Diversity and Distribution of Plankton communities in the Ariyankuppam Estuary, Puducherry, Southeast Coast of India

Abstract

The present study is the first record of plankton communities in the mangrove ecosystem of Ariyankuppam estuary, Puducherry, Southeast coast of India. It is aimed to analyse the influence of physio-chemical properties on plankton communities in an estuarine system. Sampling was carried out monthly intervals during the period from January to June 2023 (Post monsoon and summer). A total of 38 species of phytoplankton belonging to 25 genera and 22 families were identified. The dominant species are observed under three groups such as Bacillariophyceae (diatom) (63%), Dinophyceae (dinoflagellates) (21%), Cyanophyceae (blue green algae) (5%) and Chlorophyceae (Green algae) (3%). Within these the species- *Coscinodiscus granii* (1.2 x 10^6 cells/l) is most dominant in all the stations followed by *Trichodesmium erythraeum* (6 x 10^5 cells/l) and *Oscillatoria limmosa* (5.5 x 10^5 cells/l). A total of 24 species of zooplankton belonging to 14 families and 12 orders were identified containing phylum Arthropoda and Ciliophoran having 8 species respectively. In addition, phylum, Rotifer (7 species) and Chordata (1 species) also recorded in the sampling sites. Canonical Correspondence Analysis (CCA) revealed that the influence of environmental parameters on the abundance and occurrence of plankton communities in the study area.

Keywords: Plankton, Diversity, Density, Puducherry, Estuary, Southeast coast.

Introduction

Estuaries serve as a transitional area between land and sea and are commercially significant habitats for tropical fisheries. Estuaries, often known as "marginal filters," are relatively narrow bands that occur on a global scale when river and sea waters mingle (Lisitzin, 1999). They act as filter and separate sediments and pollutants from rivers and streams before they flow into the ocean. Certain biogeochemical processes occur in these filter zones, and at the end, zooplankton and zoobenthos filtering organisms transform suspended particulate matter into bottom sediments as a result of the influx of faecal pellets, causing what is known as biological modification (Telesh, 2004).The physico-chemical conditions may be altered by biological activities like primary production and decomposition, and the community structure can be altered by biological interactions including recruitment, reproduction, and predator-prey cycles (De Jonge *et al.*, 2002).

Phytoplankton initiates the marine food chain, by serving as food to primary consumers like zooplankton, shellfish and finfish. The functioning of all aquatic ecosystems revolves around primary productivity, which sustains diverse food chains and food webs (Vaghela *et al.*, 2023). The productivity of higher tropic-level organisms is largely influenced by the biomass and productivity of phytoplankton in various size ranges. The pelagic plankton communities play a significant role in the estuarine ecosystem's ability to operate properly. Mangrove estuaries have higher productivity than other estuaries due to the very high primary productivity of the leaf litter, supplemented by that of cyanobacteria, diatoms, and micro algae (Alongi 1989), and that of algae fixed on mangrove roots (Rodriguez and Stoner 1990). Owing to the varying effects of hydrographical conditions on various species, the distribution of phytoplankton species varies widely across space and time, making them useful markers of water quality, including pollution (Perumal *et al.*, 2009). Zooplankton in estuaries mirrors the phytoplankton in being limited in species composition. The species composition is diversified seasonally and with fluctuating salinity in the estuary. Marine zooplankton is more likely to be found in shallow, rapidly flushed estuaries which are carried in and out due to tide action. Estuarine zooplankton community mostly contain species of the copepod and rotifers. Earlier studies have concluded that zooplankton are good indicators of eutrophication, water quality, acidification of water bodies as well as turbidity of water bodies (Coelho *et al.*, 2015; Muylaert *et al.*, 2006).A decline in plankton population has the potential to significantly harm the coastal ecology. Anthropogenic activities particularly increasing population, industrialization and tourism in the coastal areas are the major threats to the coastal marine environment. These kinds of activities eventually increase the condition for eutrophication in the coastal environment which leads to a disparity in the marine ecosystem. Plankton dynamics follow a seasonal pattern because it is efficiently governed by a small number of physical elements in addition to hydrographic characteristics. (Punithavalli and Sivakumar, 2020). The Ariyankuppam estuary is directly influenced by various anthropogenic activities, especially the untreated discharge of solid waste into the river, which negatively affects the ecological status of the estuarine ecosystem. Therefore, the present study aimed to assess the water quality status and plankton communities in the study area. As there are no previous studies on the plankton communities in the mangrove-populated Ariyankuppam estuary, this research provides baseline data on species diversity, abundance and distribution, offering valuable insights into the ecological role of plankton in the mangrove environment. Additionally it could serve as a foundation for future studies on environmental changes, understanding ecosystem dynamic and the influence of mangroves on the plankton communities of Ariyankuppam estuary.

Materials and Methods

Study area

Ariyankuppam Mangrove Estuary (Lat. 11°55'N and 12°30'N and Long. 70°05'E and 80°05'E) is situated in Puducherry, between three coastal villages of Ariyankuppam, Murungapakkam, and Veerampattinam as well as the islets of Thengaithittu and Ashramthittu. The sampling was done in three stations with station 1 being the Estuary Mouth (EM) and station 2 being the Middle Estaury (ME) and station 3 being the Inner Estuary (IE) (Figure 1). This river basin has a drainage that extends to about 100 sq.km. Mangrove is one of the exclusive bordering vegetation found around the backwaters of this estuary. Although the waterway is a Gingee River tributary, over the past several years only municipal and agricultural discharges have entered into this mangrove ecosystem. This tidal estuary flows into the Bay of Bengal, Coromandal coast. Tidal amplitudes common between 20 and 70 cm, depending on the season. It reaches its maximum during the northeast monsoon. An area with a relative humidity of 65-75% and an average temperature of 28.8 °C (Silpa and Ramanathan, 2024) Waste generated near the Ariyankuppam river is disposed directly into rivers and affect the ecological status of estuary.

Sample collection and analysis

Samples were collected from the Ariyankuppam estuary at monthly intervals during the period of January - June 2023 (Post monsoon and summer) for the estimation of surface water temperature, salinity, dissolved oxygen, pH, nitrite and nitrate parameters in the sampling stations by in-situ parameter kits (Multi-sensor and Merck Millipore-Multi 3420). Water samples were collected in the clean polypropylene bottles and immediately transported to the laboratory for further analysis. Dissolved oxygen (DO) was estimated by standard method of Strickland and Parsons (1972). The water samples were filtered using Millipore filtering system (MFS) for nutrient analysis. The Plankton samples were collected from the surface water of each sampling stations by towing a plankton net from boat (net diameter 0.35 m, mesh size 48 µM for phytoplankton and diameter 0.35 m, mesh size 158 µM for zooplankton). The net was tied to a small sized fishing boat and toed horizontally three times at each station for 10 minutes. A flow meter was attached to the net in the center to calculate the volume of seawater passed through the net. Biological samples were preserved in 5% formalin and used for further qualitative and quantitative analysis (Parsons *et al.*,1984). Phytoplankton and zooplankton taxa were observed and identified using Phase contrast microscope (Olympus CX41) and following the standard methods outline by Davis (1955), Kasturirangan (1963), Perumal *et al.* (1999), Verlecar and Desai (2004), Todd *et al.* (2006) and Cordell (2012). Phytoplankton cell count was done with Sedgewick-Rafter counting cell. Abundance of zooplankton was presented as the individual number per m^3 of water.

Statistical analysis

The relationship between plankton and environmental parameters was determined using Canonical Correspondence Analysis. Species diversity indices were calculated by the formula of Shannon and Weaver (1963) and Pielou (1966) as follows: $H'=-\sum Pi\ln Pi$, $E'=H'/\ln S$, $D'=S-1/\ln N$ (Ludwig and Reynolds, 1988) where H' is species diversity index, Pi is the population abundance of the species calculated by ni/N, ni is number of the species, N is all individuals number in a station, E' is species evenness index, S is total species number and D' is species richness index. Monthly variation in physico-chemical parameters were depicted using line graph. The line graphs were performed in Excel. The species diversity indices and CCA were performed using PAST v4.03.

Results and Discussion

Physico-chemical parameters

Modification in physico-chemical parameters of water have a substantial effect on the distribution and abundance of many aquatic species including phytoplankton and zooplankton communities (Shekhar *et al.*, 2008). The present study, physico-chemical parameters were recorded on a monthly basis for six months *i.e.* Post monsoon and summer seasons. Surface water temperature was recorded ranged from 28.7^{o}C to 33.5^{o}C (Figure 2). The highest temperature was recorded at EM in the month of June (Summer) and the lowest temperature was observed in the IE in the month of January (Post-monsoon). Water temperature plays a major role as it influences collectively all the other parameters of water. Similary, Fauzia Ishaq and Amir Khan (2013), have done the comparative study of the physico-chemical conditions and the plankton diversity of the largest River Ton, Utarkhand, India.

