Seasonal Variation In Environmental Parameters And Their Impact on Zooplankton Species Composition, Abundance And Density At Parangipettai Coastal Waters, South East Coast of Bay Of Bengal

ManigandanVajravelu[1], Saravanakumar Ayyappan[2], Yosuva Mariyasingarayan[3]
Faculty of Marine Science
Centre of Advanced Study in Marine Biology,Annamalai University, Tamil Nadu, India.

Abstract- *Studies on zooplankton community can provide valuableinformation about the status of water, as they are meant to be an indicator organism in marine environment. Seasonal distribution in zooplankton species composition, abundance, density and environmental parameters were studied by monthly surveys (January 2015 to December 2015). Totally 83 species belonging to 11 orders Calanoida (64%), Cyclopoida (15%), Harpacticoida (7%), Tintinida (3%), Aphagramphora (2%), Copelata (2%), Decopoda (2%), Brachiopoda (1%), Cnidaria (1%),Gastropoda (1%), Amphipoda (1%)and 29 families were identified in the present study.To understand the relationship between zooplankton and physico chemical parameters, different univariate and multivariate analyzes were carried out (Diversity indices, ANOVA, PCA, and CCA). The zooplankton species diversity, richness and evenness showed maximum values during premonsoon and summer (2.59, 0.908, and 0.954) and minimum were observed during monsoon season. Analysis of Variance showed significance variation between different groups identified during the study period (P=0.005).The conducted statistical analyses PCA and CCA revealed that temperature, dissolved oxygen (DO), salinity and ammonia influences the zooplankton community. Themost dominant groups were found to be Calanoida, Cyclopoida, and Harpacticoida were evidenced significantly with CCA analysis.*

Keywords- Zooplankton, CCA, PCA, abundance, species composition.

I. INTRODUCTION

Zooplankton are very small animals exist in all aquatic environment, particularly found in the pelagic and littoral region of the sea. Based on the size and development stage, they have been classified into different categories [1]. They are considered as the primary consumer of food web and play a most fundamental role in the ecosystem by transferring the energy from the lower food web level to the top [2]. Environmental parameters plays a vital role in zooplankton community, nutrient dynamic and the important key role played by zooplankton influence the function and production of that particular ecosystem [3].Long term changes in the environmental condition such as eutrophication, pollution and global warming can be monitored with zooplankton studies as they are highly sensitive to slight changes in physical and chemical parameters. Spatio-temporal variation in physico-chemical parameters can change the abundance and diversity of zooplankton community [4].Molinero et al. [5] investigated that changes in zooplankton community was observed with respect to changes in aquatic condition and climate change, thus suggested the zooplankton community can be used as an indicator species.

Zooplankton studies in estuary and coastal region is most important as they are very useful in predicting the potential fisheries zone.The success and failure of potential fishery zone is based on the availability of zooplankton population. Similarly, Xueluet al. [6] reported the huge quantity of fish with high zooplankton concentration. Studies on environmental parameters and their impact on zooplankton community have been widely studied in India and started way back 1900 [7]. Seasonal variation in species composition of zooplankton abundance has been investigated by several authors in Indian coastal waters [8-16].However, only several studies pertaining to zooplankton diversity and distribution in Parangipettai coastal waters have been conducted by few authors [17, 4]. Therefore, the present investigation has been made to fill the lacuna on zooplankton, zooplankton community and their relationship between the environmental parameters using univariate and multivariate statistical analysis.

II. MATERIALS AND METHODS

A. Study area

The present study was carried out for one year from January 2015 to December 2015 at Parangipettai coastal waters, Tamil Nadu, Southeast Coast of India. The study area is known to have high fluctuations in tides and highly influenced by freshwater due to heavy rainfall during monsoon season (Fig. 1).The study area is often influenced by the freshwater and anthropogenic activity due to Vellar estuary. Figure 1 represents the GPS location of the study area.

