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Seasonal Variations in Copepods Diversity Along the Vettar Coastal Waters, South Eastern India

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Abstract The present study was carried out to assess the physico-chemical characteristics and marine copepods diversity from the Vettar estuary and adjacent coastal waters for the period of 1 year between January 2016 and December 2016. The water samples were collected in the early morning at 3 fixed stations and analyzed to estimate the physico-chemical properties. The copepod samples were identified using standard identification manuals. During the study period, a total of 27 species of marine copepods were recorded. The results of the ecological survey showed that Vettar estuary treasures an abundant diversity of copepod that play a key role in maintaining the ecological interlinks in the estuarine and the adjacent neritic waters of Bay of Bengal, where it joins. Our study favors a continuous monitoring and further assessment of zooplankton which is needed to explore more about the ecological enigma in Nagore coastal water, Southeast coast of India.

Keywords Vettar estuary, Physico-chemical properties, Copepod diversity.

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Introduction

The estuaries are classified as the most productive, economically important, and hydrologically variable ecosystems on Earth (Hobbie 2000). They also act as a transitional zone between sea and land (Bardarudeen et al. 1996). The nutrient input from terrestrial landscape by runoff and other anthropogenic activities improvises the productive nature and resource fulness of any estuary. Coastal waters frequently receive a vast amount of urban sewage inputs due to the high density of human population in the adjacent coastal areas which often leads to the state of nutrient-over-enrichment, causing harmful algal blooms. Most of the life in the world depends directly or indirectly on coastal waters and therefore the hydrological study is significantly crucial to comprehend the relationship among its diverse tropic levels and food webs.

The major environmental parameter such as salinity, oxygen, temperature, pH and nutrients which characterizes particular water mass also determines the composition of its flora and fauna (Karande 1991). In general, the near shore waters and estuaries exhibit considerable seasonal variations depending on the local conditions of rainfall, tidal incursions, various abiotic and biotic processes, quantum of fresh water inflow affecting the nutrient cycle of different coastal environments (Choudhury and Panigrahy 1991).

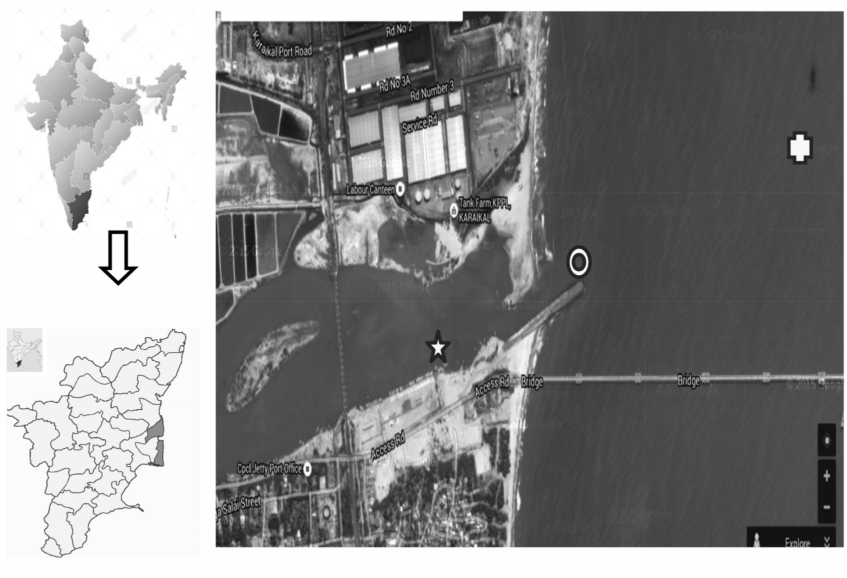
It is undeniable that copepods play a key role in transferring energy from one tropic level to other in the aquatic habitat (Ketchum 1962). Besides, they are also used as biological indicators of tropic status of waterbody. Their flucations in occurrence and abundance can be used to estimate the fishery potential of a water body (Hutchinson 1967). The knowledge of their abundance, species diversity and special distribution is important in understanding trophodynamic and trophic progression of water bodies. Hence the present study was attempted to investigate the physico-chemical properties and abundance of copepods in the Vettar estuary, Nagore, India (Govindasamy et al. (2000).