Salinity plays a major role in maintaining the quality of water and regulation of gasses and hydrogen ions (Punithavalli and Sivakumar, 2020). The salinity concentration observed in the present study ranged from 7.4 ‰ to 28 .9 ‰ (Figure 2). The highest salinity concentration was measured at EM in May and the lowest concentration was measured at IE in January. The high salinity in the month of May is due to the evaporation caused by high solar radiation. Salinity mainly triggered by dilution and evaporation process, that stimulates the phytoplankton diversity in coastal ecosystem. Normally, changes in salinity in the brackish water habitats, such as backwater, estuaries and mangrove regions, are because of the influx of freshwater flow from land runoff caused by monsoon season or tidal fluctuations (Srinivasan and Natesan, 2013). The low salinity may be influenced by cooler atmospheric temperature and less evaporation. The salinity is high near the mouth region of the estuary due to the high concentration of seawater and as the water reaches upstream salinity reduces due to high influx of freshwater from river. The hydrogen ion concentration can alter the living condition of the aquatic organism. In the present study, the pH concentration varied from 7.1 to 8.4 (Figure 2). The maximum level of pH was recorded at IE in March and the lowest level of pH was measured at EM during the month of February. The high pH values observed during the summer season may be attributed to the uptake of CO2 by photosynthetic algae (Govindasamy *et al.*, 2000). There was no significant change in the pH concentration during the study period. The dissolved oxygen (DO) concentration in the present study ranged from 3.4 mg/l to 4.5 mg/l (Figure 2). The lowest DO (Dissolved Oxygen) value was recorded during the summer season, in April, at EM. As the mouth area of the estuary, this region experiences low freshwater input and a high presence of seawater, which may contribute to the low DO concentration. The highest DO value was recorded during post-monsoon season in February, at IM. This elevated dissolved oxygen level can be attributed to the influx of oxygen-rich freshwater as the estuary extends deep upstream into the river. Our result is resemblance with similar studies like Govindsamy *et al.* (2000), Saravanakumar *et al.* (2008), Jayasingam *et al.* (2015).

Nutrients are beneficial to aquatic ecosystems in certain range, but, excessive nutrient concentrations can stimulate algal blooms and plant growth in streams, ponds, lakes, reservoirs and estuaries and along shoreline (Howrath *et al.*, 2000). In the study area, the nitrite concentration (NO_2) ranged from 0.3 µmol/L to 1.84 µmol/L (Figure 2). The low nitrite concentration was recorded in EM during summer season (Apr) and high nitrite concentration was recorded in IE during post-monsoon season (Jan). The low concentration of nitrite during summer season may be due to the consumption of nitrite by algae during photosynthesis in the environment (Gouda and Panigrahy, 1995). The high nitrite concentration may result from nitrate reduction during the nitrogen cycle and by biodegradation of planktonic detritus present in the water(Govindasamy *et al.*, 2000; Santhanam and Perumal, 2003; Vajravelu *et al.*, 2018). The nitrate concentration (NO_3) ranged from 0.65 µmol/L to 2.9 µmol/L during the study period (Figure 2). The low nitrate concentration was recorded in EM during summer season (Jun) and the high concentration was recorded in IE during post monsoon season (Jan). The high nitrite concentration during post-monsoon may be due to the intake of fresh water and terrestrial runoff. Kasan *et al.* (2023), assessment on water quality parameters and nutrient levels (0.01-0.12 mg/l) of Nyatuh River in Malaysia.

Phytoplankton composition, population density and diversity

Plankton diversity and distribution are frequently revealing the ecological status of water bodies; their variations in series can be correlated with the changes of the coastal /estuarine ecosystems and physicochemical characteristics especially the influence of nutrient runoffs into the water (Zulkifly *et al*., 2020). A total of 38 species of 25 genera, belonging to 22 families were identified during the study in the Ariyankuppam estuary (Table 1). The observed species generally comes under three groups such as Bacillariophyceae (diatom), Dinophyceae (dinoflagellates), Cyanophyceae (blue green algae) and Chlorophyceae (Green algae). The phytoplankton population density and diversity were higher during the summer season. The phytoplankton abundance was high during the summer season which may be due to the high light penetration and increased rate of nutrient content in the water (Saravanakumar *et al*., 2008). The phytoplankton species composition was observed in the following order: Diatoms (71%), Dinoflagellates (24%) and Cyanobacteria (5%) in which diatoms being the dominant group. The domination of diatoms in the mangrove environment maybe due to the fact that diatoms have the ability to tolerate the dynamic hydrographical conditions (Senthilkumar *et al*., 2002; Rajkumar *et al*., 2009). Among these *Coscinodiscus granii* was dominant species in the diatom, *Peridinium divergens* was dominant in the dinoflagellates. *Trichodesmium erythraeum* was dominant among the cyanobacteria. *Coscinodiscus gigas*, *Coscinodiscus granii*, *Rhizosolenia alata*, *Nitzschia longissima*, *Nitzschia amphibia*, *Chaetoceros didymus*, *Asterionella glacialis*, *Thalassiothrix frauenfeldii*, *Ceratium lineatum*, *Prorocentrum gracile*, *Protoperidinium claudicans*, *Oscillatoria limmosa* and *Trichodesmium erythraeum* were present in all the three stations. Similar study conducted in the in the Matang mangrove estuary of Malaysia where about 80% of the phytoplankton community is dominated by diatoms (Tanaka and Choo, 2000). Perumal *et al.* (2009) has reported 85 species of phytoplankton in the Kaduviyar estuary, Nagapattinam, southeast coast of India out of which 58 species were observed as diatoms. Rajkumar *et al.* (2009) recorded 94 species of phytoplankton in Pichavaram mangrove waters from south-east coast of India which also had diatoms as the dominant group of phytoplankton. Vajravelu *et al.* (2018) reported 117 species of phytoplankton from Parangipettai coast, South East Coast of India in which it was observed that diatoms were the dominant group of phytoplankton. Punithavalli and Sivakumar (2020) in the Ariyankuppam estuary reported that the dominance of phytoplankton was higher in summer season. Among the epiphytic community in the mangrove roots from Laguna Joyuda estuary in Puerto Rico, Cyanobacteria and diatoms had the highest biomass concentration (Rodriguez and Stoner, 1990). Compared to estuary, the mangrove waters shelters many species of epiphytic diatoms attached to the roots of the mangroves, particularly species like *Rhizophora* (Krishnamurthy and Jeyaseelan, 1983). The presence of genus *Nitzschia, Pleurosigma, Thalassionema*and*Thalassiothrix* are observed mostly in the magrove populated parts of the estuary which supports the claims of Main and McIntire (1974) and de Vijver and Beyens (1997) who sheds light on the epiphytic nature of these diatoms.

The phytoplankton abundance was highest (9.3 x 10^6 cells/l) in IE in the month of May and lowest (4.6 x 10^4 cells/l) in EM in the month of January (Figure 3). The high population density in the month of summer is also negatively correlated with nutrient values. This may be due to the high intake of nutrients by phytoplankton. Our results similarly correlated with Perumal *et al.* (2009), mentioned *Coscinodiscus granii* species was maximum in all the stations (1.2 x 10^6 cells/l) followed by *Trichodesmium erythraeum* (6 x 10^5 cells/l) and *Oscillatoria limmosa* (5.5 x 10^5 cells/l) in southeast coast of India. The plankton species diversity ranged from 1.465 to 3.28. The maximum species diversity was recorded in ME in May 2023 and the minimum species diversity was recorded in EM in February 2023. The species evenness ranged from 0.3326 to 0.8786. The maximum species evenness was recorded in EM in June 2023 and the minimum was recorded in ME in January 2023. The species richness ranged 0.618 to 1.969. The maximum species richness was recorded in ME in March 2023 and the minimum was recorded in EM in February 2023 (Figure 4).

Canonical Correspondence Analysis was employed to determine the relationship between the environmental parameters and the phytoplankton distribution (Vajrevelu *et al.*,2018). In EM, Axis 1 and 2 explained 87% of variability in the species environment biplot (Figure 5). Dissolved oxygen, Nitrate and Nitrite have a positive correlation in axis 1 and highly associated with species- *Rhizosolenia alata*, *Protoperidinium claudicans*, *Pleurosigma angulatum, Pleurosigma elongatum, Nitzschia seriata, Thalassiothrix frauenfeldii, Ceratium lineatum, Asterionella glacialis, Coscinodiscus granii* among these *Rhizosolenia alata, Protoperidinium claudicans, Pleurosigma angulatum, Nitzschia seriata* and *Pleurosigmaelongatum* are highly influenced by Nitrate and Nitrite. The month of January is positively correlated with Nitrate and Nitrite and negatively with all the other variables. In axis 2 salinity and temperature have a strong positive correlation with *Coscinodiscus gigas, Chaetoceros didymus, Ceratium macroceros, Nitzschia amphibia, Oscillatoria limmosa, Nitzschia longissimi, Trichodesmium erythraeum, and Prorocentrum gracile*. Water parameters-Salinity and temperature behave as a strong environmental factors and pH moderately correlates with species diversity during the months of April, May and June which maybe directly influences the species abundance by seawater. The pH is a strong environmental influence but not the determinant factor of phytoplankton abundance. But, Dissolved oxygen has slight or less correlation with *Coscinodiscus granni*.

In ME, Axis 1 and 2 explained 87% of variability in the species environment biplot (Figure 6). pH, nitrate and nitrite have a positive correlation in axis 1. pH and nitrate were highly associated with species - *Odentella mobiliensis, Nitzschia longissima, Nitzschia sigma, Ceratium longipes, Ceratium lineatum, Odontella sinensis, Protoperidinium oceanicum, Cheatoceros decipiens, Bacteriastrum delicatulum, Asterionella glacialis, Protoperidinium claudicans, Nitzschia amphibia, Triceratium favus* among these *Bacteriastrum delicatulum, Chaetoceros decipiens, Asterionella glacialis, Ceratium lineatum, Triceratium favus, Protoperidinium oceanicum and Protoperidinium claudicans* showed maximum canonical values (1.13998, 1.23514, 1.05293, 1.22436, 1.04788, 1.02306) during the month of January. The parameters nitrate and nitrite being the dominant determinant in phytoplankton abundance maybe due to the influence of land runoff present in the study area. In axis 2, Dissolved oxygen, salinity are positively correlated with *Trichodesmium erythraeum* and *Oscillatoria limmosa* which gives evidence on the positive influence of these parameters in the month of June. Comparatively salinity and temperature play major role by negatively influencing the phytoplankton species in the month of January which may be due to the intake of freshwater. All species in the lower part of the axis 1 are found to be abundant in the months of February, March, April and May.