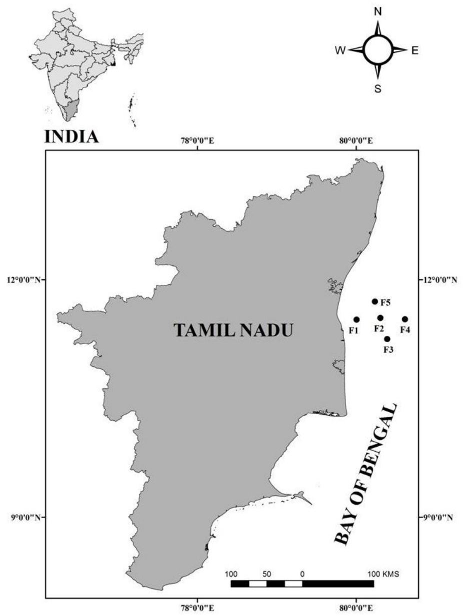

Figure 1.The geographical location of the study area.

2.2. Sampling and Identification

Monthly samples were obtained on the surface of the water using Niskin water sampler. Water samples were collected from 1L polypropylene bottle to analyze the chlorophyll and physic- chemical parameters. The collected water samples were stored in Ice box and transported to laboratory. Samples were filtered using WhatmanGF/F Filter paper for different analyses of chemical parameters. Temperature, pH and salinity were estimated on the study location itself with the help of Multistem digital Thermometer (accuracy ±0.1), pH pen and Hand held Refractometer (ATAGO S/Mill-E).

Chemical parameters like nitrite (NO_2), nitrate (NO_3), ammonia (NH_4), inorganic phosphate (PO_4), reactive silicate (SiO_4) were evaluated by adopting standard methodology [18].Estimation of chlorophyll a concentration was done by pigment extraction method with 90% acetone and was subjected for incubation under dark condition for 24 hours. The concentration of chlorophyll a was estimated by UV spectrophotometer after incubation period [18].To evaluate the Total Suspended Solids (TSS), filter papers were weighed and water samples were filtered using per-weighed glass filter papers (WhatmannGF/C, 0.45 μm)and were kept inside the oven for 24 hrs at 75°C. The dried paper were weighed again and detracted with the pre-weighed values to estimate TSS.

Monthly samples of zooplankton were collected on the surface water by horizontal towing with the help of plankton net made up of bolting silk cloth (mesh size 54 μm). The volume of seawater filtered was calculated using flow meter which was attached at the center of the net while towing. The concentrated zooplankton samples were collected and preserved for further analysis by 4% buffered formalin. Quantitative analyses of zooplankton were carried out using inverted microscope with the help of Sedgwick rafter. Zooplankton samples were identified by following the standard methodologies of [19-22].

2.3 Statistical analysis

To find out the relationship between zooplankton community and environmental parameters, canonical correspondence analysis was performed. Principal component analysis was used to determine the significant variations in physical and nutrient parameters. To estimate the seasonal variation in species diversity, richness and evenness [23], diversity index, and Pielou (1966) evenness were calculated. All the univariate and multivariate statistical analyses were performed using R software (R core Team 2016, Version. 3.4.0) with different statistical packages. CCA and diversity indices were conducted using Vegan: Community ecology Package R[25].FactoMine R (A package for Multivariate anlaysis) package was used to conduct the PCA among different environmental variables [26]. Bar diagrams were drawn using ggplot2 packages [27].

III. RESULTS AND DISCUSSION

In coastal waters it is of utmost important to study the physico chemical parameters in order to know the variations in primary organisms like phytoplankton and zooplankton as they are ecologically important [28]. In the present investigation, Parangipettai coastal waters exhibited variations in physical and chemical parameters according to the seasons. The seasonal variations in physico-chemical parameters observed during the study period are illustrated in figure 2 and 3.

In marine environment, temperature is considered as most influencing factor as it regulates the life of aquatic organisms and environmental parameters[29]. In the present study, temperature showed variation according to the seasons and ranged between26.8^{0}C (November, 2015) and 29.83^{0}C

(April 2015) with a mean of 28.59±0.09^{0}C.This pattern of variation in temperature indicates the seasonal influences of freshwater due to rainfall, wind force, high intensity of solar radiation and less atmospheric air temperature [30]. Like temperature, salinity also showed variations with maximum during summer (April 2015) and minimum on monsoon season (November, 2015). The registered high and low salinity values ranged from 31.2 PSU to 33.04 PSU (Mean 32.5 ±0.49 PSU).

