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Population composition of calanoid copepods of the Chennai coast, Tamil Nadu

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The study aims to determine the population composition of calanoid copepods from Ennore, Marina and Kovalam stations of the Chennai coast during the period of October 2018 to September 2019. Zooplankton samples were collected from 3 stations monthly. Temperature, pH, dissolved oxygen and salinity of water samples were measured. In the present study, 24 calanoid copepod species were recorded from 3 stations. Index of dominance of calanoid copepod was high in the month of October 2018 at Ennore and Kovalam stations and in the month of November 2018 was high at Marina, however, index of diversity and evenness of calanoid copepod was high in the month of March 2019 at all the stations. *Labidocera aestiva* showed high average density (68.99±11.11 nos/m^3), followed by *Subeucalanus crassus* (34.40±6.75 nos/m^3). Principal Component Analysis (PCA) of calanoid copepods between the species showed postive as well as negative correlations at the three sampling stations. The calanoid copepods were high (1253.80±11.66 nos/m^3, 1221.20±13.49 nos/m^3 and 938.90±9.45 nos/m^3) in the month of March 2019 at Marina, Kovalam and Ennore stations, respectively. Calanoid copepods densities were statistically analyzed whereas, PCA highlighted about relationship among the species.

[**Keywords**: Calanoid copepods, Chennai coast, Diversity, Ecological indices]

Introduction

Copepods play a vital role in marine food chain and biogeochemical cycle[1]. Physico-chemical parameters of water significantly contribute to zooplankton dynamics[2]. Copepod succession is mainly regulated by temperature, pH and salinity conditions[3]. Yahia *et al*[4] stated that copepods dominated the other groups of mesozoo-plankton. Tseng *et al.*[5] studied the copepod communities related to water masses with reference to spatial distribution. Few authors have reported diversity and distribution of cyclopoid copepods of Chennai coast[6,7], southeast coast[8-10], Gulf of Mannar[11,] backwater of Muttukadu[12] and Adyar[13].

Copepods are a major zooplankton population in the ocean. The changes of environmental parameters, particularly pollution can affect the zooplankton dynamics[14]. The diversity of marine copepods is determined by temperature, pH, salinity, light, and food availability[15]. The anthropogenic activities have implied the diversity of zooplankton[16]. The east coast is the second longest coast line of India. The Ennore, Marina and Kovalam are three different sampling stations, which show differences in the environment based on anthropogenic activity. The present study emphasizes the variation in distribution and population dynamics of calanoid copepods with the influence of physico-chemical parameters.

Materials and Methods

Study area

The samples were collected from Ennore (13°12'23.4864" N, 80°19'38.0100" E), Marina (13°03'00" N, 80°16'56.64" E) and Kovalam (12°47'13.2" N, 80°15'1.44" E) stations, Southeast coast, India. Ennore station is situated near to thermal power plant. Marina station has higher anthropogenic and fishing activity. Kovalam station also shows fishing activity. The coastal line has sandy beaches throughout (Fig. 1).

Sample collection and preservation

Zooplankton samples were collected offshore (about 5 nautical miles) using a motor driven Dingy boat. The collection was carried out by towing a Bongo net (0.5 m diameter mouth, 2.5 m mesh cloth, made of bolting silk 50 µm mesh size, which is fixed with 25 cm bottom–cup) for nearly 15 minutes travel in the fiber boat for each sample during early hours of the day. The samples were fixed using 5 % buffered formalin. The monthly samples were collected from October 2018 to September 2019.

Identification of calanoid copepods

The calanoid copepods from the fixed zooplankton samples were separated under binocular stereo-microscope. For taxonomic studies animals were

dissected under stereozoom dissection microscope and mounted with lactophenol[17] and species were identified using taxonomic descriptions of standard identification keys[18-20].

Quantitative analysis

Enumeration of calanoid copepod species were done with Sedgewick-Rafter counting cell. The zooplankton samples were thoroughly mixed and 1 ml sample (20 drops) was drawn using a wide mouth pipette and transferred to the counting chamber. They were counted under a compound microscope and species were recorded. Enumeration was carried out in three sub-samples and mean was calculated. The number of zooplankton per cubic meter was calculated using the following formula[21].

$$\text{Number of plankton per cubic meter} = \frac{Average\ Number\ per\ drops\ x\ Total\ drops\ in\ the\ entire\ sample}{Volume}$$

Average number of *each species* per drop sample was calculated as:

$$\frac{Number\ Observed}{Number\ of\ Drops\ Analyzed}$$

Where, Volume = $\pi r^2 L$; Length (L) is calculated by the following formula = Speed × Time.