In IE, Axis 1 and 2 explained 84% of variability in the species environment biplot (Figure 7). In axis 1, Dissolved oxygen and nitrite observed to be the high influencing explanatory variable which positively influences *Protoperidinium claudicans, Asterionella glacialis, Triceratium favus*. pH and nitrate favour the growth of *Cheatoceros decipiens, Chaetoceros curvisetus, Bacteriastrum delicatulum, Trichodesmium erythraeum* and *Pleurosigma normanii among these Chaetoceros curvisetus, Bacteriastrum delicatulum* and *Pleurosigma normanii* has the maximum canonical values (1.30153, 1.12867, 1.75937) in axis 1 and negatively correlates with temperature and salinity. The months April, May and June which is negatively influenced by DO and nitrite has the most abundance of phytoplankton species. It also demonstrates slight positive correlation with temperature and salinity which indicates high atmospheric temperature during these months. The months January, February and March are positively influenced by DO, pH, nitrite and nitrate which indicates low atmospheric temperature and high nutrient activity during these months. In all the three sampling sites temperature and salinity have a major influence on the abundance of phytoplankton species during the summer months which has been proven in previous studies that stable environmental parameters in summer behaves as a catalyst for the growth of *Chaetoceros sp., Odentella sp*. (Saravana kumar *et al*., 2008; Vajravelu *et al*., 2018). The results correlate with the observations of Vajravelu *et al.* (2018) that high nutrient input during premonsoon season maybe crucial for the increased abundance of phytoplankton during that season.

Zooplankton composition, Population density and diversity

A total of 24 species of zooplankton belonging to 14 families and 12 orders were identified from the sampling sites during the span of six months (Table 2). The overall zooplankton composition was in the following orders: Phylum Arthropoda (8 species), Phylum Ciliophora (8 species), Phylum Rotifera (7 species) and Phylum Chordata (1 species). During the study period, there are four dominant zooplankton species such as *Oithona brevicornis,Coxliella annulate,Brachionus urceolaris* and *Oikopleura dioica* were observed belonging to the above mentioned phylum. Similar observations were made by Damotharan *et al.* (2010) the copepod taxa contained the most number of species among the zooplankton from Kodiakkarai, south east coast of India. Further, Santhanam and Perumal (2003) also recorded copepod to be the most abundant species among the zooplankton in the Parangipettai coast waters. The presence of *Tinitinnids* gives a detailed image of eutrophic nature of the environment (Bojanic *et al*., 2012). The abundance of zooplankton was found to be highest (586650 org/m^3) in ME in the month of April and lowest (72464 org/m^3) in EM in the month of May (Figure 8). The high abundance in ME may be due to the high nutrient concentration in the sampling area which enhance the proliferation of zooplankton. Rotifera was the most abundant phylum followed by Arthropoda and then phylum Ciliophora. These observations corroborate the findings of Verma and Prakash (2020) who observed that rotifers dominated and constituted about 30.02% of the total zooplankton population followed by copepods in Guthiataal, wetland of Bahraich, Uttar Pradesh, India. Rotifers are a very important source of nutrition and plays a vital role in the food chain (Ramachandra *et al*., 2017). Research has shown that zooplankton communities thrive in protected, soft, muddy regions that are abundant in organic matter and nutrients, largely originating from estuarine vegetation (Rajyalkshmi, 1973; Macnae, 1974).

The species diversity indices ranged from 1.776 to 3.009. The maximum species diversity observed in EM in the month of June and the minimum species diversity recorded in ME in the month of June. The species richness ranges from 1.802 to 2.139. The maximum species richness observed in EM in the month of May and the minimum species richness observed in ME in the month of June.The species evenness ranged from 0.2272 to 0.8103. The maximum species evenness observed in EM in the month of June and the maximum species diversity observed in EM in the month of June (Figure 9).

CCA exhibited the environmental parameters and the zooplankton distributions in Axis 1 and 2 showed 89% of variability in the species environment biplot at EM (Figure 10). Parameters pH, Salinity and temperature were positively correlated with both axis 1 and 2 which also influences the majority of zooplankton species such as *Oithona brevicornicus, Oithona attenuata*, *Codonellopsis ostenfeldi*, *Canthocalanus pauper, Oncea sp, Favella ehrenbergii* and *Paracalanus crassirostris*. Abdulwahab and Rabee (2015) reported that copepod species are highly influenced by environmental parameters in the observations made in Tigris river at

Baghdad region, Iraq. Variations in salinity can cause fluctuation in the community structure of zooplankton species (Blanco *et al*., 2006). Dissolved oxygen has a positive correlation with axis 1 and negative correlation with axis 2. Nitrite and nitrate was negatively correlated with pH, salinity, temperature and DO. The month of May, April and June have positive correlation with pH, salinity and temperature. The month January, February and March have positive correlation nitrite and nitrate. Salinity and temperature being the dominant parameter is acceptable due to position of EM with close proximity with seawater and this may also explain the negative influence of nitrate and nitrite in EM.

In ME, Axis 1 and 2 having 94% of variability in species environment biplot (Figure 11). Nitrate showed positive correlation with most of the zooplankton species. This may be due to the input of land runoff and other plant organic matter with increases the nitrate concentration which in turn influences the zooplankton abundance. Temperature, salinity, Nitrite, DO and pH are negatively correlated with nitrite and the associated zooplankton species. This may be due to the fluctuating condition of parameters in ME. It is believed that relatively low temperature can positively influence the zooplankton community (San *et al*., 2006). The month of January, February, March, April and May are positively correlated with nitrate and the month of June and positively correlated with the other water quality parameters.

In IE, Axis 1 and 2 revealed 78% of variability in species environment biplot (Figure 12). DO and nitrite showed positive correlation in both axis 1 and 2. pH and nitrate showed positive correlation with axis 1 and negative correlation with axis 2. Most of the species were observed to be positively correlated with the month of April and it is also negatively correlated with DO and nitrite. The months of January, February and March observed to be negatively correlated with temperature and salinity which may be due to the increase rainfall and reduced atmospheric temperature which influences the zooplankton abundance.

Conclusion

Our study investigates the plankton assemblages of Ariyankuppam mangrove estuary and how the presence of mangrove influences the nutrient dynamics and the distribution of plankton communities over a six-month period covering the post-monsoon and summer seasons. A total of 38 phytoplankton species from 25 genera and 22 families were identified and 24 species from 14 families and 12 orders of zooplankton identified. The influence of mangrove community on plankton community was evident due to dominance of epiphytic diatoms among the phytoplankton and prevalence of rotifers among the zooplankton due to the high nutrient content exuded from leaf litter. The zooplankton community, particularly copepods and rotifers, appeared to thrive in nutrient-rich, soft, muddy regions abundant in organic matter. plankton diversity is of paramount importance in mangrove-rich ecosystems due to its critical roles in primary productivity, nutrient cycling, biodiversity support, water quality maintenance, and as an indicator of ecosystem health. But studies on the diversity of plankton in Ariyankuppam estuary has been found lacking. By regular monitoring the quality of these mangrove regions can be protected and anthropogenic pollution can be controlled. Protecting and preserving plankton diversity is essential for maintaining the resilience and functionality of these valuable coastal habitats.

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References

Abdulwahab, S., & Rabee, A. M. (2015). Ecological factors affecting the distribution of the zooplankton community in the Tigris River at Baghdad region, Iraq. *The Egyptian Journal of Aquatic Research*, 41(2), 187-196.

Alongi, D. M., Boto, K. G., & Tirendi, F. (1989). Effect of exported mangrove litter on bacterial productivity and dissolved organic carbon fluxes in adjacent tropical nearshore sediments. Marine ecology progress series. Oldendorf, 56(1), 133-144.

Blanco-Bercial, L., Álvarez-Marqués, F., & Cabal, J. A. (2006). Changes in the mesozooplankton community associated with the hydrography off the northwestern Iberian Peninsula. *ICES Journal of Marine Science*, 63(5), 799-810.

Bojanić, N., Vidjak, O., Šolić, M., Krstulović, N., Brautović, I., Matijević, S., ... & Marasović, I. (2012). Community structure and seasonal dynamics of tintinnid ciliates in Kaštela Bay (middle Adriatic Sea). *Journal of Plankton Research*, 34(6), 510-530.

Coelho, S., Pérez-Ruzafa, A., & Gamito, S. (2015). Phytoplankton community dynamics in an intermittently open hypereutrophic coastal lagoon in southern Portugal. *Estuarine, Coastal and Shelf Science*, 167, 102-112.

Cordell, J. R. (2012). Invasive freshwater copepods of North America. In A handbook of global freshwater invasive species (pp. 172-183). Routledge.

Davis, C.C. (1955) The Marine and Fresh-Water Plankton. Michigan State University Press, East Lansing.

de Jonge, V. N., Elliott, M., & Orive, E. (2002). Causes, historical development, effects and future challenges of a common environmental problem: eutrophication. In Nutrients and Eutrophication in Estuaries and Coastal Waters: Proceedings of the 31st Symposium of the Estuarine and Coastal Sciences Association (ECSA), held in Bilbao, Spain, 3–7 July 2000 (pp. 1-19). Springer Netherlands.

de Vijver, B. V., & Beyens, L. (1997). The epiphytic diatom flora of mosses from Strømness Bay area, South Georgia. Polar biology, 17, 492-501.

