# Distribution and Abundance of Planktonic Organisms of Sasthamkotta Lake, Kerala, India

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## *Abstract*

*Distribution and abundance of planktonic organisms in Sasthamkotta Lake was studied based on the samples collected from four stations during pre-monsoon period. Total of 23 species of phytoplankton and 22 species of zooplankton were identified from Sasthamkotta Lake. The phytoplankton population in the Sasthamkotta Lake was composed of 3 major families, Chlorophyceae, Cyanophyceae and Bacillariophyceae. Pollution tolerant species like Nitzschia, Navicula, Euglena, Cyclotella, Microcystis aeruginosa and Oscillatoria were reported during the present study. The zooplankton population in the Sasthamkotta Lake was composed of 3 major families – Protozoa, Rotifers and Arthropoda.*

***Key words:*** *Diversity, Phytoplankton, Sasthamkotta Lake, Water quality, Zooplankton*

## 1. Introduction

Sasthamkotta Lake is the largest fresh water lake in Kerala and categorized as a wetland. It was also designated as Ramsar site in 2002. Around 5,00,000 people in the marginal areas of Kollam and Thiruvananthapuram district of Kerala State depend this lake as a major drinking water source and always it have a rich diversity of fish fauna. Both of this support the livelihood of people [3]. The quality water in the fresh water lake is getting polluted with urbanization and industrialization [20]. Urbanization and industrialization affect the productivity of this wetland ecosystem. Water is a natural resource that is essential for our life and environment. Today all human society faced the issue of water crisis. Water quality is an important parameter of water that used to describe physical, chemical and biological features of water. Undesirable human activities towards water and water resources leads to the physical and structural change of water. The quality of water is determined by using the analysis of physico-chemical parameters of water. The causative factors responsible for degradation of water quality need to be evaluated for welfare of human life and aquatic organisms [19].

Plankton is a general term that represent both plants (phytoplankton) and animals (zooplankton) which moves in water, they are also unable to swim against water current. In an aquatic ecosystem some organisms belongs to planktonic during larval stage and nektonic during in their adult stage. Water quality is an important factor that determines the species richness,

abundance and productivity of plankton. Availability of food, geomorphologic nature of the environment and biotic factor are some other factors that determine the planktonic abundance [4]. Phytoplankton are one of the most important primary producers on earth. The productivity of an aquatic ecosystem had a direct relation with diversity of phytoplankton. They are the pioneers of aquatic food chain [1]. The nutrient discharge in to water bodies due to anthropogenic activities enhance the growth of aquatic organisms, this cause the quality changes of aquatic ecosystem [22]. If there is any sudden changes happens in biomass and composition of phytoplankton in an aquatic ecosystem, which will affect the entire food chain and reduce the biological productivity of ecosystem [11]. Zooplankton are the primary consumers which depend on phytoplankton as the source of energy. Small fishes eating zooplankton and ended up to large fish. Phytoplankton and zooplankton are good indicators of water quality changes because they are strongly affected and respond to change in environmental conditions. Rotifers, crustaceans, cladocerans and copepods are the zooplankton used as the indicators of aquatic environment [25]. The availability of phytoplankton represents the quality of water [16]. Pollution of an aquatic ecosystem can be clearly identified by using zooplankton [8]. The present study aims to estimate the plankton diversity in the Sasthamkotta Lake. In addition to that evaluate the species diversity, richness and evenness of the plankton.

## 2. Materials and Methods

### 2.1 Study Area

Sasthamkotta Lake located in Kunnathur Taluk of Kollam District in Kerala at an elevation of 33 m above MSL, has a total catchment area of about 12.69 $km^2$, average depth of 6.53 m, and total storage capacity of 22.4 $km^2$ [7]. Sasthamkotta Lake is situated 9° 2' 38.04" N and 76° 37' 30.252" E and is also a very important wetland in Kerala.

### 2.2 Sample collection

For the present study four stations were selected from this freshwater lake, Station 1 (S1) Ambalakkadavu is having comparatively high anthropogenic activities. Bathing and washing of clothes causes the deposition of soaps and detergents into the ecosystem. The adjoining lands of this station are steep which enhances agricultural runoff. It is the conventional temple bath place and a ferry service is existing here. A forest cover is present near the station that only exists within the surroundings of the sacred temple. Station 2 (S2) Adikkadumukku is protected by the Water Authority Department of the Government of Kerala and hence anthropogenic activities except fishing are comparatively low. This station is significant due to the presence of the pumping station providing water for lakhs of people. Station 3 (S3) Kayal Bundu is in the south-eastern region where, a concrete bund was constructed separating the lake from the nearby paddy fields. Rubber plantation occupies the elevated regions on the northern side of the bund. Due to the unscientific agricultural practices, fertilizers and pesticides are continuously entering into the lake in this station. Station 4 (S4) Pattenkuzhi having Rubber plantation. Fish catching is regular at this area. Bathing and washing activities are also practiced here.