Study area

The Vettar is a river flowing in the districts of Tiruvarur, Thanjavur and Nagapattinam of the Indian state of Tamil Nadu, Vettar river is a tributary of the river Kaveri (Fig. 1). This river reaches the sea near the Karaikal port in Nagore. The Vettar estuary has a year-round connection with the sea. The width of the estuary mouth is about 80 m. For the present study, 3 sampling Stations were chosen. The Station 1 was fixed in the open sea and Station 2 at the sea mouth and Station 3 in the estuary.

Materials and Methods

Samplings were conducted every month to record the physico-chemical and copepod characteristics (Balasubramanian and Kannan 2005, Paramasivam and Kannan 2005). Rainfall data was obtained from the meteorological unit located at Nagapattinam.



Station-1 (Open Sea) Station-2 (Sea mouth) Station-3 (Vettar Estuary)

Fig. 1. Study area.

Parameters like atmospheric and surface water temperature, salinity, dissolved oxygen and pH were measured in the morning. Atmospheric and surface water temperatures were measured using standard mercury filled centigrade thermometer. Salinity was estimated with the help of a hand Refractometer and pH was measured using ELICO pH meter. Dissolved oxygen was estimated by using modified Winkler's method (Strickland and Parsons 1972). For the nutrients analysis, surface water samples were collected in clean polyethylene bottles and kept in an ice box and transported immediately to the laboratory.The water samples were filtered using a Millipore filtering system (MFS) and analyzed for dissolved inorganic phosphate, nitrate, nitrite, reactive silicate and ammonia by adopting the standard methods described by Strickland and Parsons (1972).

Copepod samples were collected from surface water by using the Indian Ocean Standard plankton net with a mouth diameter of 0.35 m and mesh size of 158µ. Monthly samples were collected by horizontal to wing of plankton net for 30 min. The collected samples were preserved using 5% neutralized formalin for identification. Copepods were identified using the standard works of Kasturirangan (1963) and Perumal et al. (1998). quantitative analysis of zooplankton were carried out by filtering 500 1 of water through a bag net of same mesh size and the numerical plankton analysis was carried out using a inverted microscope. Biodiversity indices were calculated following the standard formulae : Biodiversity: H' = -S Pi log Pi; 1=1; richness : D = 1-C; C = SPi2; Pi = ni/N and evenness: J' = H'/log2S (Shannon and Weaner 1949, Gleason 1922, Pielou 1966).

Table 1. List of copepod species recorded in Vettar estuary, Southeast coast of India.

Sl. No.	Name of the species	Station 1	Station 2	Station 3
	Calanoida			
1	*Nannocalanus minor*	+	+	-
2	*Paracalanus parvus*	+	+	-
3	*Acrocalanus gibber*	+	+	-
4	*Labidocera minuta*	+	+	-
5	*Labidocera pavo*	+	+	-
6	*Calanopia elliptica*	+	+	+
7	*Acartia spinicauda*	+	+	+
8	*Acartia tonsa*	+	+	-
9	*Acartia clausi*	+	+	-
10	*Pseudodiaptomus annandalei*	+	+	+
11	*Pseudodiaptomus serricaudatus*	+	+	+
12	*Pseudodiaptomus aurivilli*	+	+	+
13	*Pontella danae*	+	+	-
14	*Centropages furcatus*	+	+	-
15	*Candacia braydi*	+	+	-
16	Nauplii of *Rhincalanus*	+	+	-
	Harpacticoida			
17	*Microsetella norvegica*	+	+	-
18	*Macrosetella gracillis*	+	+	-
19	*Nitokra affinis*	+	+	-
20	*Euterpina acutifrons*	+	+	-
21	*Metis jousseaumei*	+	+	-
22	*Longipedia weberi*	+	+	-
	Cyclopoida			
23	*Dioithona rigida*	+	+	+
24	*Oithona brevicornis*	+	+	-
25	*Oithona nana*	+	+	-
26	*Oncaea minor*	+	+	-
27	*Oncaea venusta*	+	+	-

Results and Discussion

A total of 795.5 mm of rainfall was recorded during the period of January 2016 to December 2016. It ranged from 1.01 mm to 124.18 mm, where the lowest rainfall was recorded during April 16 and the highest in October 16. Rainfall plays and important role in the hydrographical changes in any estuarine environment (Montagna et al. 2018). The Southeast coast in India is largely influenced by the Northeast monsoon rainfall (Perumal 1993, Ashok Prabu et al. 2005, Godhantaraman 2001, Krishnamoorthy and Subramanian 1999).

