with the phytoplankton species.

REFERENCES

Schriver, P., Bogestrand, J., Jeppesen, E. and Sondergaard, M. (1995): Impact of Submerged Macrophytes on Fish-Zooplankton-Phytoplankton Interactions. Large-scale Enclosure Experiments in a Shallow Eutrophic Lake. *Freshwater Biology.* 33: 255- 270.

Tatrai, I., Olah, J., Paulovits, G., Matyas, K., Kawieka, B. J., Jozsa, Y. and Pekar, F. (1997): Biomass Dependent Interactions in Pond Ecosystems': Responses of Lower Trophic Levels to Fish Manipulation. Hydrobiologia. 345: 117-129.

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

Tas, B. and A. Gonulol (2007): An ecological and taxonomic study on phytoplankton of a shallow lake, Turkey. *J. Environ. Biol*. 28, 439- 445 (2007).

Senthilkumar, R and Sivakumar, K. (2008): Studies on phytoplankton diversity in response to abiotic factors in Veeranam lake in the Cuddalore district of Tamil Nadu. Journal of Environmental Biology September 2008, 29(5) 747-752 (2008).

Pongswat S, Thammathaworn S, Peerapornipsal Y, Thanee N, Somsiri C (2004): Diversity of phytoplankton in the Rama IX lake, a man made lake, Pethumthani Province, Thailand. *Science Asia*, 30:261-267.

Altaf H. Ganai, Saltanat Parveen, Asif A. Khan and Maryam H (2010): Phytoplankton diversity at Watlab Ghat in Wular Lake, Kashmir. *Journal of Ecology and the Natural Environment.* 2(8): 140-146.

Hutchinson, G. E. (1967): A treatise on limnology. *Introduction to Lake Biology and Limnoplankton,* New York, USA, Vol. 2, p 320-337.

Muhlhauser, H.A., A. Herpic, N. Mladinic, P.N. Montecino and S. Cabrera, (1995): Water quality and limnological features of a high altitude Andean lake, Chungard in northern Chile. Rev. Chil. Hist. Nat., 68: 369–289.

Jersabek, C.D. and Schabetsberger, R. (1996): Limnological aspects of an alpine Karst lake with extreme changes in water level. *Limnologica*, 26: 1–13.

Zutshi, D. P, Subla, B. A, Khan, M. A and Wanganeo, A. 1980. Comparative limnology of nine lakes of Jammu and Kashmir Himalayas. *Hydrobiologia,* 72:101-112.

Gunale, R. Venkat, (1981): Nygaard indices and evaluation of water pollution : Paper presented in WHO workshop on Biological indicators and indices of Environmental pollution. Cent. Bd. Prev. Cont. Wat. pollu/Om University, Hyderabad, India : 113— 119.

Venkateswarlu, V. and Sampat Kumar, P.T. (1982): Chemical and Biological assessment of pollution in the river Moosi, Hyderabad. Biol. Bull. India. 4 (1) : 28 - 30.

Kar, G.K. , Mishra, P.C. , Dash, H.C. and Das, P.0. (1987): Pollution studies in River lb III. Phytoplankton and primary productivity. *Ind. Jr. Env. Health.* 29(4) : 322 - 329.

Venkateswarlu, V. and Reddy, P.M. (1987): Assessment of water quality of Turigabhadra river near Karnool (A.P.), *Jr. Env. Biology.* 8 (2) : 109 - 119.

Valecha, Vijoy, Trivedi, Rajana and Vhatnagar, G.P. (1987): Biological assessment of trophic status of lower lake of Bhopal. Poll. Res. 6 (3 and 4) : 91 - 93.

Khan, I.S.A. Nather. (1991): Effect of Urban and Industrial waste on species diversity of diatom community in a tropical river. Malaysia, Hydrobiol. 224 (3) : 174 - 184.

Rajkumar, R. , Ramani Bai and Devaraj, N. (1994): Observation of species (Plankton) environment relationship in urban aquatic ecosystem. *Jr. Env. Biol.* 15 (3) : 177 - 183.

Ragothaman, G. and Patil, T.S. (1995): Studies on physicochemical parameters and phytoplankton of Narmada estuary. Poll. Res. 14 (2) : 221 - 226.

Ryder, R.A., Kerr, S.R., Loftus, K.H. and Regier, H.A. (1974): The morphoedaphic index, a fish yield estimator: Review and evaluation. *Journal of Fisheries Research Board of Canada* 31:663-668.

Dixit, S.S., Smol, J.P., Kingston, J.C., Charles, D.F. (1992): Diatoms powerful indicators of environmental change. Environmental Science and Technology. 26, 23-33.

Palmer, C.M (1980): Algae and Water Pollution. Castle House Publications Ltd. England.

Mishra, S. R., & Saxena, D. N. (1993). Phytoplanktonic composition of sewage polluted Morar (Kalpi) river in Gwalior, Madhya Pradesh. Environment and Ecology, 11, 625–629.

Kamat, N.D. (1965): Ecological notes on the algae of Kolhapur. *Journal of Biological Sciences* 8 47-54.

Round, F.E (1981): The ecology of algae. Cambridge University Press.

Laskar, H.S. and Gupta, S. (2009): Phytoplankton diversity and dynamics of Chatla floodplain lake, Barak Valley, Assam, North East India - A seasonal study. *Journal of Environmental Biology.* November 2009, 30 (6) 1007-1012 (2009).

Upadhyay, Rahul and Pandey, Arvind. (2011): Limnochemistry and Nutrient Dynmaics in Upper Lake Bhopal, India, *Environ Monit Assess*.

Pani, S., Dubey, A., & Khan, M.R. (2014): Decadal Variation in Microflora and Fauna in 10 Water Bodies of Bhopal, Madhya Pradesh. *Current World Environment*. 9(1), 137-144.

Devi, M.B., S. Gupta, and T. Das (2016): Phytoplankton community of Lake Baskandi anua, Cachar District, Assam, North East India – An ecological study. Knowledge and Management of Aquatic Ecosystems. 4(17): 1-9.

Nissa and S.U. Bhat (2015): An Assessment of Phytoplankton in Nigeen Lake of Kashmir Himalaya. *Asian Journal of Biological Sciences*. 9: 27-40.

Navatha, K., P. Manikya Reddy (2015): Distribution of Pediastrum in Dal Lake, Kashmir. *International Journal of Science and Research* (IJSR). 5(8): 412-415.