The samples were collected during pre-monsoon season of 2017 (March, April, May). The samples were collected in the early hours of the day between 5.30 am to 7.30 am. Measured quantity of water from the Lake was collected using a plastic bucket and filtered through plankton net made of bolting silk (phytoplankton net- 20 µm mesh sized and zooplankton net- 40 µm mesh sized). The residue retained in the plankton net was transferred in to plastic bottles containing 2

ml of Lugol's iodine for further studies. The collected samples were concentrated by settling method. The water sample can be kept in measuring cylinder for settlement after preservation. Later, settled portion can be separated by siphoning out water from the top.

### 2.3 Data analysis

The qualitative analysis should be done by observing and identifying the organisms up to generic and species level with the help of standard key [14]. The plankton density can be calculated by direct count method (no. of cells/ml). The species diversity, richness and evenness were calculated by using Shannon- Wiener diversity index (H'), Margalef's richness index (R) and Pielou's evenness index (E).

i. Shannon- Wiener diversity index (1949):

$$H' = \sum [ni/N] \times \ln[ni/N]$$

ii. Margalef's richness index (1958):

$$R = S\text{-}1 / \ln N$$

iii. Pielou's evenness index (1977):

$$E = H' / \ln S$$

Where, N = total number of plankton cells per liter of water filtered counted

n = average number of cells in 1 ml of plankton sample

V2 = volume of plankton concentrate (ml)

V1 = volume of total water filtered (L)

