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# Aquatic Diversity with Reference to Phytoplankton, Zooplankton and Benthos in Lake Vembanad, Kottayam, Kerala, India

**Nitin Walmiki[1-2]*, Deepti Sharma[1] and Priti Kubal[2]**
[1]Terra Nero Enterprises, S-3, 108, Vedant Commercial Complex, Vartak Nagar, Thane (W), 400606, Mumbai, Maharashtra, India
[2]Eco-Echo, D/85, Meghwadi, Lalbaug, Dr. S. S Rao Road, Mumbai, 400012, Maharashtra, India
nitinwalmiki007@gmail.com

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## Abstract

*For healthy and productive fisheries, it is essential that the lower portion of the food web comprising of plankton and benthic organisms are monitored, analyzed and maintained. The Vembanad estuary is also a part of the Vembanad - Kole Ramsar site. Also, Lake Vembanad is an Important Bird Area. It is a fishery of immense local significance as well. The data regarding Phytoplankon, Zooplankton and Benthos (PZB) from the Kottayam region of Lake Vembanad are relatively scarce. Studies were carried out in the pre-monsoon months of May-June. Total 13 locations were selected for PZB studies near the Kumarakom Bird Sanctuary. 40 species of phytoplankton, 8 groups of benthos and 16 groups of zooplankton were observed. The sampling station closest to the Kumarakom Bird Sanctuary was found to have highest species richness.*

**Keywords**: Lake Vembanad, Kumarakom Bird Sanctuary, Phytoplankton, Zooplankton, Benthos.

## Introduction

In a lake or wetland ecosystem, the importance of phytoplankton, zooplankton and benthos (PZB) cannot be stressed enough[1]. Commercially, too, the importance of PZB for maintaining productive fisheries is enormous. To briefly outline the food web in a typical aquatic ecosystem, the producers are the phytoplankton, which is fed upon by zooplankton groups. Planktivorous fish feed on zooplankton and are, in turn, predated upon by piscivorous fish. Benthivorous fish feed on the benthos that inhabit the lake bottom. Admittedly, the PZB groups are taxonomically ill-defined - they are a heterogeneous amalgamation of species from several taxonomic groups, largely composed of lower invertebrates like copepods, amphipods, rotifers, cladocerans and larvae of fish, prawn, shrimp, and crabs[2].

Regular monitoring of PZB is essential to maintaining a healthy fishery. Lake Vembanad in Kerala, India, is a lake well-known for its fish reserve[3]. The Vembanad estuarine system is the largest tropical wetland ecosystem on the western coast of India, replete with mangroves, aquatic birds and a rich fishery. Vembanad Lake was declared a 'Ramsar site' in the year 2002[4]. Also, it was designated an Important Bird Area (IN 254) in 2004[5]. The heronry is of 112 acres (45.3 ha), located 14 km west of Kottayam. It is connected to the Western Ghats through six rivers, *viz.*, Periyar, Moovattupuzha, Meenachil, Manimala, Pampa and Achencoil, which are its freshwater sources; it is also connected to the Arabian Sea through which it gets its tidal influx[4].

Zooplankton diversity in the Vembanad Lake region near the Kochi backwaters has been studied by several authors[6,7], but most recently by Varghese and Krishnan[8]. Phytoplankton have been most recently reported by Bindu and Padmakumar[9]. Considering the heterogeneous nature of the benthos group, varied groups have reported the occurrence of black clam[10-13]. Since these benthic organisms are sedentary as well as sessile in nature, Kubal et al[14] studied macrofaunal habitation around Tarapur Atomic Power Station to check health status of surrounding environment.

However, to have a holistic view of an ecosystem, it is necessary to have as complete a picture of the food web as possible. Hence, this study was undertaken to include the survey of the three groups – PZB together, which may be considered the first such effort from the Kottayam region of Lake Vembanad. The study was further supplemented with the data of fish catch through a survey of the local fishermen.

The present study forms part of a larger Environment Impact Assessment (EIA) work that was carried out in Kottayam for the purpose of collecting baseline data.