F.Ishaq, A. Khan, Diversity pattern of macrozoobenthos and their relation with qualitative characteristics of River Yamuna in Doon valley Uttarakhand. *American-Eurasian Journal of Toxicological Sciences*. 5(1), (2013) 20-29. ISSN: 2079-2050. doi: 10.5829/idosi.aejts.2013.5.1.72125.

Gouda, R., & Panigrahy, R. C. (1995). Seasonal distribution and behaviour of nitrate and phosphate in Rushikulya estuary, east coast of India.

Govindasamy, C., L. Kannan and Jayapaul Azariah. 2000. Seasonal variation in physico-chemical properties and primary production in the coastal water biotopes of Coromandel coast, *India. J. Environ. Biol.*, 21: 1-7

Howarth, R., D. Anderson, J. Cloern, C. Elfring, C. Hopkinson, B. Lapointe, T. Malone, N. Jayasingam, P., Gopinath, M., Umamageswari, P., & Sampathkumar, P. (2015). Physico-biochemical variations in Parangipettai, Pondicherry and Nagapattinam Coastal waters, Southeast coast of India. *Int J Curr Micro Appl Sci*, 4(2), 1-14.

Kasturirangan, L. R. (1963). A key for the identification of the more common planktonic copepoda: of Indian coastal waters (No. 2). Delhi: Council of Scientific & Industrial Research.

Krishnamurthy, K. and M.J. Prince Jeyaseelan, (1983). The Pichavaram (India) ecosystem. Inter. J. Ecol. Environ. Sci., 9, 79-85.

Lisitzin, A. P. (1999). The continental-ocean boundary as a marginal filter in the World Oceans. In Biogeochemical cycling and sediment ecology (pp. 69-103). Dordrecht: Springer Netherlands.

Ludwig, J. A., & Reynolds, J. F. (1988). Statistical ecology: a primer in methods and computing (Vol. 1). John Wiley & Sons.

Macnae. (1974). Mangrove Forest and Fisheries, FAO Rome.

Main, S. P., & McIntire, C. D. (1974). The distribution of epiphytic diatoms in Yaquina Estuary, Oregon (USA).

Marcus, K. McGlathery, A. Sharpley and D. Walker. (2000). Nutrient Pollution of Coastal Muylaert, K., Zhao, L., Van der Gucht, K., Cousin, S., Declerck, S., & Vyverman, W. (2006). Trophic coupling in the microbial food web of a eutrophic shallow lake (Lake Visvijver, Belgium). Archiv für Hydrobiologie, 166(3), 307-324.

Nor Azman Kasan, Ikhwanuddin, Hidayah Manan, Nur Syafirah Zakaria, Amyra Suryatie Kamaruzzan, Ahmad Ideris Abdul Rahim, and Ahmad Najmi Ishak. (2023). Assessment on Water Quality Parameter and Nutrients Level of Nyatuh River in Relations with *Macrobrachium Rosenbergii* Prawn Populations. *Trop Life Sci Res.* 2023 Mar; 34(1): 51–66.

Parsons, T. R.; Maita, Y.; Lalli, C. M. (1984). A Manual of Chemical and Biological Methods for Seawater Analysis. New York, Pergamon Press, 173 pp.

Perumal, N. V., Rajkumar, M., Perumal, P., & Rajasekar, K. T. (2009). Seasonal variations of plankton diversity in the Kaduviyar estuary, Nagapattinam, southeast coast of India. *J. Environ. Biol,* 30(6), 1035-1046.

Perumal, P., Sampathkumar, P., & Karuppasamy, P. K. (1999). Studies on the bloom-forming species of phytoplankton in the Vellar estuary, southeast coast of India.

Prabu, V. A., Rajkumar, M., & Perumal, P. (2008). Seasonal variations in physico-chemical characteristics of Pichavaram mangroves, southeast coast of India. Journal of Environmental Biology, 29(6), 945-950.

Punithavalli, M., & Sivakumar, K. (2020). Predominantly Occurring Phytoplankton In Ariyankuppam Coastal Waters, Southeast Coast Of India.

Rajkumar, M., Perumal, P., Prabu, V. A., Perumal, N. V., & Rajasekar, K. T. (2009). Phytoplankton diversity in Pichavaram mangrove waters from south-east coast of India. *Journal of Environmental Biology*, 30(4), 489-498.

Rajyalakshmi, T. (1973). POPULATION CHARACTERISTICS OF THE GODAVARY HILSA OVER THE YEARS 1963-1967. Indian Journal of Fisheries, 20(1), 78-94.

Ramachandra, R.R., Manjulatha, C. and Raju, D.V.S.N. (2017). Zooplankton diversity in Madduvalasa reservoir, India. *Int. J. Life. Sci. Scienti. Res*. 3(1): P771-778.

Rodriguez, C., & Stoner, A. W. (1990). The epiphyte community of mangrove roots in a tropical estuary: distribution and biomass. Aquatic botany, 36(2), 117-126.

Rodriguez, C., & Stoner, A. W. (1990). The epiphyte community of mangrove roots in a tropical estuary: distribution and biomass. Aquatic botany, 36(2), 117-126.

San Martin, E., Irigoien, X., Harris, R., Lopez-Urrutia, A., Zubkov, M., Heywood, J., 2006.Variation in the transfer of energy in marine plankton along a productivity gradientin the Atlantic ocean. *Limnology and Oceanography*. 51 (5), 2084–2091.

Santhanam, P., & Perumal, P. (2003). Diversity of zooplankton in Parangipettai coastal waters, southeast coast of India. *J. mar. biol. Ass. India*, 45(2), 144-151.

Saravanakumar, A., Rajkumar, M., Thivakaran, G. A., & Serebiah, J. S. (2008). Abundance and seasonal variations of phytoplankton in the creek waters of western mangrove of Kachchh-Gujarat. *Journal of environmental biology*, 29(2), 271.

Shannon, C. E., & Weaver, W. (1949/1963). The mathematical theory of communication. Urbana-Champaign, IL: University of Illinois Press.

Shekhar, T. S., Kiran, B. R., Puttaiah, E. T., Shivaraj, Y., & Mahadevan, K. M. (2008). Phytoplankton as Index of Water Quality with Reference to Industrial Pollution. *Journal of Environmental Biology*, 29, 233-236.

Silpa.P., Ramanathan, T. (2024). Mangrove species diversity in Ariyankuppam estuary, Puducherry, India. *Chelonian Research Foundation*, 19(01), 32–38.

Srinivasan, K., & Natesan, U. (2013). Spatio-Temporal Variations in Water Quality of Muttukadu Backwaters, Tamilnadu, India. *Water Environment Research*, 85, 587-595.

Strickland, J.D., Parsons, T.R. (1972). A Practical Handbook of Seawater Analysis. Ottawa: Fisheries Research Board of Canada, Bulletin 167, 1968. 293 pp. in: *Internationale Revue Der Gesamten Hydrobiologie Und Hydrographie*. https://doi.org/10.1002/iroh.19700550118.

Tanaka, K., & Choo, P. S. (2000). Influences of nutrient outwelling from the mangrove swamp on the distribution of phytoplankton in the Matang Mangrove Estuary, Malaysia. Journal of Oceanography, 56, 69-78.

Telesh IV (2004) Plankton of the Baltic estuarine ecosystems with emphasis on Neva Estuary: a review of present knowledge and research perspectives. Marine Pollution Bulletin, 49(3), 206-219.

Todd, C. D., Laverack, M. S. and Boxshall, G. A. (2006). Coastal marine zooplankton: A practical manual for students. 2nd edn. Cambridge University Press, London, UK, 106 pp.

Vaghela, K. B., Shukla, D. P., & Jain, N. K. (2023). A Study of Phytoplankton and Zooplankton Diversity in the River Sabarmati, Gujarat, India. *Asian Journal of Environment & Ecology*, 22(4), 28-38.

Vajravelu, M., Martin, Y., Ayyappan, S., & Mayakrishnan, M. (2018). Seasonal influence of physico-chemical parameters on phytoplankton diversity, community structure and abundance at Parangipettai coastal waters, Bay of Bengal, South East Coast of India. *Oceanologia*, 60(2), 114-127.

Verlecar X., Desai S., (2004). Phytoplankton identification manual. National Institute of Oceanography, Goa, 35 p.

Verma, A. K., & Prakash, S. A. D. G. U. R. U. (2020). Zooplankton diversity in Guthia Taal, Wetland of Bahraich (UP), India. *International journal of Zoology and Research*, 10(2), 9-18.

Zulkifly, S., Rosli, N. S., Lazim, N. N. F., & Yong, C. (2020). Physico-Chemical Influence on the Diversity of Phytoplankton at Putrajaya Lake and Wetlands, Putrajaya, Malaysia. *Malayan Nature Journal*, 72, 153-163.