During the study period the atmospheric temperature values (^{0}C) ranged from 27 to 31 in Station 1,26 to 30 in Station 2 and 26 to 29 in Station 3 (Table 1), (Fig. 2a-e). The atmospheric temperature seemed increasing during the summer and gradually decreased during the monsoon period. The increase in the temperature was influenced by the high solar radiation and evaporation. The maximum atmospheric temperature was recorded in June 16 (31^{0}C) and minimum in November 16 (27^{0}C) at Station 1. In Station 2 the maximum atmospheric temperature was recorded in June 16 (30^{0}C) and minimum in Novem-

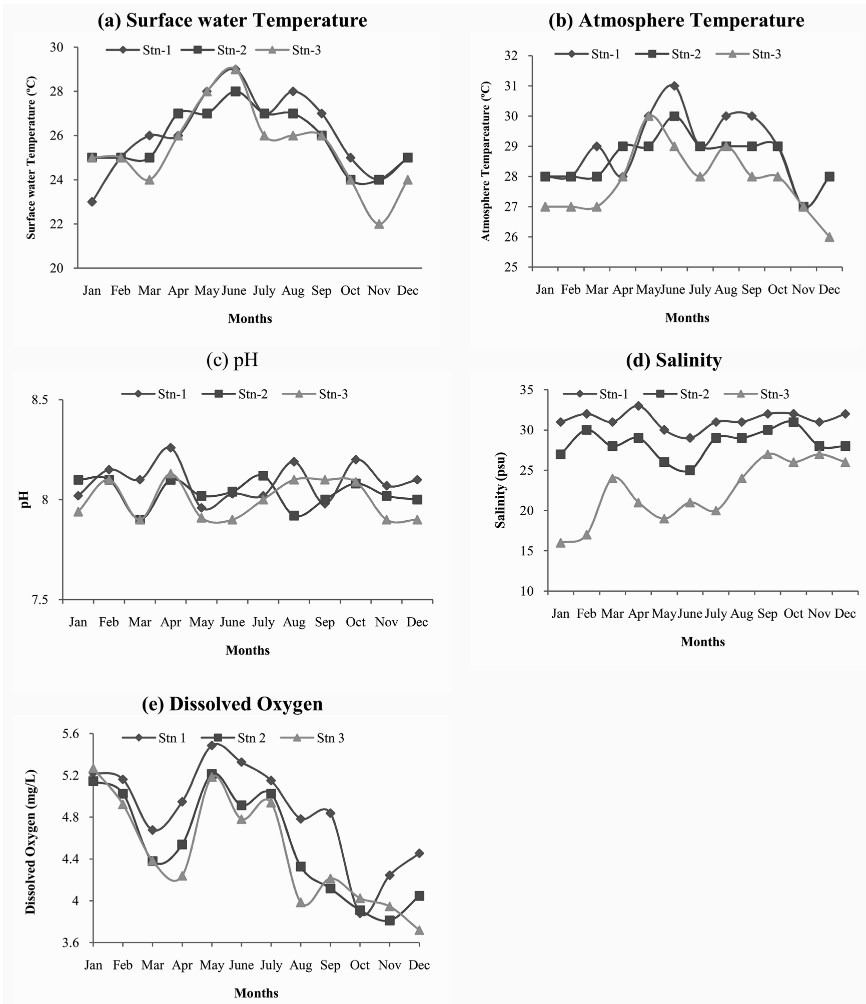


Fig. 2a-e. Physico-chemical properties of Nagore coastal waters.

ber 16 (27^0C), In Station 3 the maximum atmospheric temperature was recorded in May 16 (30^0C) and minimum in December 16 (26^0C). The surface water temperature (^{0}C) was measured at a range between 24 and 29 at Station 1, 24 to 28 at Station 2 and 22 to 29 at Station 3. The maximum surface water temperature was noticed in June 16 (29^0C) and minimum in January 16 (23^0C) in Station 1. In Station 2, the maximum surface water temperature was recorded in June 16 (28^0C) and minimum in October 16 and November 16 (24^0C). In Station 3, the maximum surface water temperature was recorded in June 16 (29^0C) and minimum in November 16 (22^0C).