Statistical analysis

The data was statistically analyzed using SPSS 21.0 ver. The density of calanoid copepods between the stations and species were performed by one way Analysis of Variance (ANOVA). Ecological indices and Principle Component Analysis (PCA) of calanoid copepods and correlation coefficient of physico-chemical parameters were carried out using Paleontological statistics (PAST-3.21) software.

Results and Discussion

Physico-chemical parameters

Physico-chemical parameters of water samples were analysed from Ennore, Marina and Kovalam stations. Water temperature, salinity, pH and DO ranged between 26 – 31.4 ℃, 24.78 – 34.3 ppt, 7.8 – 8 and 2.69 – 6.62 mg/l, respectively (Table 1). Correlation

Fig. 1 — Sampling stations, Chennai coast, Tamil Nadu

Table 1 — Physico-chemical parameters of sea water sample of Ennore, Marina and Kovalam stations

Stations	Parameters	Oct '18	Nov '18	Dec '18	Jan "19	Feb '19	Mar '19	Apr '19	May '19	Jun '19	Jul '19	Aug '19	Sep "19
Ennore	Air temperature (°C)	35.8	31.8	29.4	28.8	31.8	30.2	30	31.6	27.8	31	32	32.2
	Surface water temperature (°C)	31	31.4	27.4	26.6	28.2	30	29.4	28	27.8	28	30	31
	Salinity (ppt)	31.49	31.6	24.78	25.86	33.4	34.3	32.14	33.4	34.3	33.2	34.8	33.5
	pH	8	7.8	8	8	8	8	7.8	7.8	8	8	7.8	8.2
	DO (mg/l)	2.89	5.6	3.1	5.12	5.41	4.85	5.8	5.88	6.21	5.8	5.6	6.1
Marina	Air temperature (°C)	28.3	31.2	30	29.7	30	28	26.5	26	29	31	32	32.2
	Surface water temperature (°C)	29	31	28	26	29	29.8	27	27.4	26.2	27	29	29.2
	Salinity (ppt)	34.29	29.09	30.53	32.14	33.22	33.94	33.86	31.48	33.22	37.88	35.91	34.49
	pH	8	7.8	8	8	8	8	7.9	7.8	7.8	8	8	8.2
	DO (mg/l)	2.72	2.94	3.1	6.62	6.12	6.21	5.32	5.62	5.41	6.83	4.34	3.1
Kovalam	Air temperature (°C)	27.8	32	30.2	29.8	32.6	20.5	21.4	27.8	29.8	30.2	32.5	35.6
	Surface water temperature (°C)	30	31	28.2	26.5	28.4	29.8	27	27.4	26.2	26.2	30.5	29.2
	Salinity (ppt)	34.29	29.09	30.53	32.14	33.22	33.94	33.86	31.48	33.22	34.47	35.01	36.26
	pH	8	7.8	8	8	8	8	7.9	7.8	7.8	7.8	8	7.8
	DO (mg/l)	2.69	3.1	3.1	6.62	6.12	6.21	5.32	5.62	5.41	5.17	5.79	3.72

co-efficient of physico-chemical parameters of seawater between pH and other parameters was negatively correlated at Ennore station (Fig. 2a). In Marina station, salinity with other parameters showed moderate positive correlation (Fig. 2b). However, pH v/s water temperature, salinity, and DO showed positive correlation at Kovalam station (Fig. 2c). Regression analysis of physico-chemical parameters negatively correlated to density of calanoid copepods in all the 3 stations, but with no significant difference at $P < 0.05$ (Table 2). Santhanam *et al*.[22] have stated that water temperature was positively correlated with density of zooplankton in the estuarine samples. In the present study, calanoid copepods highly depended on the physico-chemical parameters that influence the population.