ni = number of individuals in a species

N = total number of individuals

S = total number of species

ln = natural log

C = number of species the 3 communities common

A = total number of species found in community

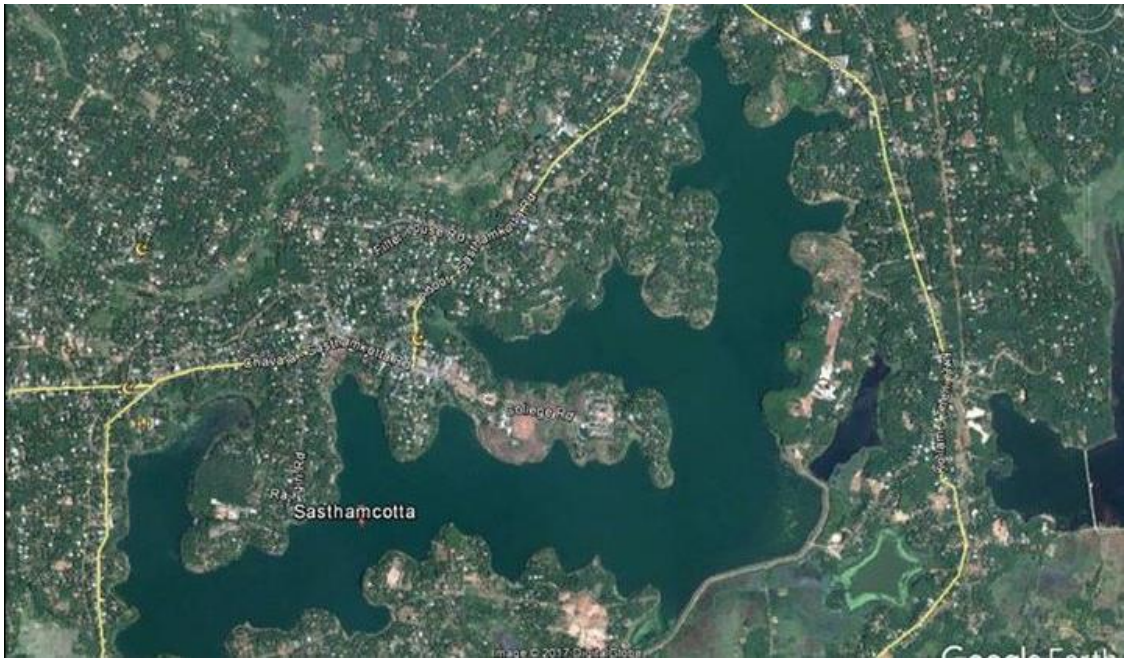


**Figure 1. A general map showing location of Sasthamkotta Lake**

## 3. Results

The phytoplankton population in the Sasthamkotta Lake was composed of 3 major families – Chlorophyceae, Cyanophyceae and Bacillariophyceae. Altogether 22 genera comprising 23 species of phytoplankton were observed during the present study. Chlorophyceae was represented by 9 species (39%), Cyanophyceae was represented by 5 species (22%) and Bacillariophyceae was represented by 9 species (39%). The chlorophyceae species such as *Synechocystis pevalekii, Chlorosterium ehrenbergii* and *Zygnema* were reported throughout the stations during the study period. Cyanophycean such as *Nostoc* found in all stations during the entire study period. *Peridinum thorianum* and *Cocconeis* were the bacillariophyceae present throughout the stations during the study period (Table 1; Figure 2). The species diversity was maximum during May (23 sp.) followed by April (21 sp.) and March (17 sp.). The population density of phytoplankton was ranged from 14104 No./L to 22177 No. /L. Maximum density was observed during April (22177 No./L) and minimum during March (14104 No./L). Considering the stations, highest population density was observed at station 2 (22177No./L) and lowest in station 1(14104 No./L). From the diversity indices analysis, the highest Shannon-Weiner index reported in station 3 during May (3.494), the lowest were reported in station 1 during May (0.089). High Margalef's richness index were reported in station 1 during March (2.302), and lowest in station 2 during April (2.198). Maximum Pielou's evenness index were reported in station 3 during May (1.114) and minimum in station 1 during March (0.043). (Table 2; Figure 3). Pollution tolerant species like *Nitzschia, Navicula, Euglena, Cyclotella, Microcystis aeruginosa* and *Oscillatoria* were reported during the present study.

The zooplankton population in the Sasthamkotta Lake was composed of 3 major categories – Protozoa, Rotifers and Arthropod. Altogether 21 genera comprising of 22 species of zooplankton were observed during the present study. Protozoa was represented by 8 species (36%), Rotifers was represented by 5 species (23%) and Arthropoda was represented by 9 species (41%). Among

Protozoa *Colpoda cucullus* were present throughout the study period in all the stations. *Keratella* was the Rotifer having the uniform representation from all stations during the entire study period. Arthropoda such as *Diaptomus* and *Cyclops* were reported in all the stations during the entire study period (Table 3; Figure 4). The species diversity was maximum during March May (21 sp.) followed by April (18 sp.). Considering the stations, highest diversity was observed at station 4 (18 sp.) during March, and lowest in station 1 and 2 (11 sp.) during March. The population density of zooplankton was ranged from 2200 No./L to 4688 No./L. Maximum density was observed during April (4688 No./L) and minimum during March (2200 No./L). Considering the stations, highest population density was observed at station 3 (4688 No./L) and lowest in station 2 (2200 No./L). Highest Shannon- Weiner index were reported in station 4 during May (3.366), the lowest in station 4 during March (0.114). Margalef's richness index were maximum in station 2 during March (2.73) and minimum at station 3 during April (2.484). Pielou's evenness index is maximum at station 4 during May (1.088) and minimum at station 4 during March (0.036) (Table 4, Figure 5).