Table 1. Checklist of phytoplankton species recorded during the study period

Phytoplankton	station 1	station 2	station 3
Bacillariophyceae (Diatoms)			
Coscinodiscus gigas	+	+	+
Coscinodiscus granii	+	+	+
Skeletonema costatum	−	+	+
Odontella mobiliensis	−	+	−
Odontella sinensis	−	+	−
Bacillaria paradoxa	−	−	+
Rhizosolenia alata	+	+	+
Rhizosolenia imbricata	−	+	−
Gyrosigma balticum	−	−	+
Nitzschia longissima	+	+	−
Nitzschia amphibia	+	+	+
Nitzschia seriata	+	−	−
Nitzschia sigma	−	+	−
Pleurosigma angulatum	−	+	−
Pleurosigma elongatum	−	+	−
Pleurosigma normanii	−	+	+
Bacteriastrum delicatulum	−	+	+
Chaetoceros decipiens	−	+	+
Chaetoceros curvisetus	−	+	+
Chaetoceros didymus	+	+	+
Asterionella glacialis	+	+	+
Thalassionema nitzschioides	−	+	+

Thalassiothrix frauenfeldii	+	+	+
Lithodesmium undulatum	−	+	+
Stephanopyxis palmeriana	−	+	−
Guinardia flaccida	−	+	+
Triceratium favus	−	+	+
Dinophyceae (Dinoflagellates)			
Ceratium lineatum	+	+	−
Ceratium fusus	−	+	+
Ceratium longipes	−	+	+
Ceratium macroceros	+	−	−
Peridinium divergens	−	−	+
Prorocentrum gracile	+	+	+
Protoperidinium oceanicum	−	+	+
Protoperidinium claudicans	+	+	+
Cyanophyceae (Blue-greens)			
Oscillatoria limmosa	+	+	+
Trichodesmium erythraeum	+	+	+
Chlorophyceae (Green algae)			
Pediastrum simplex	−	+	+

Table 2. Checklist of zooplankton species recorded during the study period

Zooplankton	station 1	station 2	station 3
Phylum Arthropoda			
Canthocalanus pauper	+	+	+
Paracalanus indicus	+	+	+

Parvocalanus elegans	+	+	+
Parvocalanus crassirostris	+	+	+
Oithona attenuata	+	+	+
Oithona brevicornis	+	+	+
Oncea sp	+	+	+
Clytemnestra sp	+	+	+
Phylum Rotifera			
Brachionus plicatilis	+	+	+
Brachionus urceolaris	+	+	+
Brachionus rotundiformis	+	+	+
Lecane bulla	+	+	+
Lecane lunaris	−	+	+
Rotaria rotatoria	+	+	+
Keratella cochlearis	+	+	+
Phylum Ciliophora			
Codonellopsis ostenfeldi	+	+	+
Tintinnopsis gracilis	+	+	+
Tintinnopsis tocantinensis	+	+	+
Coxliella annulata	+	+	+
Helicostomella longa	+	+	+
Metacylis lucasensis	+	+	+
Protorhabdonella simplex	+	+	+
Favella ehrenbergii	+	+	+
Phylum Chordata			
Oikopleura dioica	+	+	−