Qualitative and quantitative analysis of calanoid copepods

Qualitatively zooplankton samples of Ennore, Marina and Kovalam stations showed 16, 21 and 22 copepods species, respectively, during the study period (Table 3). In the present study, 24 species were recorded from 3 sampling stations. Rajthilak *et al*.[9] have reported 23 species from 5 stations of Tamil Nadu coast. However, Shanthi & Ramanibai[13] have reported 31 calanoid copepod species from Coovum and Adyar stations.

The average density of *Labidocera aestiva* was high (68.99±11.11 nos/m^3) at Marina station. *Subeucalanus crassus* recorded high density (40.69±5.40 nos/m^3 and 34.40±6.75 nos/m^3) at Kovalam and Ennore stations, respectively. *Acartia* species was absent in Ennore station (Table 3). Thirunavukarasu *et al*.[23] has reported that high genotoxicity to zooplankton at Ennore and Kalpakkam coastal region. This is might be reason for low density at Ennore stations.

ANOVA for density of calanoid copepods species between Ennore, Marina and Kovalam stations showed that *A. tonsa*, *Acartella sewelli*, *Acartia southwelli*, *Canadacia pachydactyla*, *Centropages furcatus*, *S. crassus*, *Eucalanus elongates*, *Subeucalanus monachus*, *Subeucalanus subcrassus*, *Euchaeta marina*, *L. aestiva*, *Metacalanus aurivilli*, *Pseudodiaptomus aurivilli*, and *Temora discaudata* were siginficantly different ($P < 0.05$) in density. Duncan Multiple Range Test (DMRT) showed significant difference ($P < 0.05$) between *E. elongatus*, *L. aestiva*, and *M. aurivilli* of

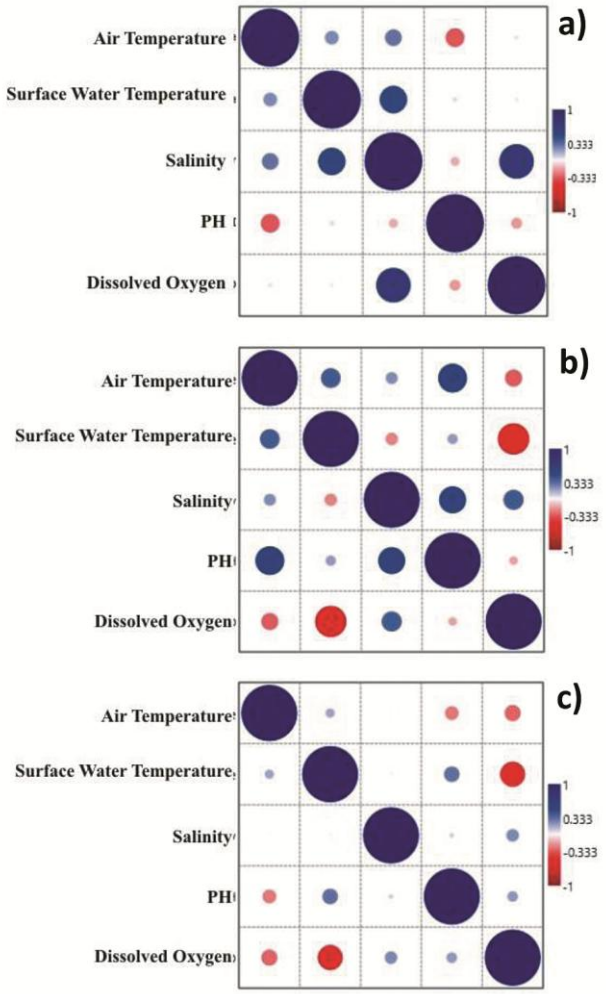

Fig. 2 — Correlation coefficient of physico-chemical parameters of sea water: a) Ennore station; b) Marina station; and c) Kovalam station

Table 2 — Regression analysis between physico-chemical parameters and calanoid copepods

Parameters	Calanoid Copepods (Ennore)	Calanoid Copepods (Marina)	Calanoid Copepods (Kovalam)
Air temperature (°C)	-0.331	-0.198	-0.082
Surface water temperature (°C)	0.108	0.516	0.167
Salinity (ppt)	-0.055	-0.672	0.009
pH	-0.022	0.851	0.547
DO (mg/l)	0.341	0.672	0.206
Significance value	0.800^{NS}	0.101^{NS}	0.476^{NS}