## Methodology

**Study Area Details:** Vembanad is the longest backwater lake of India, about 65km long and 0.5-15km wide. Its depth varies from 1.0-12.0 m. It extends from 09° 30' N - 10° 20' N lat and 76° 13' E to 76° 50' E [10]. Being a Ramsar site as well as an Important Bird Area, Lake Vembanad has immense ecological significance.

Aninteresting feature of Lake Vembanad is the 1,252 metres

(4,108 ft)-long Thanneermukkom salt water barrier, located where the lake is narrow. The salt bridge was constructed under the Kuttanad Development Scheme to stop tidal action and salt water entry into the Kuttanad low-lands. This largest mud regulator in India divides the lake into two parts –one with brackish water all the year round and the other receiving fresh water from rivers. The salt barrier has been of help to the local farmers, ensuring that saline waters did not spoil their lands and helping them grow an additional crop per year. The salt bridge functions by opening two-thirds of the gatesin July to release flood flow; until mid-November, these gates are shut. However, there are clear negative ecological repercussions of the same. The salt bridge has prevented fish and prawn upstream migration.Weed infestation, noticeably water hyacinth, has increased upstream, interfering with natural wetland functions.

**Sampling Locations:** The locations where samples were taken have been enlisted in Table-1 and Figure-1. Roughly, the 13 locations were spread south of the Kumarakom Bird Sanctuary.

**Sampling Protocols:** The Sampling of Phytoplankton, Zooplankton and Benthic organisms were collected from the 13 locations.

**Sampling for Phytoplankton:** Large-bottle-type samplers have been found to be slightly more efficient for phytoplankton sampling[15]. The sampling protocol followed was as per USEPA (LG400), with the significant difference that instead of a rosette sampler, a large bottle type sampler was used. Briefly, composite samples were collected at each point till the euphotic depth. A Secchi disk was used to calculated the euphotic depth.The Secchi Disk is a convenient method of measuring euphotic depth. The limit of visibility is approximately the region of transmission of 5% sunlight[16]. Once the limit of visibility is established, calculations can be made to determine the lower limits of the euphotic zone (light) which is usually three times the Secchi Disk depth[17]. Samples were mixed and preserved with Lugol's iodine (final concentration 1% v/v). Samples were stored in the dark and refrigerated. Phytoplankton was viewed under a 40X lens in a compound microscope.

**Sediment Sampling for Benthic Invertebrates:** Benthic invertebrates were sampled using a Van Veen Grab Sampler. The procedure used for sampling and preservation of sample was as per USEPA protocol (LG406). Briefly, the sediment sampler was lowered slowly through the water column, being allowed to fall freely towards the end. Post that, it was pulled up, and the contents lowered into a tub. The sediment was then mixed with water to have a slurry-like consistency. This was then filtered through a mesh of size 500µm after thorough but low pressure rinsing to ensure sample concentration. Residue was fixed with 4% (v/v) formalin (final volume of formalin 5-10% v/v of sample). Benthic organisms were viewed under a 20X lens of a stereo microscope.

**Sampling for Zooplankton:** Zooplankton was sampled using a standard zooplankton net of mesh size 75µm. The net was dipped slowly in water and raised. It was rinsed thoroughly and the sample was concentrated. It was fixed first with 4-5% formalin (1 part formalin and 9 parts sample). Few drops of Rose Bengal solution was used for sample staining. This protocol was as per NIO Field manual[18].

Zooplanktons were viewed under a 20X lens in a stereomicroscope. Sampling was conducted in the pre-monsoon months of May-June.

**Observations:** During the time-period of the study, air temperature ranged from 28-32°C while water temperature was comparable at 19-21°C.

The phytoplankton, zooplankton and benthos diversity of Lake Vembanad was assessed, results of which have been given in Tables-2, 3 and 4.