Salinity plays a vital role in marine environment, as it act as controlling agent for the fauna and flora diversity [31-33]. Previously, many investigations reported that Parangipettai coastal waters exhibit high seasonal variation due to the influence of Vellar estuary [31-35]. The observed high salinity during summer and monsoon season might be due to the influence of freshwater and fluctuations in tides [20,36]. The recorded high pH value (8.2) was observed in summer (March 2015) and the less (7.5) was recorded during monsoon season (November, 2015). pH remained alkaline almost all the season except monsoon (Mean; 7.9 ± 0.17). These changes in pH could be due to CO_2 removal by phostosynthetic organisms,
freshwater influx, reduced salinity and temperature [37].

Dissolved oxygen (DO) considered as the most important component of marine ecosystem due to their role in determining the quality of water and supporting system for aquatic life. DO values varied from 4.02mg $L^{-1}$to mg $L^{-1}$with the mean of 4.67 mg L^{-1} (± 0.59) and was found to be fluctuated throughout the study period. The recorded high and low concentration of DO in postmonsoon and monsoon might be attributed to high temperature, salinity, biological activity and freshwater influence due to heavy rainfall [38-40].

The maximum and minimum chlorophyll a concentration was observed at the beginning and end of postmonsoon season. Chlorophyll a concentration ranged from 0.17 µg L^{-1} to 3.4 µg L^{-1} (Mean 1.06 ±1.06). This implies that phytoplankton enhances during postmonsoon season due to accessibility of high amount of UV light, clear water thereby increasing the chlorophyll content [41-42].

Variation in Total Suspend Solids (TSS) was found to be 17.37 mg L^{-1} and 41.02 mg L^{-}(Mean 31.8±6.91 mg/L) during premonsoon and monsoon season. High content in TSS during monsoon season could be due to high terrestrial run off with high suspended solids brought to coastal waters during monsoon season [43-44].

3.1. Nutrient Dynamics

Chemical parameters such as nitrite, nitrate, phosphate and silicate in the coastal waters shows substantial variations based on seasonal changes in rainfall, freshwater influx, tides and utilization of nutrients by the primary producers. The observed nitrate and nitrite concentration varied from 0.25 µmol$L^{-1}$to 6.40 L^{-1}µmol and from 0.23 L^{-1}µmol to 1.93 L^{-1}µmol L^{-1} with the mean of 2.94 ± 1.63 L^{-1} and 0.79 ± 0.74 L^{-1}. Both nitrite and nitrate parameters registered highest value during monsoon season which implies high biological production and biological degradation of planktonic detritus during monsoon[13,33&45]. Recorded reduced values of nitrate and nitrite concentration on other season could attribute to the consumption of nitrate component by photosynthetic organisms [33, 46-47]

Ammonia showed noticeable fluctuation and deviated highly from the mean during the study period maximum value of 1.93 µmol L^{-1} (November 2015) on monsoon season and the minimum value of 0.04µmol L^{-1} (July 2015) was recorded on premonsoon season with the mean of 0.59 ± 0.48. The recorded high value during monsoon season might attribute to terrestrial run off and phytoplankton degradation. Decreased concentration of ammonia on premonsoon season might be due to consumption by phytoplankton [48-52].

Phosphate acts as a primary component in aquatic ecosystem as it is highly useful in promoting the growth and proliferation of primary producers [53]. Phosphate concentration varied from 0.34 µmol L^{-1} to 1.33µmol L^{-1} during summer and premonsoon with the mean of 0.81 µmolL^{-1}(±0.34). Variation in phosphate is highly contributed because of consumption by phytoplankton, buffering process and monsoonal influences such as rainfall and terrestrial run off [54-55].Silicate concentration varied from 3.15 µmol L^{-1} to 10.01 µmol L^{-1} and registered high value during monsoon and premonsoon season and the less was observed on summer. Utilization of silicate by silicoflagellates, diatoms and high terrestrial run off could be the reason for increased and decreased concentration of silicate [54].