NS – Non-significant value ($P > 0.05$)

Table 3 — Mean Density of calanoid copepods from Ennore, Marina and Kovalam (October 2018 – September 2019)

Calanoid copepod species	Ennore (Nos./m^3)	Marina (Nos./m^3)	Kovalam (Nos./m^3)
Acartia tonsa	-	$37.51\pm6.84^{a,4,5,6}$	$32.33\pm3.19^{a,1,2,3}$
Acartella sewelli	-	-	$29.27\pm4.72^{a,1,2,3}$
Acartia southwelli	-	$29.83\pm4.38^{a,2,3,4}$	-
Acrocalanus gibber	$24.27\pm4.76^{a,b,1}$	$17.56\pm3.23^{a,1,2}$	$30.80\pm4.05^{b,1,2,3}$
Acrocalanus gracilis	$27.33\pm6.25^{a,1}$	$36.65\pm5.41^{a,3,4,5,6}$	$28.02\pm3.66^{a,1,2,3}$
Calanopia elliptica	$22.73\pm4.05^{a,1}$	$37.91\pm6.30^{b,4,5,6}$	$33.87\pm3.72^{a,b,2,3}$
Calanus calaninus	$21.48\pm5.92^{a,1}$	$16.31\pm5.29^{a,1,2}$	$32.33\pm6.26^{a,1,2,3}$
Canadacia pachydactyla	-	-	$26.20\pm4.72^{a,1,2,3}$
Centropages dorsispinatus	$31.37\pm6.10^{a,1}$	$27.45\pm5.46^{a,1,2,3,4}$	$33.87\pm4.91^{a,2,3}$
Centropages furcatus	-	$35.41\pm4.12^{a,3,4,5,6}$	$36.94\pm6.21^{a,2,3}$
Subeucalanus crassus	$34.40\pm6.75^{a,b,1}$	$19.09\pm4.83^{a,1,2,3}$	$40.69\pm5.40^{b,3}$
Eucalanus elongates	$30.12\pm6.65^{a,1}$	$11.99\pm5.21^{b,1}$	$36.65\pm5.72^{a,2,3}$
Subeucalanus monachus	-	-	$24.95\pm8.01^{a,1,2,3}$
Subeucalanus subcrassus	$28.58\pm7.75^{a,1}$	$52.99\pm7.04^{b,6,7}$	$27.73\pm6.01^{a,1,2,3}$
Euchaeta marina	-	$49.90\pm7.40^{a,5,6,7}$	-
Labidocera aestiva	$27.05\pm4.92^{a,1}$	$68.99\pm11.11^{b,8}$	$17.28\pm5.42^{a,1}$
Metacalanus aurivilli	$23.98\pm4.80^{a,1}$	$55.18\pm5.80^{b,7,8}$	$26.20\pm4.14^{a,1,2,3}$
Paracalanus aculeatus	$28.59\pm6.69^{a,1}$	$39.15\pm48.99^{a,4,5,6,7}$	$23.70\pm3.38^{a,1,2}$
Pontella danae	$26.09\pm8.32^{a,1}$	$39.72\pm5.34^{a,4,5,6,7}$	$31.09\pm4.17^{a,1,2,3}$
Pseudodiaptomus annandalei	$24.94\pm5.76^{a,1}$	$33.87\pm4.35^{a,2,3,4,5}$	$31.37\pm5.36^{a,1,2,3}$
Pseudodiaptomus aurivilli	$19.09\pm5.33^{a,1}$	$36.65\pm5.25^{b,3,4,5,6}$	$31.09\pm4.20^{a,b,1,2,3}$
Pseudodiaptomus serricaudatus	$28.59\pm4.92^{a,1}$	$26.48\pm2.85^{a,1,2,3,4}$	$32.33\pm3.92^{a,1,2,3}$
Temora discaudata	-	$24.66\pm4.66^{a,1,2,3,4}$	$24.95\pm4.22^{a,1,2,3}$
Temora stylifera	$26.76\pm4.43^{a,1}$	$30.80\pm6.36^{a,2,3,4}$	$27.73\pm2.66^{a,1,2,3}$

The values are represented as Mean±SEM; Anova followed by DMRT's performed; different (alphabet) superscripts in same rows shows significantly different ($P < 0.05$); different (number) superscripts in same column shows significantly different ($P < 0.05$); - Not Present

Marina station compared to Kovalam and Ennore stations and *A. gibber* and *S. subcrassus* of Marina station compared to Kovalam stations while at Ennore no significant differences ($P > 0.05$) was found in the density. However, for Ennore station, between the species there was no significant different at $P > 0.05$ level (Table 3).