**Table 1. Distribution of phytoplankton (No./L) in Sasthamkotta Lake during pre-monsoon season**

| | March 2017 | | | | April 2017 | | | | May 2017 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PHYTOPLANKTON** | **S1** | **S2** | **S3** | **S4** | **S1** | **S2** | **S3** | **S4** | **S1** | **S2** | **S3** | **S4** |
| **CHLOROPHYCEAE** | | | | | | | | | | | | |
| *Pediastrum tetras* | - | - | 80 | 96 | 120 | 100 | 100 | 119 | - | 189 | 131 | 139 |
| *Pediastrum angulosum* | - | - | 158 | | 960 | 980 | 800 | 900 | 789 | 814 | 839 | - |
| *Cosmarium conspersum* | 280 | 280 | 280 | 300 | - | - | - | - | 321 | 290 | 297 | 283 |
| *Chlorella vulgaris* | - | 3200 | 3160 | 3240 | 3400 | 3520 | 3420 | 3580 | 3240 | 2911 | 2820 | 3000 |
| *Treubaria triappendiculata* | 480 | 540 | 460 | 440 | 640 | 720 | 680 | 760 | 727 | 784 | - | 803 |
| *Tetraendron triangular* | - | - | - | - | 480 | 540 | 600 | 440 | 638 | 625 | 540 | 606 |
| *Synechocystis pevalekii* | 780 | 600 | 540 | 720 | 900 | 600 | 640 | 700 | 714 | 635 | 629 | 810 |
| *Chlorosterium ehrenbergii* | 104 | 218 | 120 | 98 | 100 | 158 | 141 | 130 | 100 | 103 | 140 | 90 |
| *Zygnema* | 460 | 540 | 500 | 480 | 164 | 780 | 740 | 900 | 654 | 629 | 608 | 718 |
| **BACILLARIOPHYCEAE** | | | | | | | | | | | | |
| *Eunotia pectinalis* | - | - | - | - | 720 | 600 | 700 | 840 | 541 | 559 | 680 | 601 |
| *Achanthes exigua* | - | 120 | - | - | 500 | 560 | 480 | 560 | - | 420 | 301 | 219 |
| *Navicula panhagarhensis* | - | - | - | - | 400 | 559 | 380 | 320 | 379 | - | - | - |
| *Nitschia fonticola* | - | - | - | - | 80 | 100 | 100 | 120 | 68 | 54 | 62 | - |
| *Peridinum thorianum* | 1700 | 980 | 1520 | 1580 | 1840 | 1960 | 1700 | 1660 | 1290 | 980 | 1218 | 1100 |
| *Euglena polymorpha* | 500 | 317 | 360 | 223 | - | - | - | - | - | 290 | - | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Gomophonema abbreviatum* | - | 380 | - | - | 300 | 520 | 580 | 340 | 392 | - | 319 | 424 |
| *Cocconeis* | 620 | 300 | 580 | 680 | 740 | 660 | 580 | 340 | 658 | 718 | 579 | 628 |
| *Cyclotella* | 2400 | 600 | 2480 | - | 740 | 660 | 580 | 800 | - | 1929 | 1800 | - |
| **CYANOPHYCEAE** | | | | | | | | | | | | |
| *Aphanothece microscopica* | - | - | - | - | 500 | 560 | 540 | 400 | 490 | 500 | 479 | 450 |
| *Microcystis aeruginosa* | 300 | 380 | 320 | 440 | 520 | 360 | 500 | 640 | 540 | 524 | 572 | - |
| *Oscillatoria subbrevis* | - | - | - | - | 580 | 420 | 521 | 720 | 428 | 405 | - | - |
| *Nostoc* | 6180 | 5600 | 6500 | 6800 | 7200 | 7500 | 7600 | 6800 | 6518 | 6220 | 7285 | 7018 |
| *Anabena* | 300 | 300 | 220 | 320 | 180 | 320 | 341 | 380 | - | - | 318 | 292 |
| **TOTAL** | **14104** | **14355** | **17278** | **15417** | **21064** | **22177** | **21723** | **21449** | **18487** | **19579** | **19616** | **17181** |

**Table 2. Diversity indices of phytoplankton in Sasthamkotta Lake during pre-monsoon period**

| **SI. No.** | **Diversity Indices** | **MARCH 2017** | | | | **APRIL 2017** | | | | **MAY 2017** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **S1** | **S2** | **S3** | **S4** | **S1** | **S2** | **S3** | **S4** | **S1** | **S2** | **S3** | **S4** |
| 1 | Shannon-Weiner diversity index | 1.375 | 1.312 | 2.835 | 1.925 | 3.079 | 2.608 | 1.35 | 1.54 | 0.0895 | 1.394 | 3.494 | 1.722 |
| 2 | Margalef's richness index | 2.302 | 2.298 | 2.254 | 2.281 | 2.21 | 2.198 | 2.203 | 2.205 | 2.239 | 2.226 | 2.225 | 2.256 |
| 3 | Pielou's evenness index | 0.043 | 0.418 | 0.904 | 0.614 | 0.982 | 0.831 | 0.43 | 0.491 | 0.285 | 0.444 | 1.114 | 0.549 |