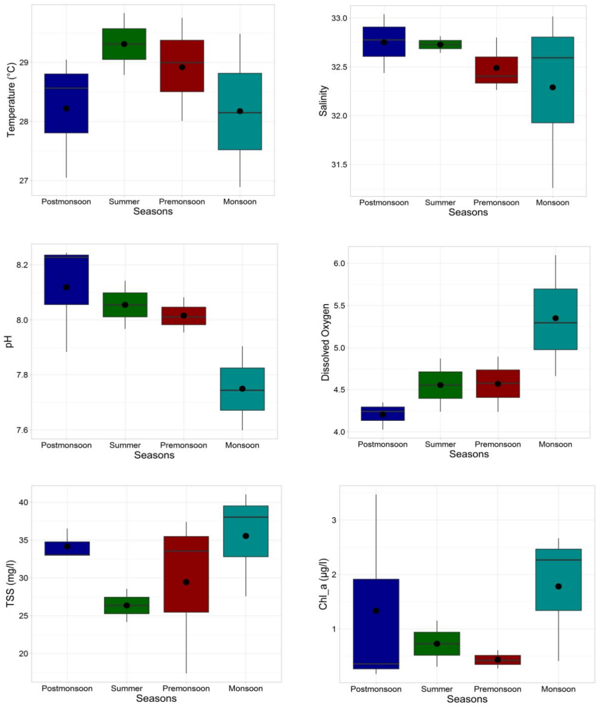

Figure 2.Seasonal variation in Physico chemical parameters.

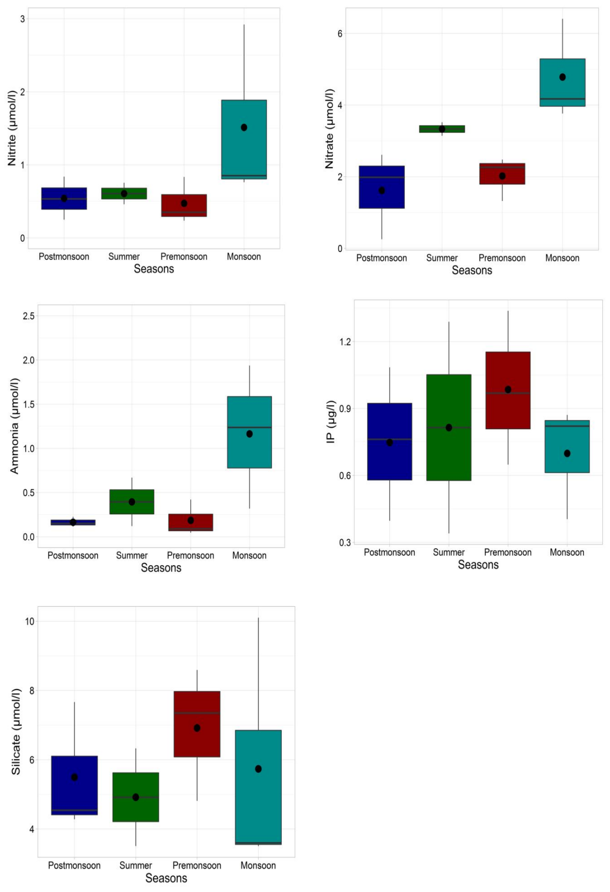

Figure 3. Seasonal Variation in Physico chemical parameters

3.2. Principal component analysis of Environmental parameters

Principal component analysis is used widely to infer the most significant information from multivariate data. In the present investigation, the conducted PCA exhibited 100% significant variation with five components (Fig. 4). The first two components alone explained high significant variation of 34.3 % and 17.7 % which accounts for 50 % in both axis 1 and 2 (Fig.4).Physical parameter like temperature (0.723) and salinity (0.85) showed significant loadings with high positive correlation in dimension 1and 2 whereas nutrients such as Ammonia (-0.869), DO (-0.818), Nitrite (-0.12) and IP (-0.100) showed significant negative loadings in dimension 1. The high positive correlation in temperature and salinity clearly indicates that salinity is majorly influenced by temperature. Similarly, increased temperature and salinity in coastal waters might reduce DO content which is clearly evidenced in PCA with negative loading of DO [56].Likewise high consumption of nitrite and IP by primary producers might have resulted in decreased concentration of DO and this pattern was explained clearly by PCA with negative loadings. Silicate, pH and TSS showed positive correlation in dimension 1 on the other hand chlorophyll a showed significant positive and negative correlation in both dimension 1(-0.61) and 2 (0.72). This implies the positive and negative relationship of chlorophyll a with silicate and TSS indicating the enhancement of primary producers with silicate and decreased level of chlorophyll a with increased Total suspended solids.