Density of calanoid copepods were recorded in the order of Marina (8958.43±80.05 nos/m^3) > Kovalam (8160.45±77.92 nos/m^3) > Ennore (5350.84±75.90 nos/m^3) stations (Fig. 3). The density of calanoid copepods showed gradual increase in the population from October '18 to March '19 and subsequently decrease in their density. The density was high in the month of March '2019 at Marina (1253.80±11.66 nos/m^3), Kovalam (1221.20±13.49 nos/m^3) and Ennore (938.90±9.45 nos/m^3) stations. However, low density was recorded in the month of May '2019 at Marina (350.83±10.37 nos/m^3) and Kovalam (367.93±10.57 nos/m^3) and in the month of July '2019 at Ennore (132.87±11.35 nos/m^3) (Fig. 4). The high density of zooplankton was recorded during summer and

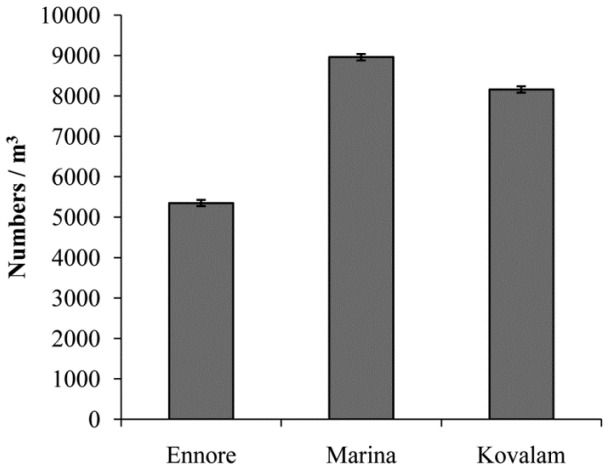

Fig. 3 — Density of Calanoid Copepods (Nos/m^3) from Ennore, Marina and Kovalam stations of Chennai coast (October 2018 – September 2019) (Mean ± SEM)

low during monsoon season[9,24,25] in other studies. The present study too showed similar trend with reference to calanoid copepods. DMRT's of density of calanoid copeods in the month of January'19, March'19, May'19, June'19 and July'19 showed no significant

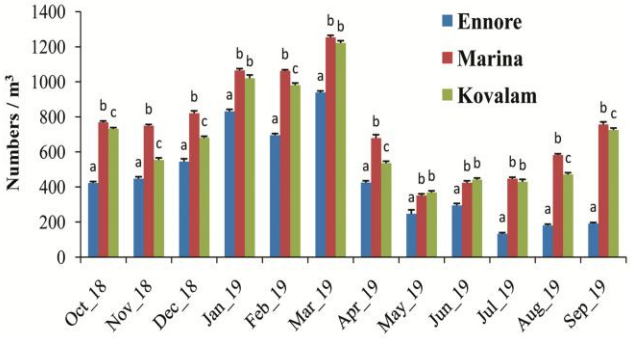

Fig. 4 — Monthly wise population of calanoid copepods of Ennore, Marina and Kovalam stations (October 2018 – September 2019) (Mean ± SEM). The values are represented as Mean±SEM; Anova followed by DMRT's performed; Different alphabet on the column shows significantly different ($P < 0.05$) between the station

variations ($P > 0.05$) in populations between Marina and Kovalam stations (Fig. 4).

Ecological indices *viz*. index of dominace, diversity and evenness were calculated. In Ennore stations, index of diversity of calanoid copepd was high (2.736) in the month of January'19 (Fig. 5a). The calanoid copepod species diversiy and evenness were high in the month of March'19 at Marina (2.967 and 0.9715) (Fig. 5b) and Kovalam (3.062 and 0.9715) (Fig. 5c) stations, while index of dominance was low. Index of evenness is directly propotional to diversity values.