**Table 3. Distribution of zooplankton (No./L) in Sasthamkotta Lake during pre-monsoon period**

| | March 2017 | | | | April 2017 | | | | May 2017 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ZOOPLANKTON** | **S1** | **S2** | **S3** | **S4** | **S1** | **S2** | **S3** | **S4** | **S1** | **S2** | **S3** | **S4** |
| **PROTOZOA** | | | | | | | | | | | | |
| *Euglena asus* | 80 | 100 | 80 | 100 | - | 38 | 41 | 38 | 10 | 18 | 21 | 24 |
| *Amoeba* | 80 | 100 | 60 | 60 | 51 | 59 | 61 | - | 32 | 39 | 45 | 47 |
| *Didinum nasutum* | 140 | 100 | 80 | 160 | 32 | - | - | - | - | 20 | - | 15 |
| *Colpoda cucullus* | 80 | 100 | 120 | 120 | 78 | 92 | 91 | 79 | 60 | 69 | 75 | 54 |
| *Paramoecium* | - | - | 60 | 80 | - | - | - | - | 60 | 69 | 75 | 54 |
| *Stentor coerleus* | - | 80 | 60 | 60 | 60 | 71 | 60 | 64 | 39 | 41 | 48 | 56 |
| *Glenodinum cinctum* | 320 | - | - | 340 | - | - | - | - | - | - | 235 | - |
| *Chlorogonium euchlorum* | - | - | 80 | - | - | - | 25 | 41 | - | - | 13 | - |
| **ROTIFERA** | | | | | | | | | | | | |
| *Brachionus quadridentus* | - | - | 80 | 60 | - | - | | - | 9 | - | - | - |
| *Brachionus caudate personatus* | - | - | 80 | | - | - | 42 | - | 35 | - | - | 29 |
| *Philodena citrina* | 80 | 100 | 80 | 80 | - | - | - | - | - | - | - | - |
| *Lepadella crestata* | 80 | 100 | 80 | 80 | - | 78 | 69 | 60 | - | 78 | 69 | 71 |
| *Keratella* | 600 | 100 | 560 | 520 | 780 | 760 | 740 | 800 | 780 | 150 | 325 | 351 |
| **ARTHROPODA** | | | | | | | | | | | | |
| *Artema salina* | - | - | - | 59 | 80 | 80 | 80 | 60 | 78 | 65 | 71 | - |
| *Allona dhiloni* | - | - | - | 80 | 100 | 80 | 100 | 100 | 70 | 91 | 79 | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Chirocephalus priscus* | - | - | - | - | 60 | - | - | 80 | - | - | 55 | - |
| *Simocephalus acutirostratus* | - | - | - | 80 | 80 | 80 | - | - | 71 | 68 | - | - |
| *Trichocera porcellus* | 80 | 120 | - | - | - | 99 | - | - | - | 39 | - | - |
| *Moina* | - | - | 860 | 920 | 840 | 960 | 1040 | 800 | - | 885 | 917 | 908 |
| *Calanus* | - | - | 640 | 800 | 760 | 920 | 980 | 720 | 618 | 701 | 621 | 600 |
| *Diaptomus* | 700 | 760 | 580 | 600 | 380 | 920 | 840 | 900 | 518 | 618 | 519 | 680 |
| *Cyclops* | 520 | 540 | 460 | 420 | 580 | 340 | 520 | 480 | 435 | 229 | 400 | 411 |
| | | | | | | | | | | | | |
| **TOTAL** | **2760** | **2200** | **3740** | **4639** | **3651** | **4557** | **4688** | **4186** | **2755** | **3111** | **3493** | **3281** |

**Table 4. Diversity indices of Zooplankton in Sasthamkotta Lake during pre-monsoon period**

| | | **MARCH 2017** | | | | **APRIL 2017** | | | | **MAY 2017** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SI.No.** | **Diversity Indices** | **S1** | **S2** | **S3** | **S4** | **S1** | **S2** | **S3** | **S4** | **S1** | **S2** | **S3** | **S4** |
| 1 | Shannon-Weiner diversity index | 1.989 | 1.96 | 2.133 | 0.114 | 2.901 | 1.387 | 3.01 | 1.979 | 0.796 | 1.569 | 1.182 | 3.366 |
| 2 | Margalef's richness index | 2.65 | 2.73 | 2.535 | 2.487 | 2.541 | 2.492 | 2.484 | 2.517 | 2.651 | 2.611 | 2.574 | 2.594 |
| 3 | Pielou's evenness index | 0.643 | 0.063 | 0.690 | 0.036 | 0.938 | 0.448 | 0.973 | 0.640 | 0.257 | 0.507 | 0.382 | 1.088 |