The PCA analysis also revealed the most significant component and their contribution in both dimension 1 and 2.Ammonia, Salinity, DO and Temperature exhibited highest contribution among other variables (20.01, 19.41, 17.74, and 13.85). Similarly high positive correlation was observed with salinity(r=0.85, *P*= 0.0007) and temperature (r=0.723, *P*= 0.011) in dimension 1. This clearly indicates that temperature and salinity are highly correlated and dependant variable, similar correlations were observed by several authors [57-58]. In contrast to temperature and salinity chlrorophyll a(r=-0.613, *P*=0.04), DO (r= -0.818, *P*=0.002) and ammonia(r=-0.869, *P*= 0.0005) showed significant negative correlation whereas in dimension 2 nitrite(r=0.865, *P*= 0.0005) and chlorophyll .a (r=0.721, *P*= 0.012) significantly correlated positively. The negative loadings of chlorophyll a with DO apparently evidence the reduced level of chlorophyll a as DO found to be most important parameters for phytoplankton growth.

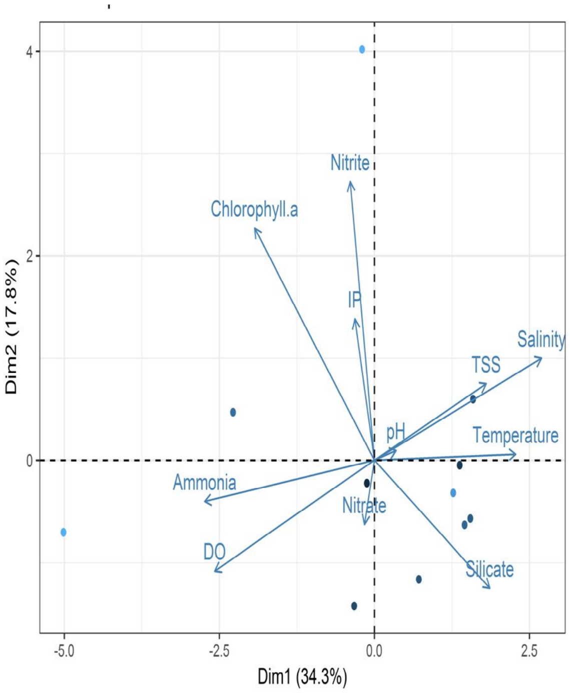

Figure 4. Prinicipal Component analyis of Environmental variables.

3.3. Zooplankton Species composition, population density and Diversity

The proliferation and growth of plankton community is highly influenced by the physical and chemical parameters of that specific ecosystem. The present study identified 83 species belonging to 11 orders (Calanoida (64%), Cyclopoida (15%), Harpacticoida (7%), Tintinida (3%), Aphagramphor (2%), Copelata (2%), Decopoda (2%), Brachiopoda (1%), Cnidaria (1%), Gastropoda (1%), Amphipoda (1%)) Of these the most dominant group was found to be order calanoida, Harpacticoida and cyclopoida which represented more families than other group.During the study period continuous occurrences were observed from many zooplankton species such as *Acaratia danae, Acartia southwelli* of Acartidae *Nanocalanus minor, Canthocalanus pauper, Calanopia eliptica*, *Calanopia minor* of Calanidae, *Centropages furcatus, Centropages* species Of Centropagidae, *Oithona brevicornis, Oithona nana, Oithona similis of* Oithonidae family, *Acrocalanus gibber, Acrocalanus longicornis* of Paracalanidae, *Euterpina acutifrons* of Euterpinidae, *Eucalanus crassus* of Eucalanidae, *Sagitta enflata* of Sagittoidae, *Pontella dana* of Pontellidae, *Lucifer hanseni* of Luciferidae and *Temora turbinata* of Temoridae showed maximum occurrences throughout the study period. These results well agree with earlier investigations conducted in Parangipettai and adjacent coastal waters by several authors [13, 59-60]. Similarly, Velmurugan [61] and Acchuthankutty [62] also reported high domination of the same zooplankton species in their investigation.