Principal Component Analysis (PCA) of calanoid copepods between *A. gracilis*, *S. subcrassus*, *E. elongata*, *S. crassus*, *P. aculeatus* and *P. danae* was positively correlated at Ennore station (Fig. 6a).

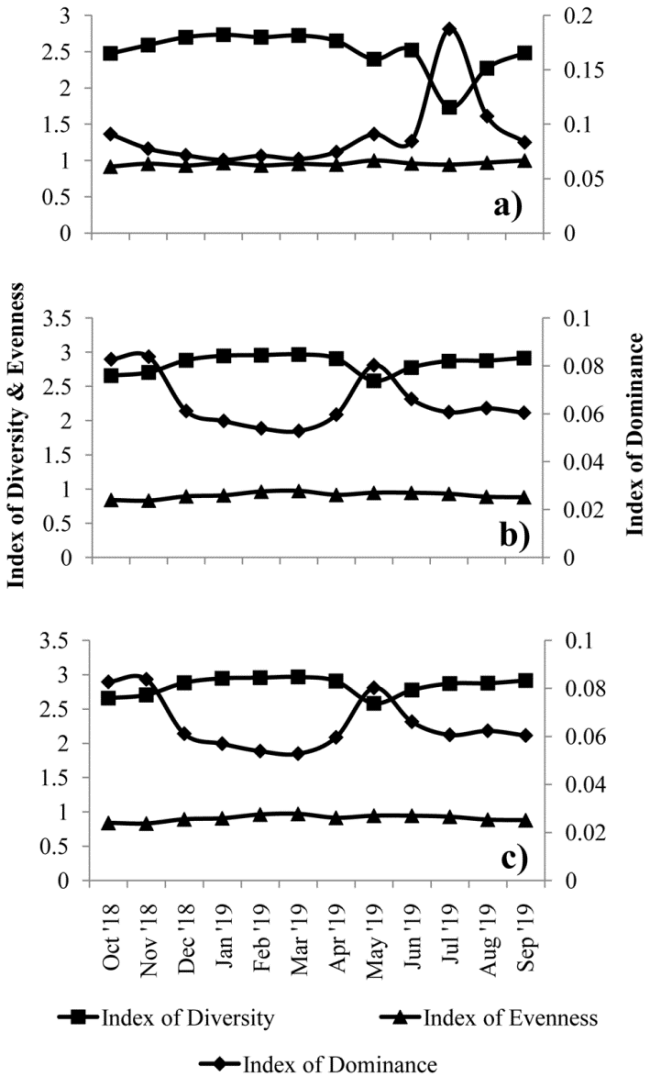

Fig. 5 — Ecological indices of calanoid copepods (October 2018 – September 2019): a) Ennore station; b) Marina station; and c) Kovalam station