**Table-1**
**Sampling Locations**

| Location | Global Coordinates | Euphotic Depth (in feet) |
|---|---|---|
| Station 1 | 9°37'53.08"N; 76°25'2.60"E | 0.8 |
| Station 2 | 9°37'36.07"N; 76°24'26.19"E | 1.0 |
| Station 3 | 9°36'53.27"N; 76°24'29.58"E | 2.0 |
| Station 4 | 9°36'3.72"N; 76°24'25.02"E | 2.5 |
| Station 5 | 9°35'21.69"N; 76°24'54.63"E | 1.5 |
| Station 6 | 9°35'13.44"N; 76°24'8.31"E | 3.0 |
| Station 7 | 9°34'36.53"N; 76°24'20.13"E | 2.9 |
| Station 8 | 9°36'57.84"N; 76°23'10.38"E | 3.4 |
| Station 9 | 9°32'10.17"N; 76°21'50.19"E | 2.0 |
| Station 10 | 9°33'31.58"N; 76°22'16.47"E | 2.0 |
| Station 11 | 9°35'30.04"N; 76°22'31.59"E | 2.8 |
| Station 12 | 9°34'16.854"N; 76°25'00.90"E | 3.5 |
| Station 13 | 9°37'36.63"N; 76°23'31.83"E | 2.5 |