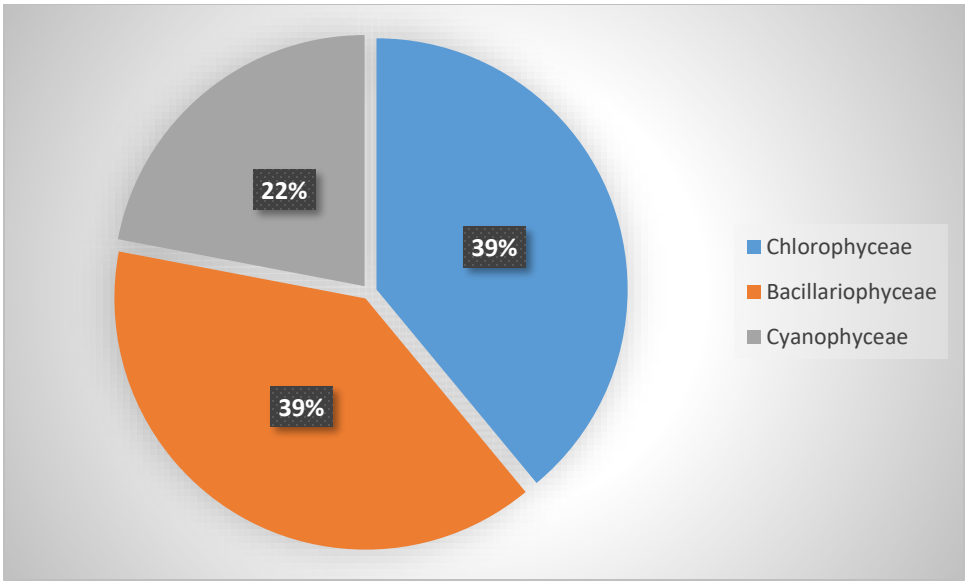


**Figure 2. Frequency distribution of phytoplankton in Sasthamkotta Lake during pre-monsoon period**

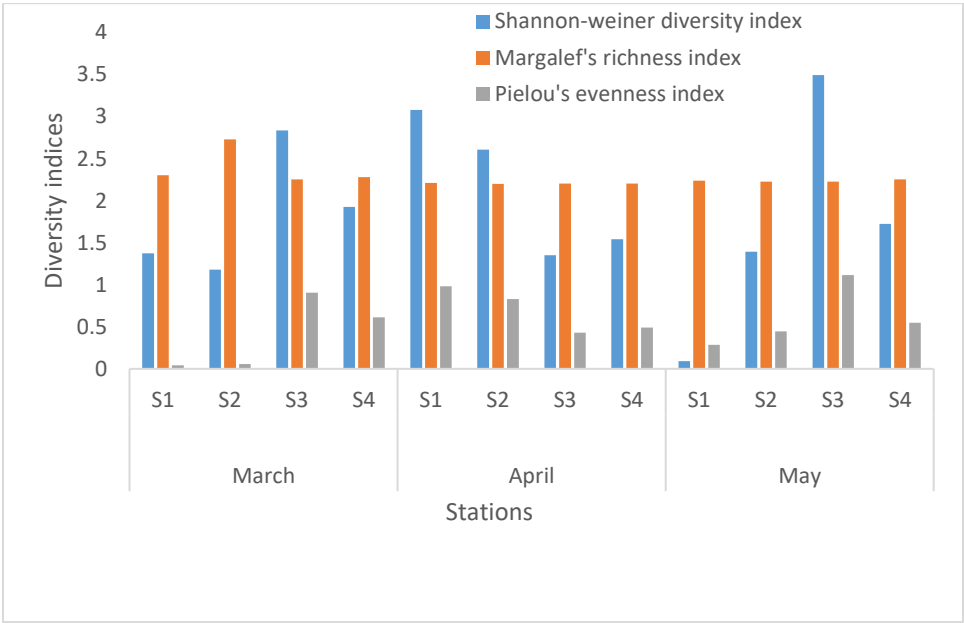


**Figure 3. Diversity indices of phytoplankton in Sasthamkotta Lake during pre-monsoon period**

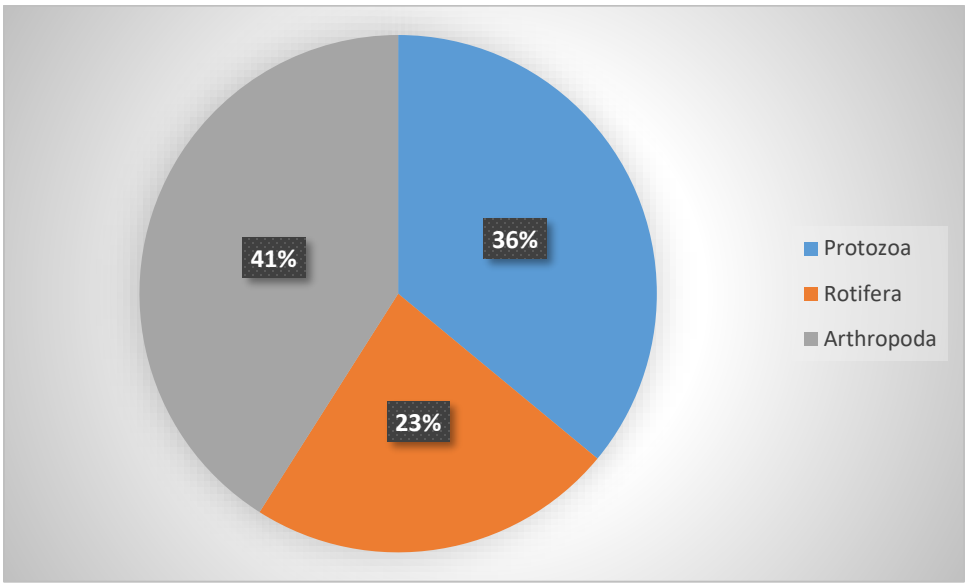


**Figure 4. Frequency distribution of zooplankton in Sasthamkotta Lake during pre-monsoon period**

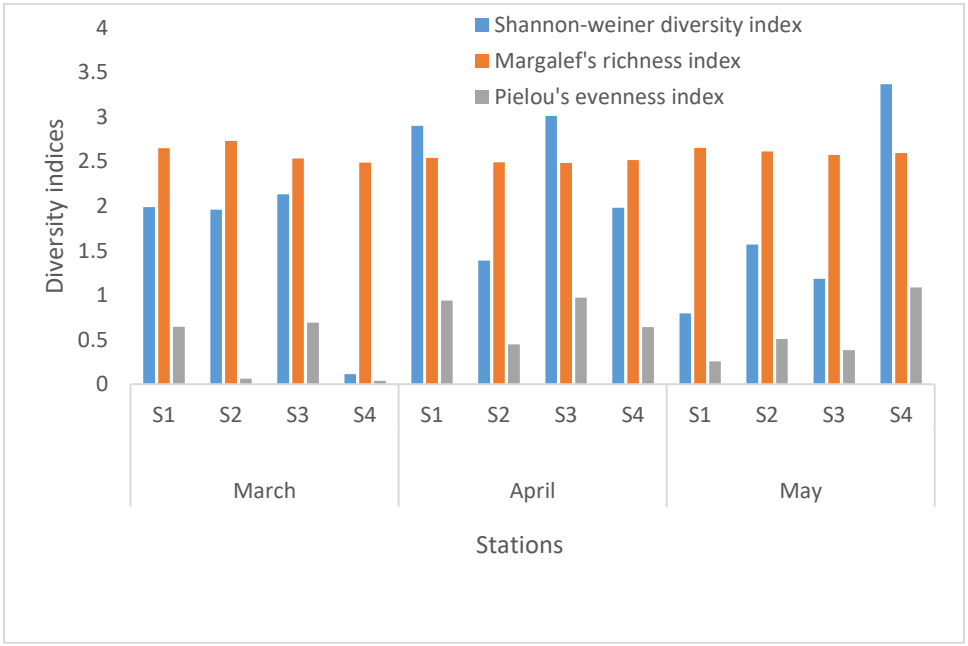


**Figure 5. Diversity indices of zooplankton in Sasthamkotta Lake during pre-monsoon period**

## 4. Discussion

Lakes form a significant component in aquatic resources of India and they have high conservation values. In the present study three families of phytoplankton were identified, Chlorophyceae, Cyanophyceae and Bacillariophyceae. Chlorophyceae and Bacillariophyceae have maximum diversity during the study period. Chlorophyceae had 9 species. Cyanophyceae were represented by 5 genera. The species *Nostoc* was observed throughout the study period. In Sasthamkotta Lake the diversity of Cyanophycea was comparatively low. Similar findings were reported by [22] in Vellayani and Sasthamkotta fresh water Lakes in Southern Kerala. Bacillariophyceae includes 9 genera. *Peridinum thorianum* and *Cocconies* sp. were observed throughout the study period. [18] has shown that the algal genera *Nitzshia, Navicula, Euglena, Cyclotella* and *Oscillatoria* were the species found in organically polluted waters. Similar genera were recorded in the present investigation may be showing the lake is on the verge of organic pollution. The Cyanophyceae *Microcystis aeruginosa* was used as the best single indicator of pollution and it was associated with the highest degree of civic pollution [18]. In the present study, *Microcystis* was also recorded from all the stations. The occurrence of *Oscillatoria* in all the stations during the present study indicates pollutants of biological origin which agreed with the observations of [10].