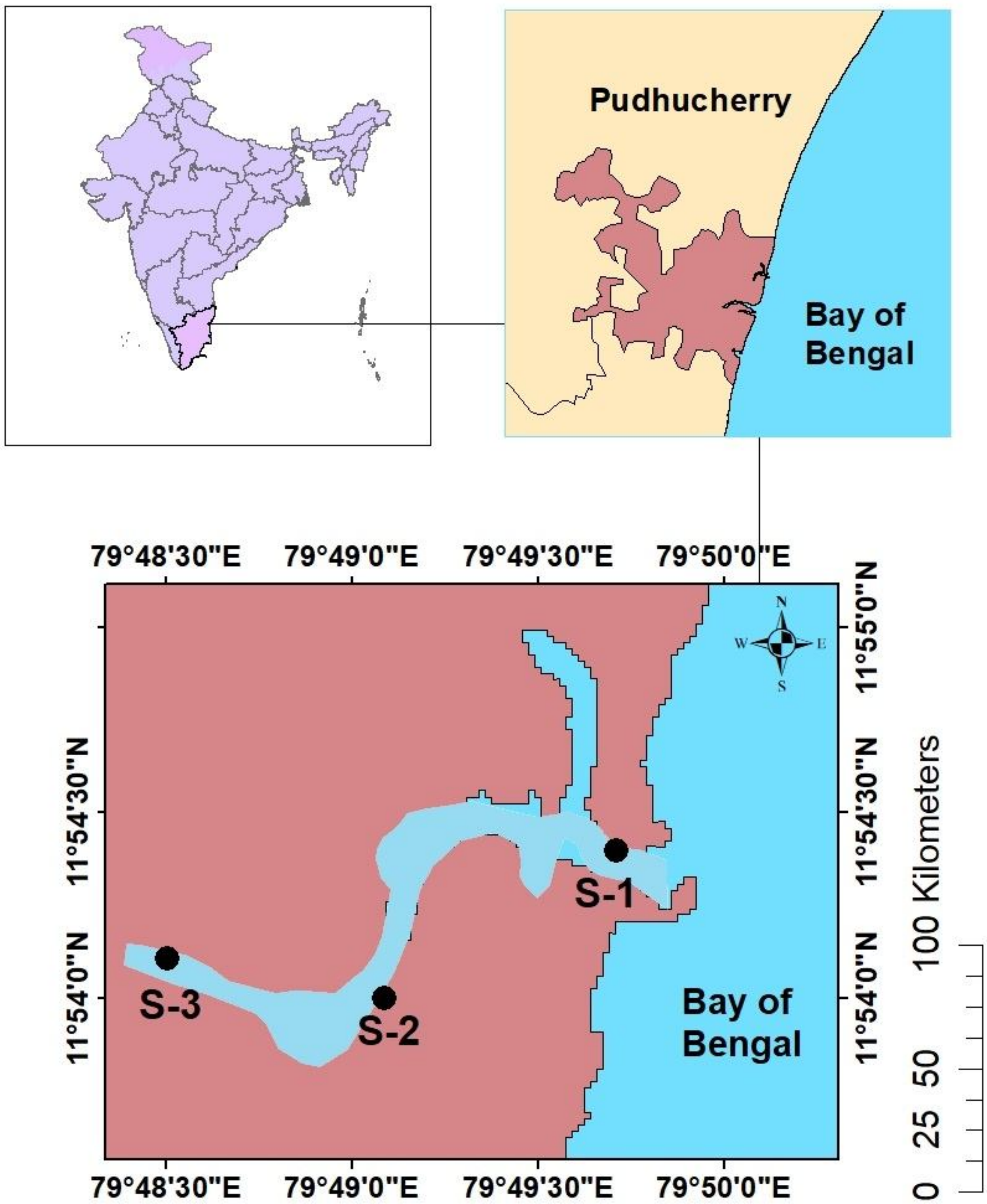

Figure 1. Sampling sites along the Ariyankuppam estuary

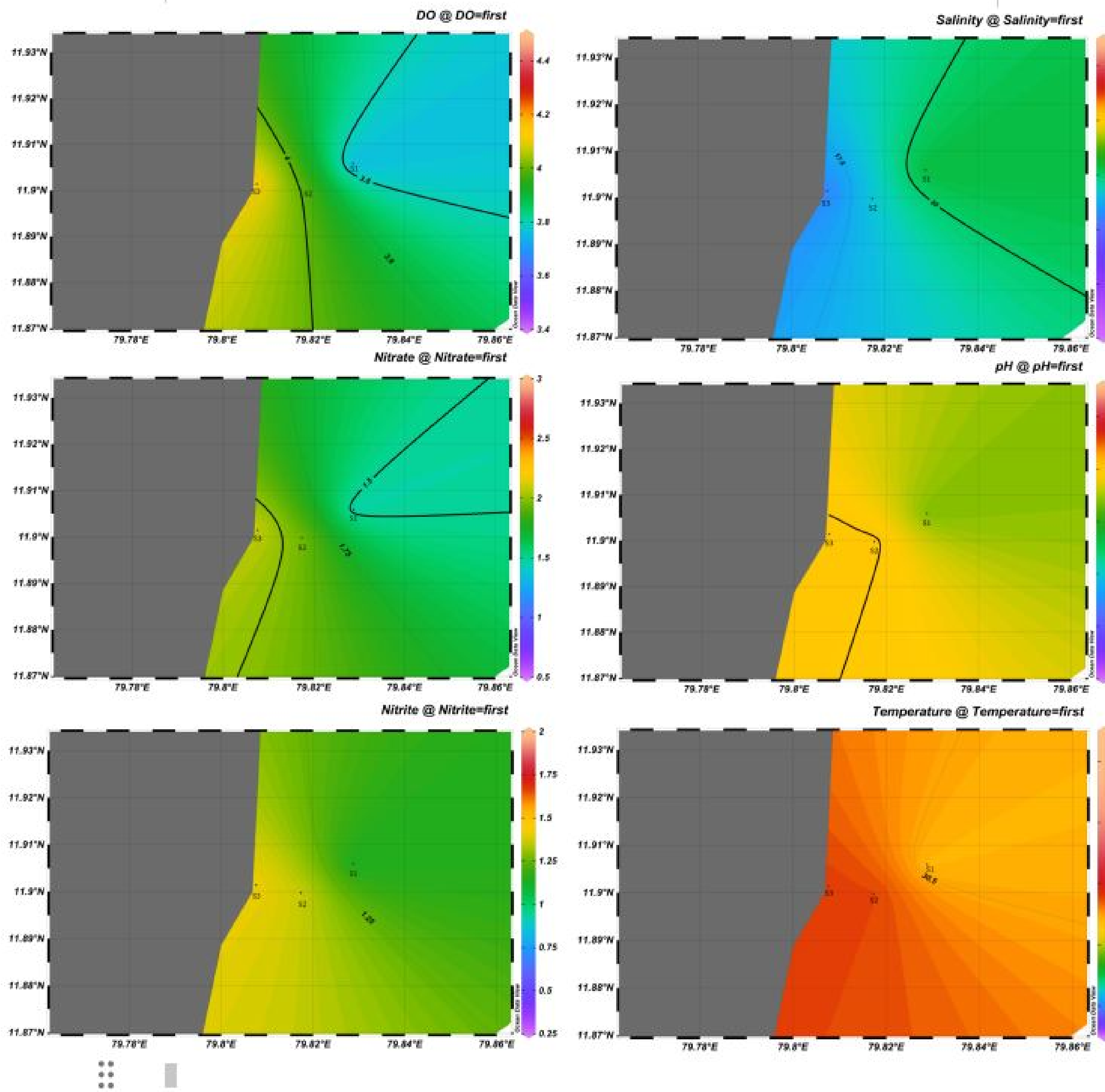

Figure 2. Physico - chemical parameters of Ariyankuppam estuary

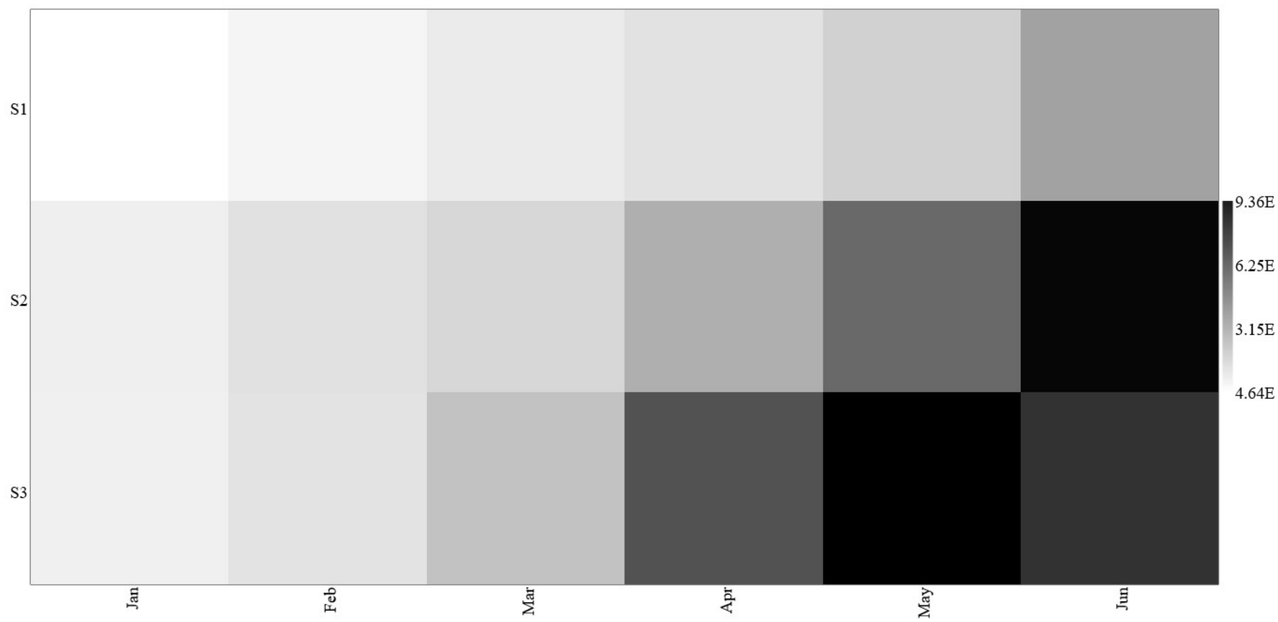

Figure 3. Abundance of phytoplankton in Ariyankuppam estuary

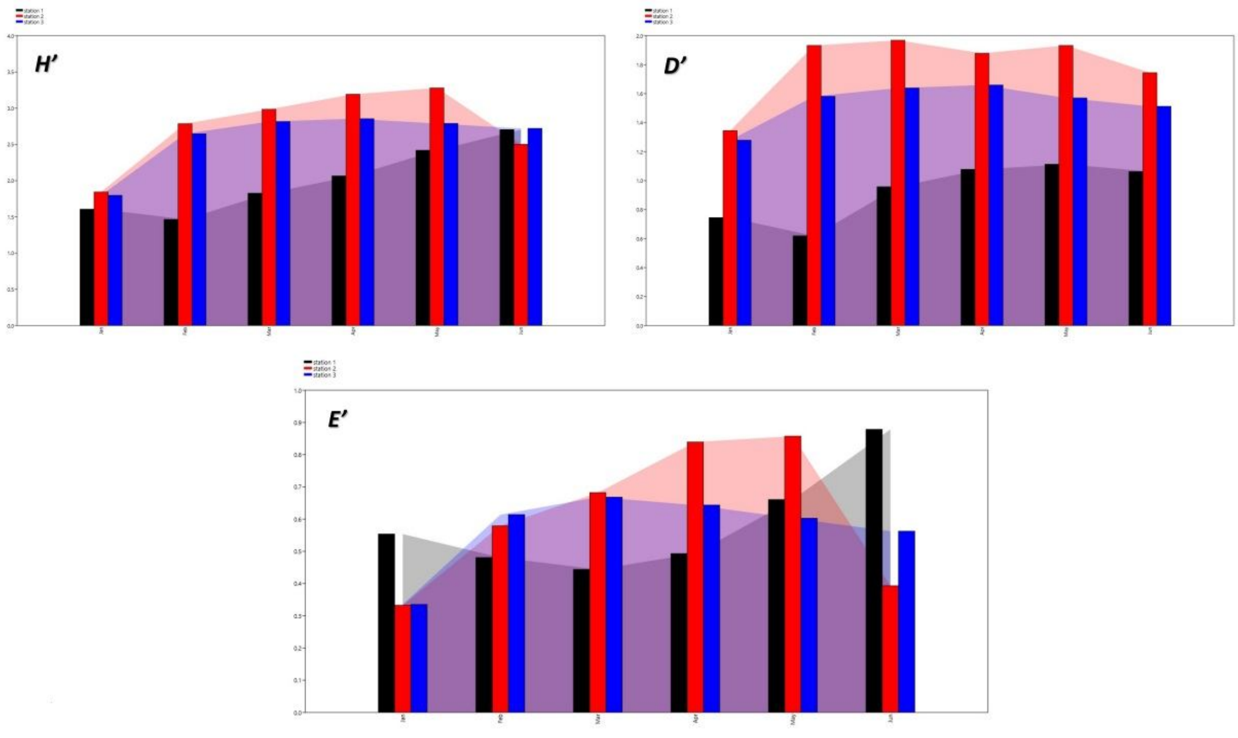

Figure 4. Variation in Phytoplankton diversity indices in Ariyankuppam estuary

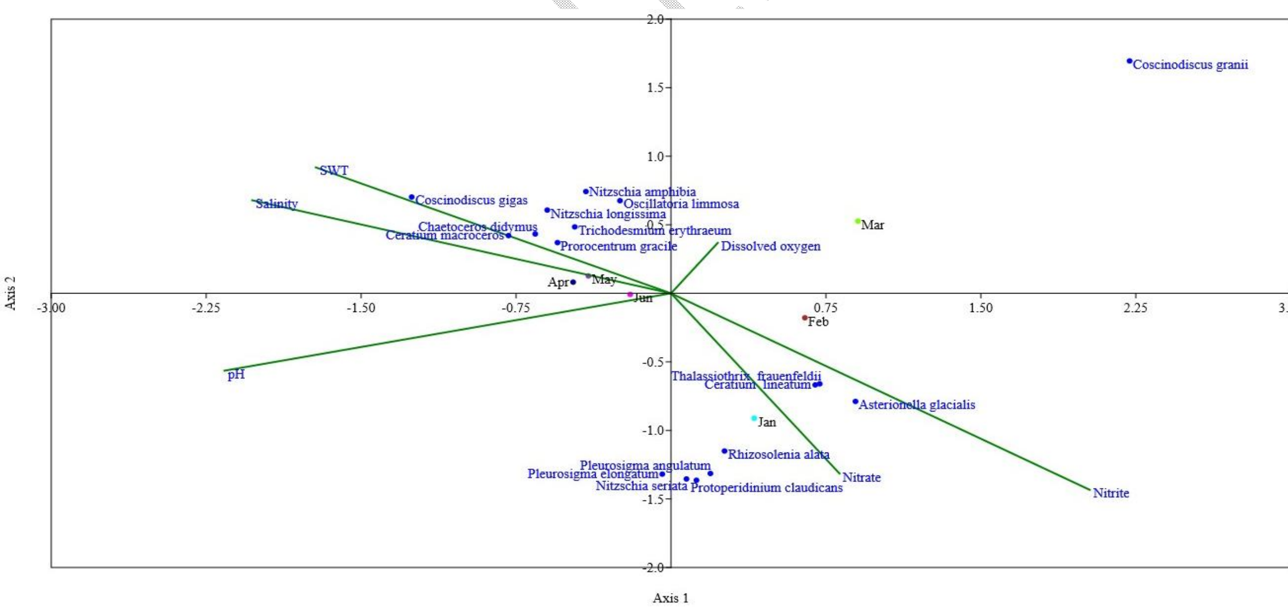

Figure 5. CCA biplot for phytoplankton and physico - chemical parameters of station 1