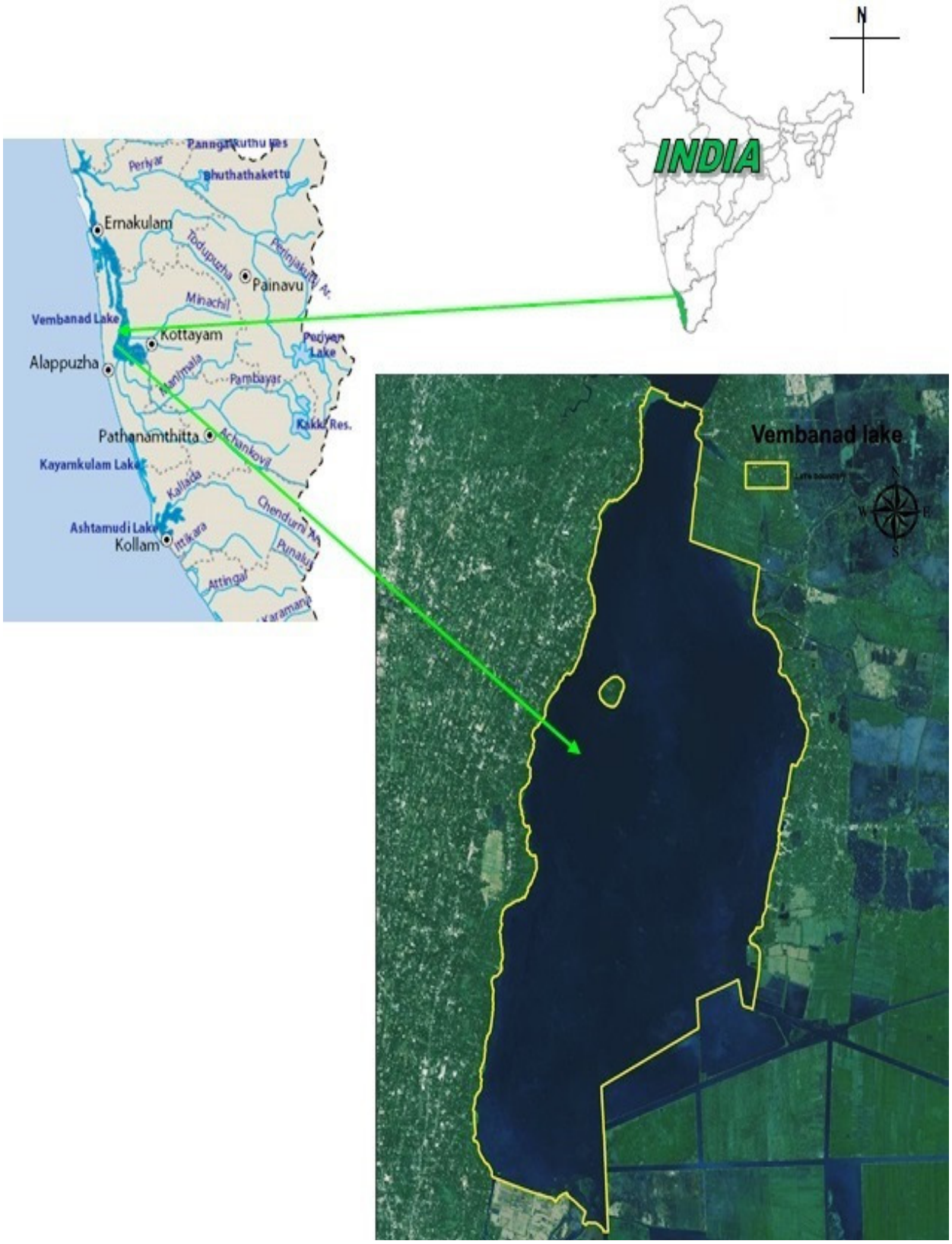


**Figure-1**
**Map showing location of Vembanad lake, Kottayam district, Kerala, India**

40 species of phytoplankton were observed in Lake Vembanad (Table-2). Most common phytoplankton species was *Navicula* (42 individuals/lit). *Ocillaotoria limosa* (33 individuals/lit), *Skeletonema costatum* (30 individuals/lit), *Nitzschia* sp. (29 individuals/lit), *Chaetoceros* sp. (28 individuals/lit) and *Scenedesmus* sp. (22 individuals/lit) were the other commonly observed species. The highest species richness and phytoplankton density was observed at Site 1 with 26 species and 92 individuals/lit. Presence of *Navicula, Ocillatoria, Spirogyra, Lyngbia, Nitzschia, Pleurosigma* and *Fragilaria* has been reported previously by Bindu and Padmakumar[9], as being commonly predated by the endemic Lake Vembanad fish pearlspot. To the best of these authors' knowledge, recent published reports of quantitative phytoplankton diversity in Lake Vembanad are not available.

High zooplankton diversity was observed at locations 1, 2, 3 and 4 (Table-3). Copepods, decapods and gastropods were the most commonly observed taxons (69, 34 and 31 individuals/lit, respectively). Highest zooplankton density was observed at Station 3, with 74 individuals/lit, followed by Stations 1 and 2 with 48 and 41 individuals/lit. Interestingly, though Stations 4, 5 and 6 showed comparable number of taxonomic groups, number of individuals/group was rather low. This may be attributed to the relatively lower phytoplankton species richness of these stations (Table-2).

Verghese and Kurien[8] reported an average 4,95,156 number per $m^3$ of zooplankton in their study area, which lay north to ours. Comparable to our study, they, too, reported 17 groups of zooplankton, including rotifers, copepods, tintinnids, medusae, nematodes, polychaetes, cladocera, ostracods, Balanus nauplii, mysids, amphipods, crab larvae, prawn larvae, gastropods, bivalves, tunicates and fish larvae.

As clear from Table-4, 8 taxonomic groups were observed in Lake Vembanad among the benthic organisms. Site 1 showed the highest species richness while the commonest taxons observed were gastropods, oligochaetes and polychaetes. Station 1 showed the highest richness in terms of the presence of individual taxonomic groups (8), but Station 4 showed the highest density of benthic organisms at 1675 individuals/$m^2$. An old study by Ansari[19] reports the presence of polychaeta, bivalves, crustaceans, decapods, amphipods and gastropods. This study reported 55-1100 no./$m^2$ of benthic organisms.

**Table-2**
**Phytoplankton Species Richness Observed at Lake Vembanad**

| **Taxons** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Oscillatoria limosa* | 8 | - | 4 | 1 | 11 | - | 4 | - | - | - | 2 | - | 3 |
| *Spirulina* sp | 2 | - | - | - | - | - | 4 | 1 | - | - | - | - | - |
| *Pediastrum* sp | - | 5 | 1 | - | 1 | - | 2 | - | 2 | 3 | - | 1 | - |
| *Mougeotia* sp | 1 | - | - | - | - | 1 | - | - | - | - | - | - | 1 |
| *Coscinodiscus granii* | 4 | 2 | 1 | 3 | 1 | - | 1 | - | - | - | - | 1 | - |
| *Closterium* sp | 1 | | 1 | - | - | - | 1 | 1 | 1 | - | 3 | 2 | - |
| *Triceratium* sp | - | 5 | - | 1 | - | - | 1 | - | 1 | - | - | 1 | - |
| *Lyngbya* sp | 3 | - | - | - | - | - | 1 | - | - | - | 4 | 1 | - |
| *Chaetoceros* sp | 7 | 1 | - | 2 | - | 2 | 12 | - | 2 | - | - | 2 | - |
| *Amphora* sp | 1 | - | - | 3 | 1 | - | - | 1 | 3 | 4 | 2 | 1 | - |
| *Biddulphia aurita* | 2 | 2 | 1 | 1 | 2 | - | 1 | - | - | - | - | 1 | - |
| *Ulothrix* sp | 1 | 1 | 1 | - | - | 2 | - | 1 | 2 | - | - | - | - |
| *Odontella sinensis* | 3 | - | 2 | 1 | 1 | 1 | - | - | - | - | - | - | - |