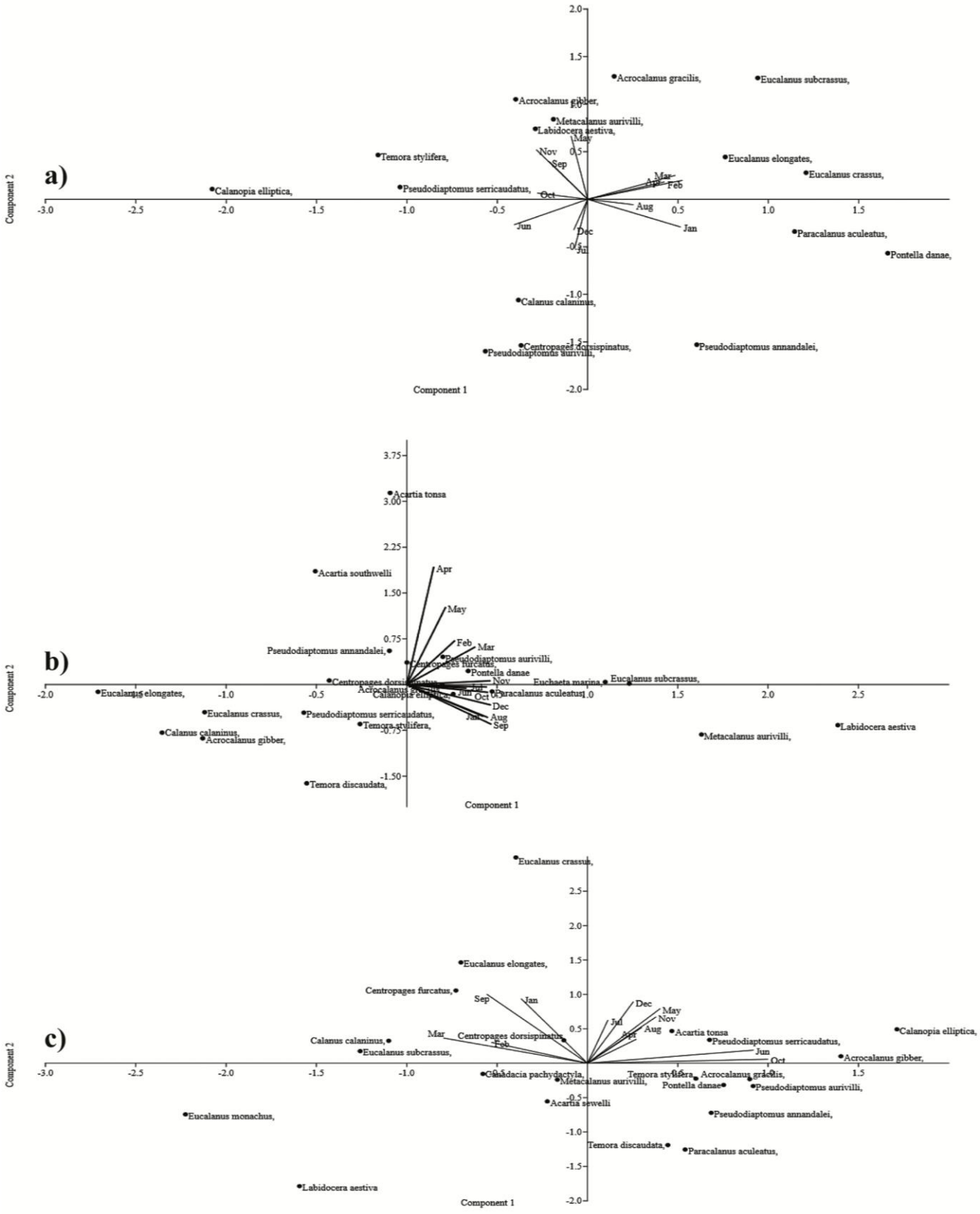

Fig. 6 — Principal component analysis of calanoid copepods (October 2018 – September 2019): a) Ennore station; b) Marina station; and c) Kovalam station

P. aurivilli, C. furcata, P. danae, E. marina, S. subrcrassus, P. aculeatus, M. aurivilli, L. aestiva, C. eliptica, and *A. gracilis* were postively correlated between the species at Marina stations (Fig. 6b). At Kovalam, *P. aculeatus, T. discaudata, P. annandalei, P. aurivilli, Pontella danae, Temora stylifera, Acrocalanus gracilis, Acrocalanus gibber, Calanopia elliptica, Pseudodiaptomus serricaudatus* and *Acartia tona* species were positively correlated between the species (Fig. 6c), while other species were negatively correlated.

Conclusion

In the present study, calanoid copepod population showed variations between the monthly sampling. The changes of calanoid copepod densities are due to the influence of physico-chemical parameters. Among the 3 sampling stations, Marina and Kovalam showed no significant variations in densities of calanoid copepods, however, Ennore was significantly diferent with less numbers. The reason of decline appears to be environmental factors which influence the water quality as well as density of primary producer in the food chain. Therefore, long-term study is required to monitor the nurients, chlorophyll and physico-chemical parameters to assess and correlate with density and diversity of marine calanoid copepods.

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Conflict of Interest

The authors declare that no conflict of interests in financial or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

KSK designed and drafted the research work and also interpretation of the data statistically. KSK & MAN performed zooplankton sample collection and analyzed the samples**.** KSK & AS carried out identification of species and drafted the manuscript.

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