The zooplankton population density varied from 20820 org.m^{-3}(July 2015) to 37 m^{-3}(January 2015) Figure 5. Variation in zooplankton population density was found to be seasonal and was statistically proven to be significant. The Analysis of Variance was performed to find out the differences in zooplankton population density among different groups within seasons and it showed high variation with significant p value (a= 0.005, F= 20.34). Further Turkey HSD test was conducted to observe the differences among 11 groups and it was found to be highly significant. The population density of zooplankton was found to be more during pre-monsoon followed by summer and postmonsoon.

The high zooplankton population density during premonsoon and summer could be due to stable condition of hydrochemical parameters [63-66].The density and species composition of zooplankton showed gradual increase from post-monsoon to premonsoon implying that drop down in salinity reduce zooplankton composition and density [67-68]. In addition the species composition and density reduced during monsoon season which clearly indicates the stenohaline nature of zooplankton [69]. Further the addition of freshwater during monsoon season due to heavy rainfall might have contributed to less population density.

The maximum population density was highly contributed by families of Acartidae, calanidae, paracalanidae and centropagidae belonging to order Calanoida and Oithonidae, Corycaeidae families belonging to order Cyclopoda. Earlier investigations made by Nair and Azis[70]; Madhu et al., [71] and Reddy et al., [72]in Parangipettai coastal waters also registered the same group as more dominant. Similarly, several studies pertaining to zooplankton have reported the same groups were found as dominant in both east and west coast of India [73-75].Order Cnidaria and Amphipoda found to have less population density and consisted very less species composition during the study period.

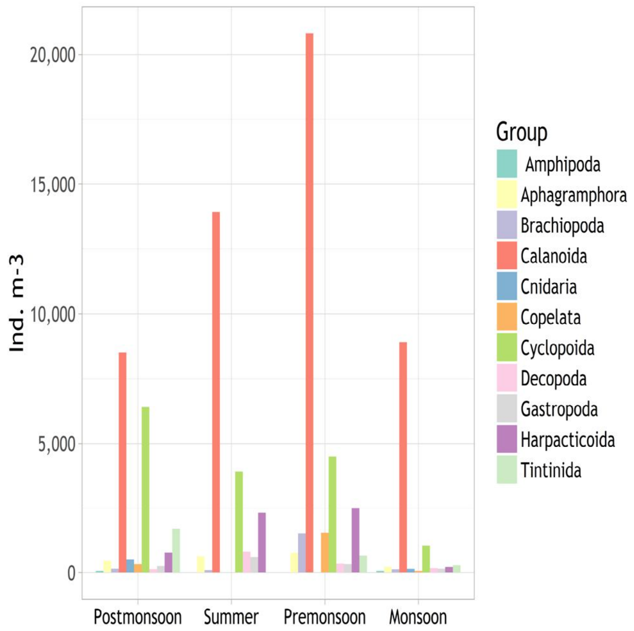

Figure 5. Seasonal variation in zooplankton population denisty.

The carried outstatistical analysis of species diversity, richness and evenness revealed highest value during postmonsoon, summer and premonsoon (Fig. 6). The range of species diversity was found as 1.56 and 2.59 during summer and monsoon season. Similarly,simpson richness also expressed high value of 0.908 during summer and less value of 0.710 on monsoon season. In contrast to species diversity and richness the highest evenness value (0.954) was obtained in premonsoon season and the lowest was found in monsoon season. This could be due to the high population density contributed by group Calanoida. This evidence as described in earlier reports as premonsoon and summer found to have stable hydro chemical parameters and renders more phytoplankton growth thereby increasing the population density and species composition of zooplankton [76-78]. Similarly recent studies conducted neighboring region of Parangipettai coastal water also reported high species richness and evenness on pre-monsoon season and less on monsoon season [13].