| **Taxons** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Gyrosigma* | 1 | 1 | | 1 | 1 | 1 | 1 | - | 2 | - | - | 1 | - |
| *Nitzschia* sp | 11 | 3 | 2 | - | 2 | - | 1 | - | - | - | 2 | 1 | 7 |
| *Navicula* sp | 14 | 11 | 2 | 3 | 1 | - | 1 | 2 | 2 | - | 1 | 1 | 4 |
| *Spirogyra* sp | 1 | - | - | - | - | - | - | 2 | 1 | 1 | - | 1 | - |
| *Pleurosigma* sp | 2 | 1 | 2 | 1 | - | - | - | 2 | 2 | - | - | 1 | - |
| *Thalassiosira* sp | 4 | - | 1 | - | 2 | 2 | 2 | - | - | - | - | 1 | - |
| *Bacteristrum* sp | 1 | 3 | - | - | - | 1 | 2 | - | 2 | - | - | 1 | - |
| *Skeletonema costatum* | 8 | 2 | - | 3 | 2 | - | - | 8 | 3 | - | - | 4 | - |
| *Cerataulina* sp | - | 1 | - | - | - | - | 1 | - | 1 | - | - | - | - |
| *Thalassionema* sp | 1 | 1 | - | 1 | - | 1 | - | - | - | - | - | - | - |
| *Eucampia* sp | 1 | - | - | - | - | 1 | 1 | - | - | - | - | - | - |
| *Actinastrum* sp | 3 | - | - | - | - | - | - | 2 | - | - | - | - | 2 |
| *Eudorina* sp | - | - | - | 1 | - | - | - | - | 1 | 1 | - | - | - |
| *Zygnema* sp | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Scenedesmus* sp | 3 | 4 | - | - | - | - | - | 11 | - | 3 | - | - | 1 |
| *Nodularia* sp | - | - | - | - | - | 1 | - | - | - | - | 2 | - | - |
| *Euglena* sp | - | - | - | 1 | - | - | - | - | - | 1 | - | - | - |
| *Fragilaria* sp | 3 | - | - | - | - | - | - | - | 1 | 1 | | - | - |
| *Desmidium* sp | - | 3 | - | - | - | - | - | - | - | - | 1 | - | - |
| *Surirella* sp | 1 | 2 | - | - | 1 | - | - | - | - | - | - | - | - |
| *Cymbella* sp | - | - | 1 | - | - | - | 1 | - | - | - | - | - | 1 |
| *Phytoconis* sp | - | - | - | - | - | - | - | 1 | - | - | - | 1 | - |
| *Synedra* sp | - | - | 1 | - | - | - | - | 1 | - | - | - | - | - |
| *Hyalotheca* | 2 | 1 | | - | - | - | - | 1 | - | - | - | - | - |
| *Volvox* sp | 1 | 2 | - | - | - | - | 1 | - | - | - | - | - | - |
| *Planktoniella* sp | 1 | 1 | | - | - | - | - | - | - | - | - | 1 | - |
| *Ceratium* sp | - | 1 | - | - | - | 1 | - | - | - | - | - | - | 1 |