Water quality analysis were done by [24] in Sasthamkotta Lake and they concluded that anthropogenic activities are high in the Lake. This findings are similar to the present study. During the study the phytoplankton were most abundant in April. Same findings were reported by [5] from Sasthamkotta Lake. They observed the phytoplankton pulse in the month of April, which was termed as the 'summer peak'. The maximum population density and diversity during April may be due to the high temperature and sunlight available during that period. The result of the present study was also supported by [11] and reported that phytoplankton shown its maximum abundance in summer. Considering the stations, the phytoplankton were more abundant in station 2 in April. This station may be comparatively less polluted and the pumping station is situated here. The low density during March may be due to the influence of post monsoon effects.

In the present study zooplankton of the Sasthamkotta Lake comprises Protozoa, Rotifera and Arthropoda. Arthropoda was the most abundant category of zooplankton observed. A similar kind of zooplankton work were done by [15] on tropical wetland system. Protozoa and Rotifera were the dominating groups. Rotifers are the significant component of zooplankton. Their peek range is obtained in summer season. Similar kind of observation were made by [2] in Nangal wetland, Punjab. The study of [6] on zooplankton diversity reported that Rotifers are the most commonly reported zooplankton. They are always rich in pre -monsoon period. This observation is always similar to the present findings.

Shannon- Weiner diversity index represents the number of species living in a habitat that means richness of a species, and also the abundance of a species. 1.5 to 3.5 is the range of Shannon-Weiner diversity index [12]. In the present study, the index of phytoplankton ranged from 1.282 to 3.079. Zooplankton diversity ranged from 0.18 to 3.366. Both phytoplankton and zooplankton diversity indices showed a high species diversity of the Lake. Margalef's richness index means total number of species in a community. It has no certain limit [12]. The Margalef's richness of phytoplankton ranged from 2.195 to 2.298 and zooplankton ranged from 2.484 to 2.73. So it may concluded that the Lake has high species richness. Pielou's evenness index describes that the species having even kind of distribution in all the stations. It has a limit of 0 to 1. The range 0

indicate no evenness and 1 indicate complete evenness. In the present study phytoplankton ranged from 0.285 to 0.904. In case of zooplankton it ranged from 0.036 to 1.088. So it may concluded that both the plankton doesn't having even kind of distribution. More than 0.5 of Pielou's index values indicated that the zooplankton ecology is balanced during the study period. If the values are less than 0.5, it could be an indicator of the presence of ecological stress with the occurrence of few dominant species at high density in the study site [9].

## 5. Conclusion

The qualitative and quantitative study of plankton in Sasthamkotta Lake revealed the presence of diverse phytoplankton and zooplankton community. The phytoplankton are the main components of aquatic ecosystem, as they trap sun energy and it convert into chemical energy and organic material. They play a key role in maintaining the proper equilibrium between abiotic and biotic components of aquatic ecosystem [13]. The occurrence of pollution tolerant species like *Nitzschia, Navicula, Euglena, Cyclotella, Microcystis aeruginosa* and *Oscillatoria* may indicates the polluted nature of water in certain stations. The polluted nature of some stations are due to various human interferences. The villagers near to the Sasthamkotta Lake used it for multiple purpose like bathing, washing clothes, vehicles, animals, numerous religious rituals and other human daily activities. The anthropogenic activities affect the growth and distribution of plankton diversity in the lake ecosystem. Lack of awareness of is one of the major cause behind this pollution. So there is a need for preventing unscientific anthropogenic activities towards this Lake. That will maintain purity of this ecosystem. Sasthamkotta Lake is the second RAMSAR convention site in Kollam district and the Lake provide drinking water for people in two districts. Hence the Lake has to be conserved and protected from further pollution.

## Acknowledgments

The authors are thankful to Dr. Achamma George, Principal, St. Stephen's College, Pathanapuram, Kollam for providing necessary facilities during the research work.

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