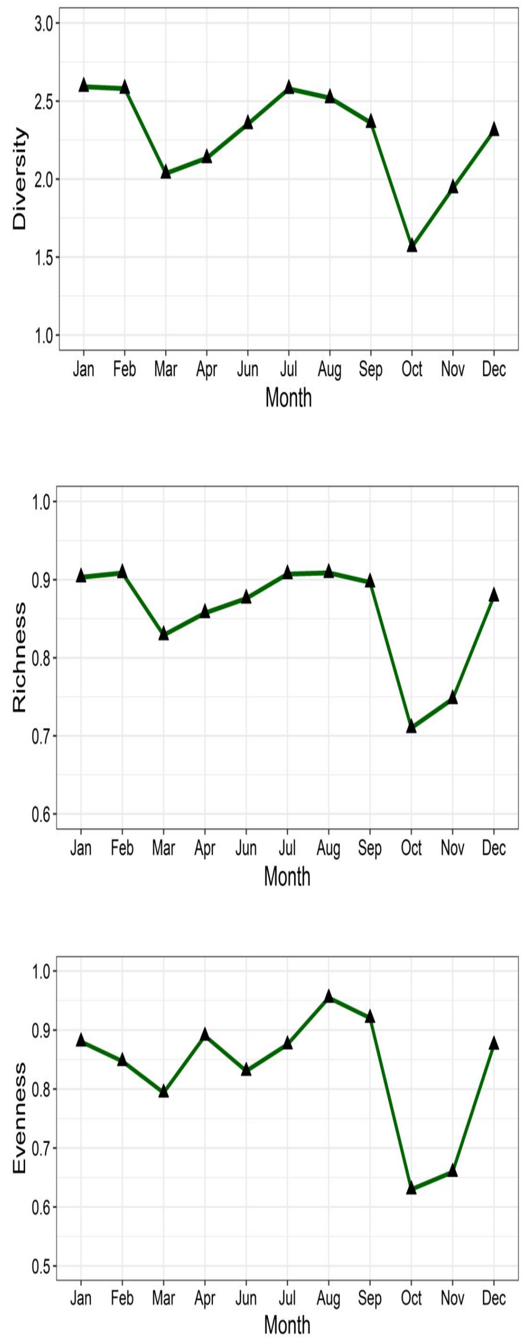

Figure6. Species diversity, richness and evenness of zooplankton species.

3.4. Canonical correspondence analysis of zooplankton and physico chemical parameters

Canonical correspondence analysis is widely used to determine the relation among environmental variables and plankton distribution [79]. Totally 29 families were taken for analysis which included the mostly occurred species during the present study. The biplot of canonical correspondence analysis of zooplankton species and physico chemical parameters is illustrated in figure 7. Changes in Physico chemical parameters of aquatic ecosystem can bring variation in the zooplankton species composition and abundance [80]. CCA revealed the pattern in distribution between zooplankton and environmental parameters with high eigenvalue in CCA1 (0.30) and CCA2 (0.19). Totally 80 % of cumulative variation was explained in five axis in which axis1 and axis 2 showed maximum variations (27% and 17 %). Temperature showed significant positive correlation in axis 1 and 2 whereas salinity exhibited significant negative correlation in both axis. DO and chlorophyll a showed significant positive and negative correlation in axis 1 and 2 with high correlations. On the other hand nitrite, nitrate, IP, silicate and pH explained significant negative correlation in axis 1 and 2. In contrast to other variables Ammonia alone exhibited a significant positive correlation in both axis 1 and axis 2.

In axis 1 groups such as pontellidae (Pont), Eucalainidae (Euca), Calanidae (Cala), Oithonidae (Oith), Ectinosomatidae (Ecti) and Okipleuridae (Okip) explained high positive correlation with temperature in axis 1 with maximum canonical values (0.67, 0.23, 0.30, 0.54, 0.33 and 0.68). Similarly, families like Temoridae (Temo), Pseudodiaptomidae (Pseu), Penaidae (pena), Miracidae (Mira), Canadacidae (Cana) and Pandaidae (Pand) showed positive and negative correlation with axis 1 and 2 and showed high association with DO and chlorophyll a. Likewise a study conducted by waidi et al., [81] also found the same pattern in CCA with negative correlation with DO and chlorophyll a.Corycaeidae (cory) and Sagittadiae (Sagi) shwoed positive correlation in axis 1 and 2 and was highly associated with ammonia in axis 2. Negative correlation was explained by CCA between families such as Euchatidae (Euch), Centropagidae (Cent), Oncaeidae (Onca), Luciferidae (Luci), Euterpinidae (Eute) and Nitrite, Nitrate, IP, TSS, silicate, salinity and IP. These families showed significant negative correlation in axis 1 and 2 and showed higher association negatively with Salinity, TSS, silicate, nitrite,nitrate and IP.Salinity considered to be one of the most influencing factor to zooplankton community [82] thus, the observed negative relation of salinity with families registered less population density clearly evidence that salinity act as a limiting agent for certain zooplankton community [83-84]. Similarly the negative correlation with other parameters might be factors like less tolerance to pH changes [85] and nitrite, nitrate and IP, same negative correlation was also observed in PCA. Naves et al., [86] reported that turbid water reduces the zooplankton population density and diversity; this could also one of the reasons for the negative association of families with TSS in CCA. CCA analysis revealed that environmental parameters contribute significantly in the distribution and abundance of zooplankton community.