**Table-3**
**List of Zooplankton from Lake Vembanad**

| **Taxons/Locations** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Copepods | 13 | 11 | 16 | 7 | 5 | 1 | 1 | - | - | - | 1 | 3 | 11 |
| Decapods | 4 | 2 | 13 | 4 | 2 | 1 | - | - | - | 1 | 2 | 4 | 1 |
| Fish larvae | 2 | 3 | 8 | - | 3 | 2 | - | 2 | 1 | - | - | 9 | - |
| Gastropods | 4 | 7 | 6 | 2 | 1 | 2 | - | 2 | 3 | - | 2 | 2 | - |
| Amphipods | - | 2 | 4 | 5 | 2 | 1 | 4 | - | - | - | - | 1 | - |
| Lucifer sps. | 1 | - | 3 | 2 | 1 | 2 | - | 1 | 2 | - | 9 | - | - |
| Cladocerans | 2 | 1 | 1 | 1 | - | - | - | 2 | 2 | 2 | - | - | - |
| Mysids | 1 | 2 | 1 | 2 | 1 | 1 | 1 | - | - | 1 | 2 | - | - |
| Appendicularians | 1 | - | 2 | 1 | - | - | 1 | - | 5 | - | - | 1 | - |
| Foraminiferans | - | 7 | | - | - | 1 | - | - | - | - | 3 | 2 | 1 |
| Bivalves | 4 | 1 | 2 | 2 | - | 1 | - | 1 | - | - | 7 | - | 4 |
| Siphonaceae | 2 | - | 1 | 1 | - | 1 | - | 1 | - | 1 | - | - | - |
| Crab Zoea | - | 1 | 2 | - | 1 | - | 1 | - | - | 1 | - | 1 | - |
| Insect larvae | 11 | 3 | - | 2 | 1 | - | 1 | - | - | - | 4 | - | 7 |
| Isopods | - | 1 | - | 1 | 3 | - | - | - | - | 2 | - | 1 | - |
| Oikopleura | 1 | - | - | - | 2 | - | - | 1 | - | - | - | - | 1 |

**Table-4**
**List of Benthic Organisms from Lake Vembanad**

| **Taxons/Locations** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chironomus larvae | 400 | 700 | 25 | 25 | - | 100 | 50 | - | - | 100 | 225 | - | 250 |
| Gastropods | 100 | 25 | 400 | 350 | 25 | - | 350 | 500 | 400 | 350 | 25 | - | 25 |
| Ostracod | 25 | - | - | - | 25 | - | - | | - | - | 50 | - | - |
| Oligochaeta | 500 | 300 | 100 | 700 | 100 | 200 | 400 | 100 | 50 | 50 | | 25 | - |
| Polychaeta | 250 | 200 | 300 | 200 | 50 | 150 | 25 | 50 | 25 | 25 | 50 | - | - |
| Unidentified Insect larvae | 100 | 25 | 25 | - | - | 25 | - | 100 | - | 25 | 100 | - | 150 |
| Pelecypoda | 50 | 25 | - | 400 | - | 25 | 25 | - | 50 | - | - | 25 | - |
| Brachyurans | 25 | 25 | - | - | - | - | - | - | 50 | - | - | - | - |

The bivalve Black clam (*Villorita cyprinoides*) was observed in rich numbers in the lake bottom and in benthos samples as well. Local fishermen confirmed these were edible, and their shells were sold to a local cement factory. Black clam in Lake Vembanad has also been reported elsewhere[9].

In Figure-2, a comparison of the 13 Stations with respect to the number of phytoplankton species and groups of zooplankton and benthos observed has been presented.

Clearly, Station 1 showed the highest diversity. This is an interesting observation, considering that Station 1 is closest to the point where the canal from Kumarakom Bird Sanctuary meets Vembanad Lake and has the highest disturbance from tourism-related activities. This observation may be explained by the intermediate disturbance hypothesis[20]. This hypothesis states that "species diversity is low after a disturbance, when only a few species have survived or few colonizing species dominate under the new environmental conditions, or when the system has approached an equilibrium stage which is dominated by few species with high competitive abilities." However, contrastingly, diversity is high when disturbances occur at an intermediate frequency or with intermediate intensity[21,22]. Studies proving this hypothesis in laboratory-based plankton populations have been reported by Sommer[23] and Polishshuk[24]. Weithoff et al.[25] have proved the same in plankton data obtained from field experiments. Some of the observed plankton and benthos species have been presented through Figure-3-9.