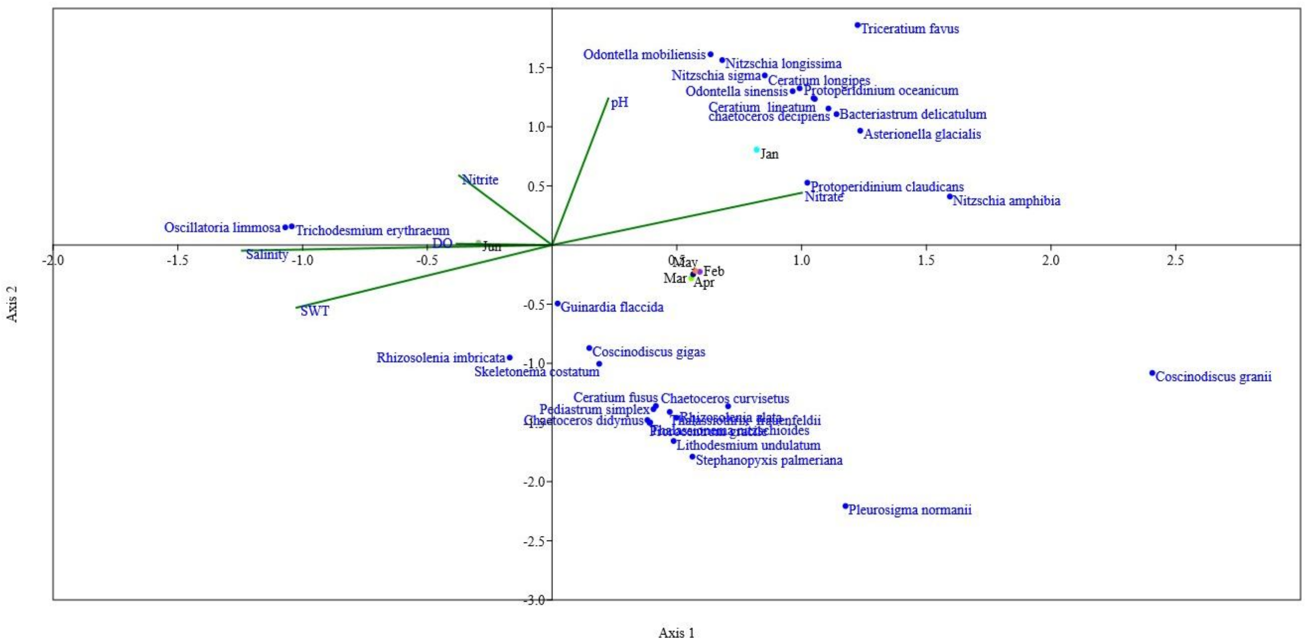

Figure 6. CCA biplot for phytoplankton and physico - chemical parameters of station 2

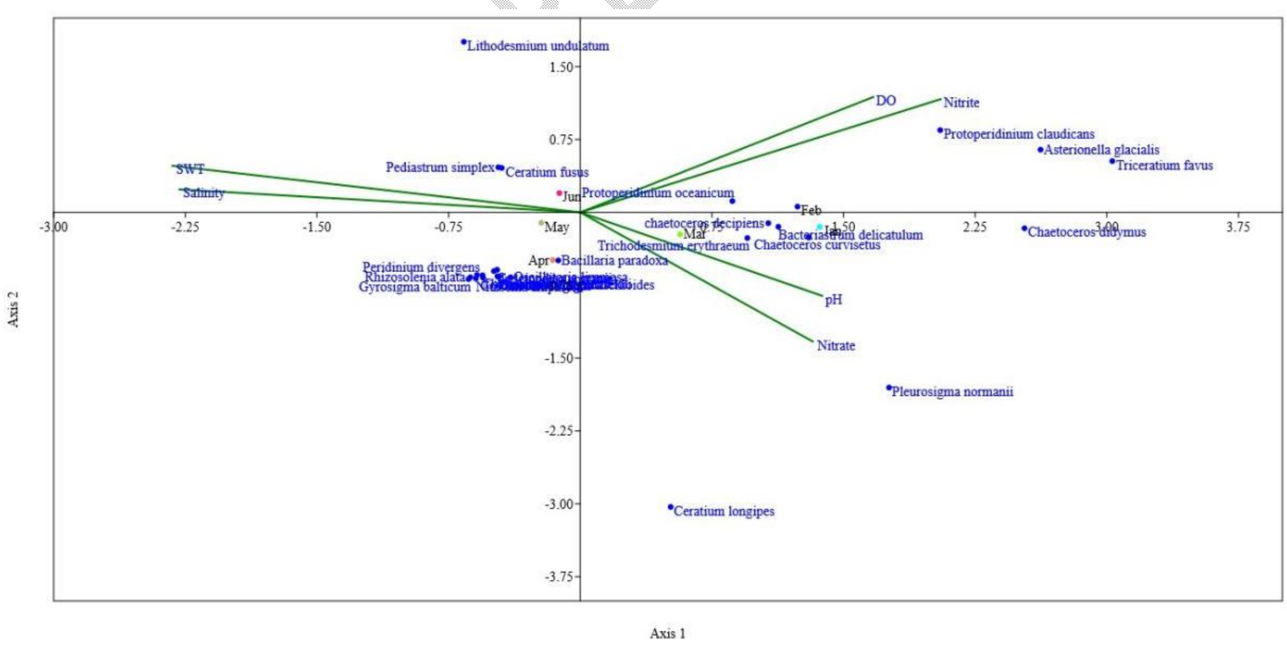

Figure 7. CCA biplot for phytoplankton and physico - chemical parameters of station 3