Sites scores in CCA analysis revealed that the months of premonsoon and summer had higher association with DO, chlorophyll a, and temperature, mostly contributed by families that belonged to the groups of Calanoida, Cyclopoida and Harpacticoida (Calanidae, Pontellidae, Ectisomatidae, Temoridae, Miracidae, Pseudodiaptomidae) which found to be most dominant groups during the investigation period.This clearly evidencesthe distribution pattern of zooplankton and population density is highly influenced by temperature, DO and Chlorophyll a. Sautor and Castel, [87] also reported that DO can positively influence the production and abundance of zooplankton species. It has been reported that salinity and temperature majorly affect the abundance and distribution of zooplankton species [88-92]. Further, it is clearly evidenced from PCA that the most significant environmental variables are found as temperature, salinity, DO and Ammonia and influences the growth and density of zooplankton community.

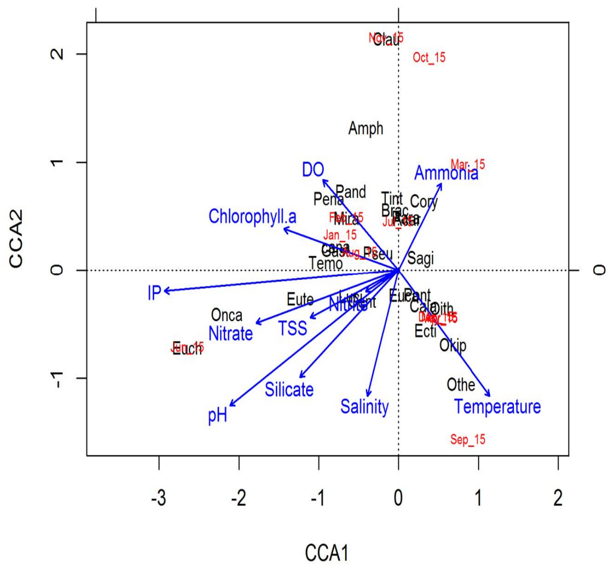

Figure7.Canonical correspondence analysis of zooplankton and environmental variables.

IV. CONCLUSION

The present investigation summarizes the seasonal variation in zooplankton population, species composition and how their distribution is influenced by environmental parameters. Present study identified major taxa as *Acaratia danae*, *Acartia southwelli*, *Nanocalanus minor*, *Canthocalanus pauper*, *Calanopia eliptica*, *Calanopia minor*,*Centropages furcatus*, *Centropages species*, *Oithona* *brevicornis, Oithona nana*, *Oithona similis*, *Acrocalanus gibber*, *Acro-calanus longicornis*, *Euterpina acutifrons*, *Eucalanus crassus*, *Sagitta enflata*, *Pontella dana*, *Lucifer hanseni* and *Temora turbinata* belonging to family Acartidae,Calanidae, Centropagidae, Oithonidae, Paracalanidae,Euterpinidae,Eucalanidae,Sagittoidae,Pontellidae,Luciferidae and Temoridae. Most of the species belongs to major order groups of Calanoida, Cyclopoida and Harpacticoida and the results well agreed with earlier investigations []13,93]). Similarly, statistical analyzes (Species diversity, richness, evenness) also revealed the same pattern in distribution and abundance of zooplankton community during premonsoon and summer seasons. From CCA and PCA,it is evident that the most important parameters that influences the zooplankton species is temperature, salinity, DO and Ammonia, and the study implies that seasonal variation in physical and chemical concentration can change the community composition and abundance of zooplankton significantly.

Data Availability Statement

The data that support the findings of this study are available from [third party name] but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Indian national centre for ocean information services.

V. ACKNOWLEDGEMENT

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