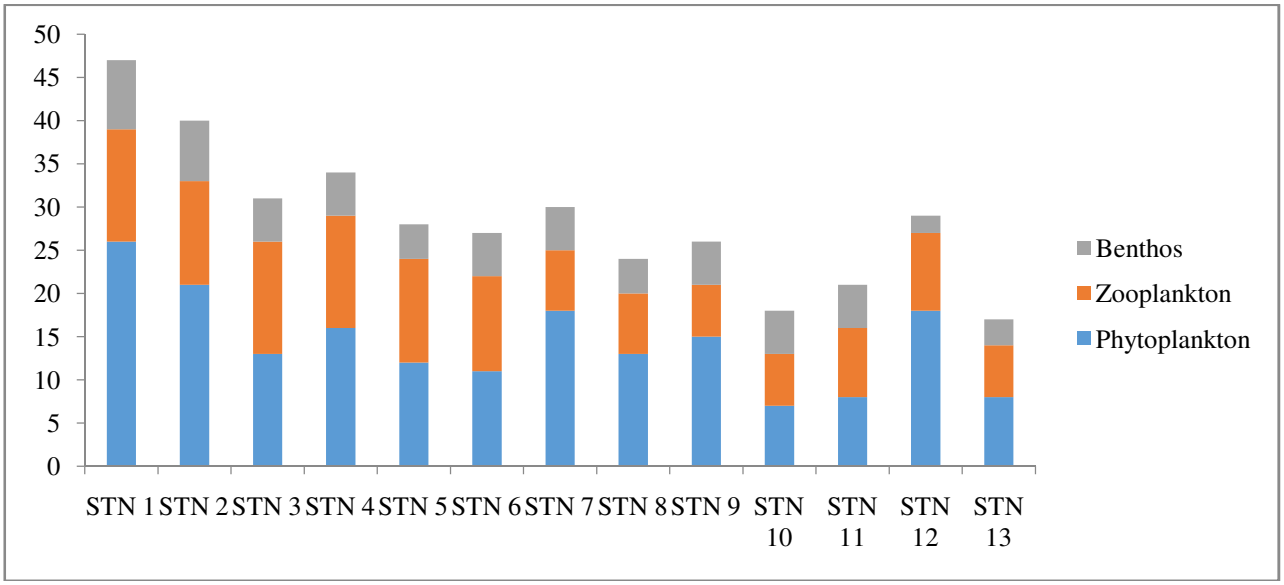


**Figure-2**
**A Comparison of Species Richness of the 13 Stations Sampled**

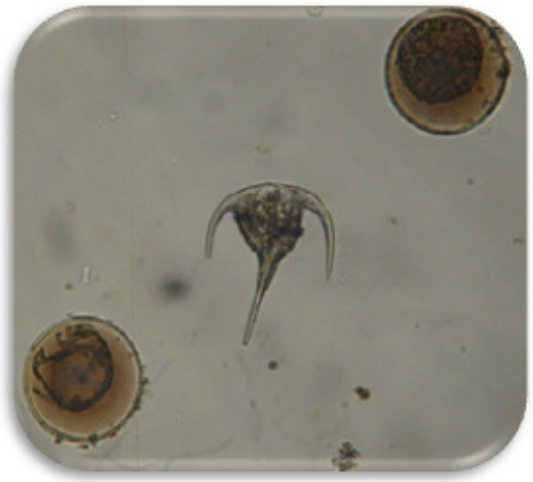

**Figure-3**
**Phytoplankton *Ceratium***

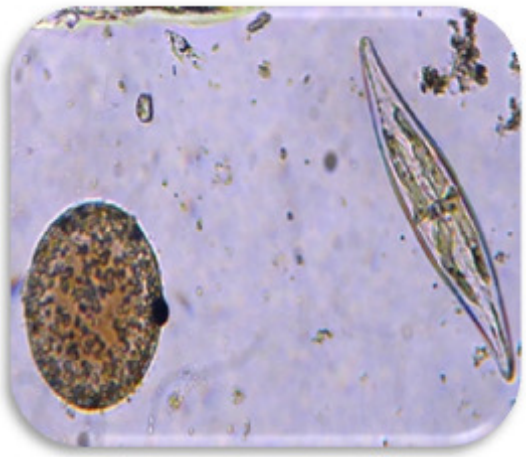

**Figure-4**
**Phytoplankton- [Left] *Coscinodiscus* and [Right] *Pleurosigma***

**Figure-5**
**Zooplankton- Copepod**

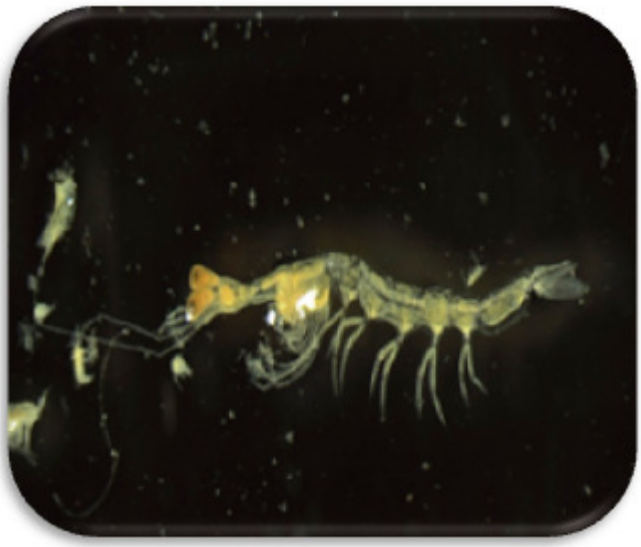

**Figure-6**
**Zooplankton- Lucifer sps.**

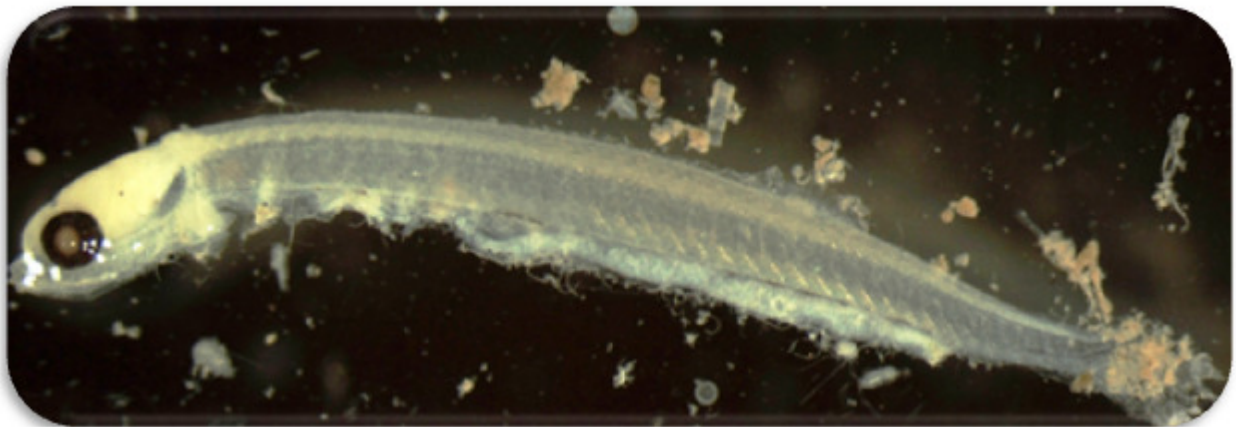

**Figure-7**
**Zooplankton- Fish Larvae**

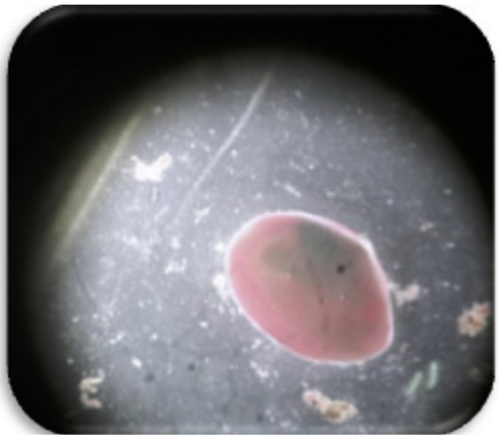

**Figure-8**
**Benthos- Pelecypod**

**Figure-9**
**Benthos- Polychaete**

## Conclusion

In the absence of published reports of Kottayam region Lake Vembanad plankton and benthos, it is not possible to compare our results minutely with the other reports of nearby regions. Admittedly, the time period of this study is far too short to justify any concrete explanation of the obtained results. However, this study clearly indicates the necessity of more such studies, especially those linking plankton and benthic diversity with nutrient concentrations and carrying capacity of the water body.

## Acknowledgement

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