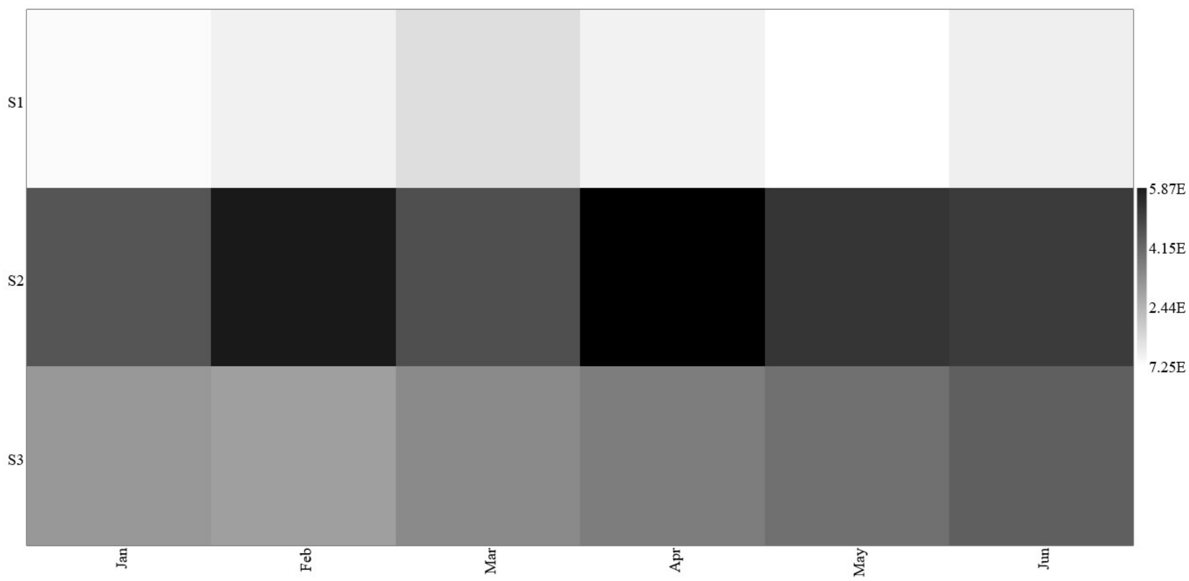

Figure 8. Abundance of zooplankton in Ariyankuppam estuary

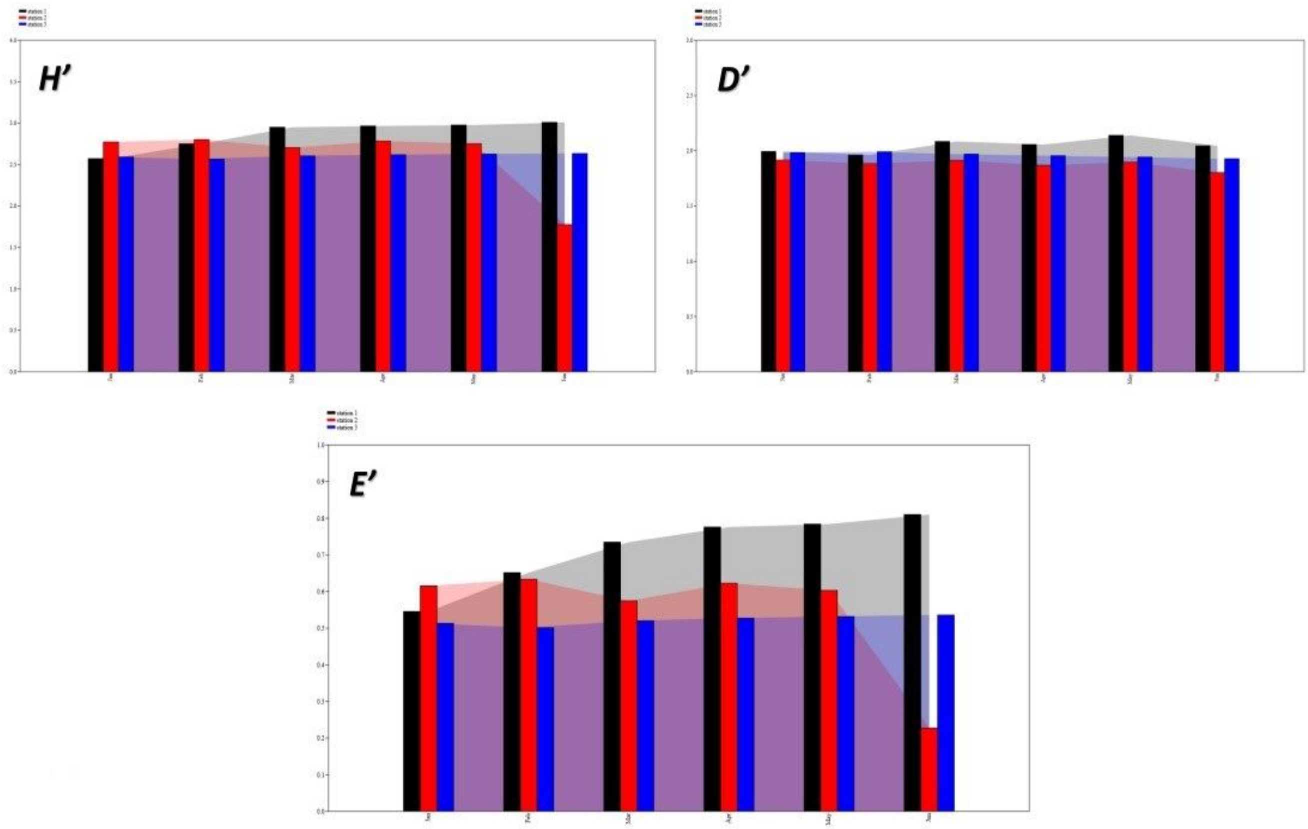

Figure 9. Variation in zooplankton diversity indices in Ariyankuppam estuary

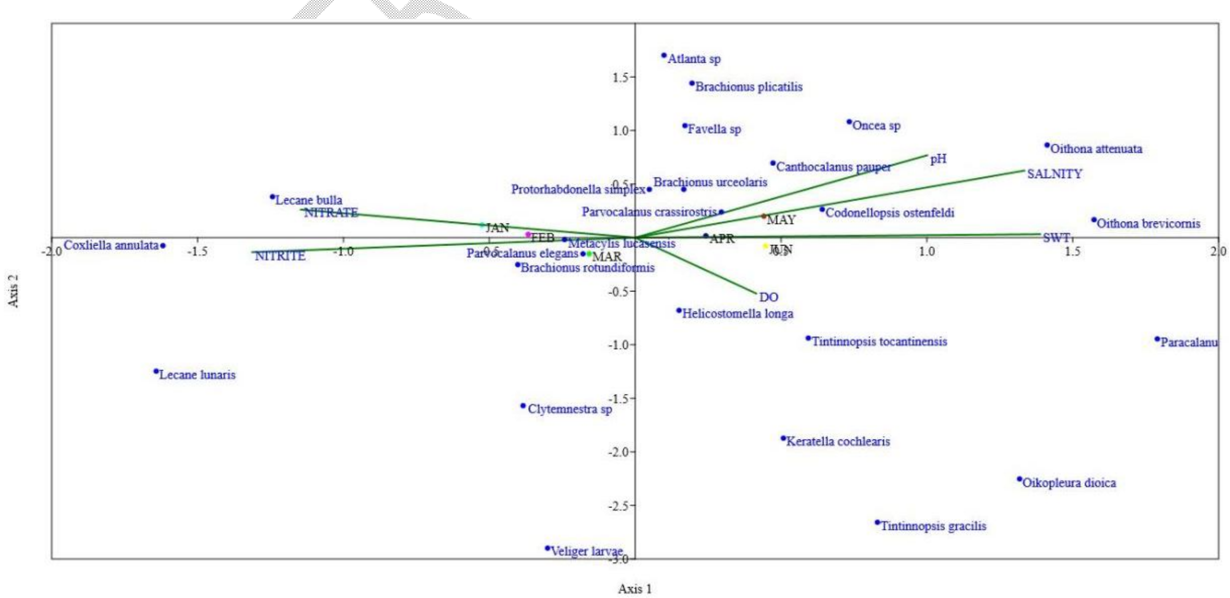

Figure 10. CCA biplot for zooplankton and physico - chemical parameters in station 1

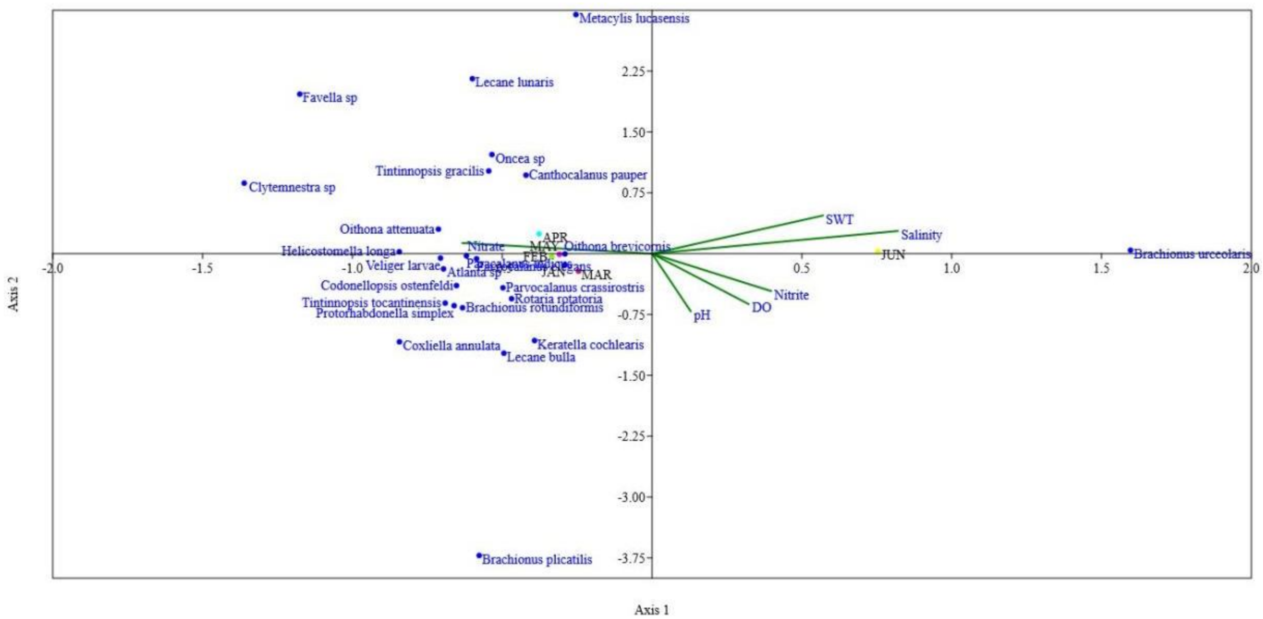

Figure 11. CCA biplot for zooplankton and physico - chemical parameters in station 2

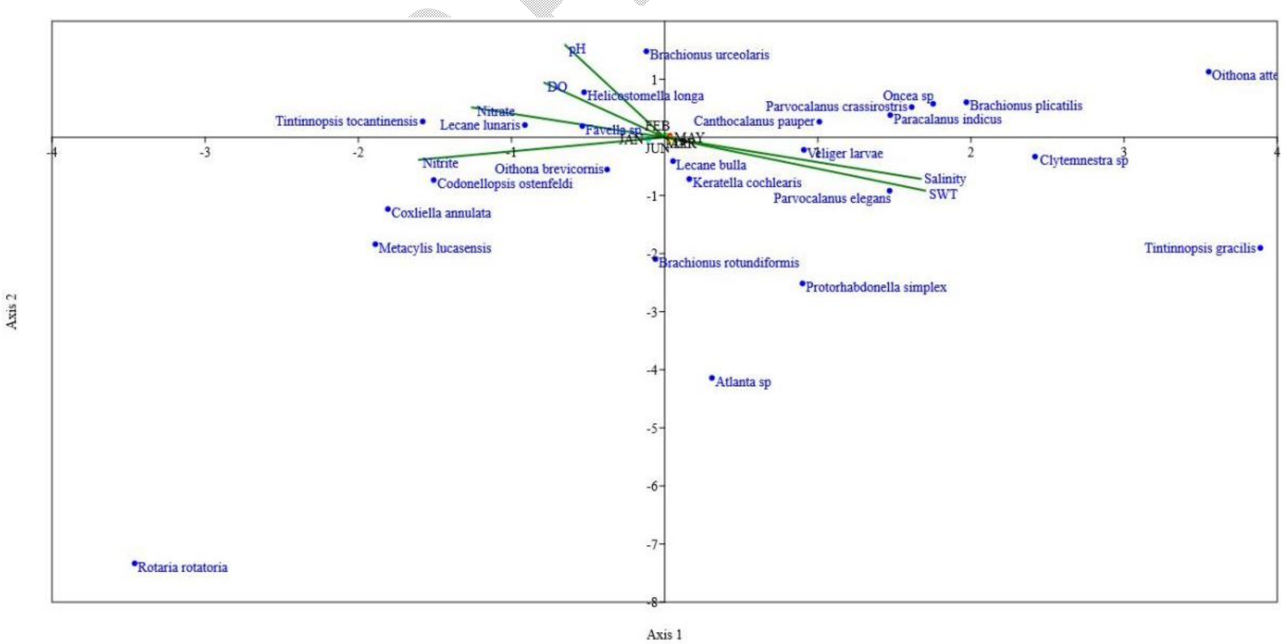

Figure 12. CCA biplot for zooplankton and physico - chemical parameters in station 3