In this study a wide range of salinity was recorded between the 3 Stations during the study period (Table 1). A maximum of 33 psu was observed in Station 1 during April and the minimum value of 16 psu was noticed during January in Station 3. The salinity plays a major role in the distribution of living organisms in the marine environment and the salinity difference influenced by dilution and evaporation in most likely to impact the fauna in the coastal ecosystem (Santhanam et al. 2019). Generally, the differences in the salinity in estuaries and open sea are due to the influx of freshwater from land run off, caused by monsoon or by tidal variations.

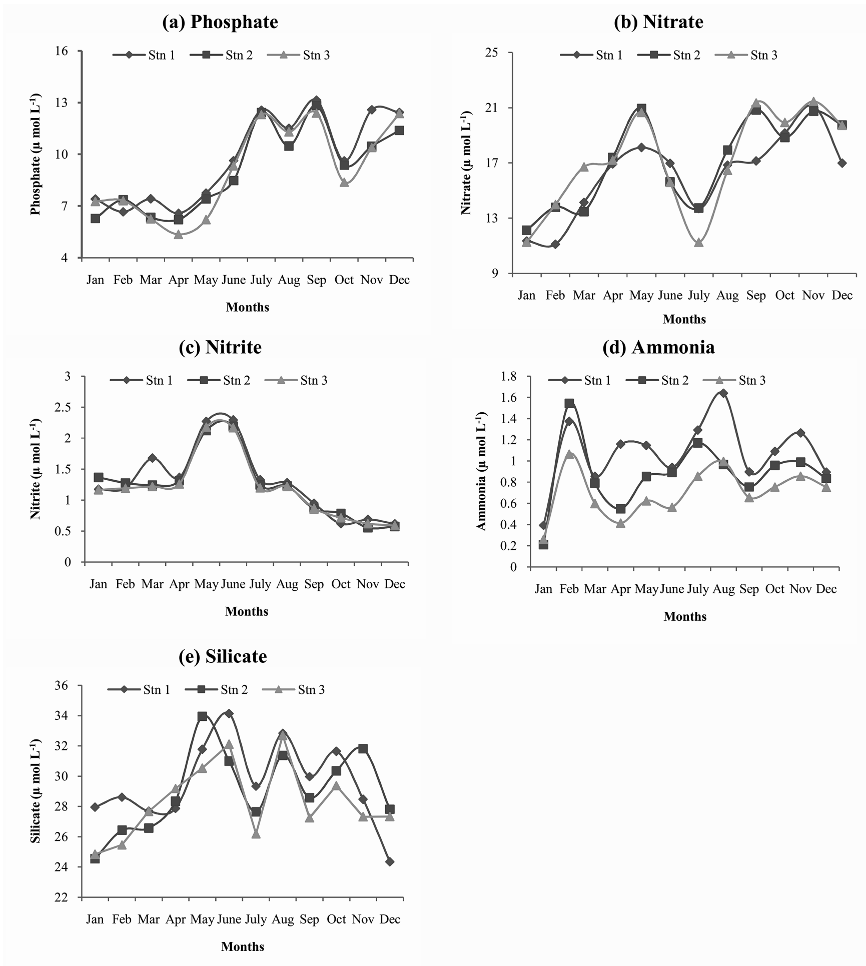


Fig. 3a-e. Inorganic nutrients characteristics of Nagore coastal waters.

In all the 3 Stations, the hydrogen ion concentration (pH) remained alkaline all through the year. The highest value was noticed in April 16 at Station 1 (8.26) and the lowest in March 16 (7.8) at Station 3. The seasonal variation in the hydrogen ion concentration depends on the factors like removal of carbon dioxide by photosynthesis through bicarbonate degradation, dilution of seawater by freshwater influx, decrease in primary productivity, decrease in salinity and temperature, and organic matter decomposition (Bragadeeswaran et al. 2007, Jayasingam et al. 2015). The dissolved oxygen concentration was varied from 3.81 to 5.48 mg/l. The oxygen concentration was low during November 16 at Station 3 and high during May 16 at Station 1. Saravanakumar et al. (2008) have stated that oxygen solubility varies inversely with salinity and water temperature. Dissolved oxygen consumption and production are mostly influenced by algal biomass, light intensity and water temperature.

The recorded inorganic nitrate concentration was varied from 11.1 to 21.45 µmol/l. The minimum nitrate was noticeded during February 2016 at Station 1 whereas the maximum during November 2016 at Station 3 (Fig. 3a-e). The recorded nitrite content was ranged from 0.55 to 2.29 µmol/l. The minimum

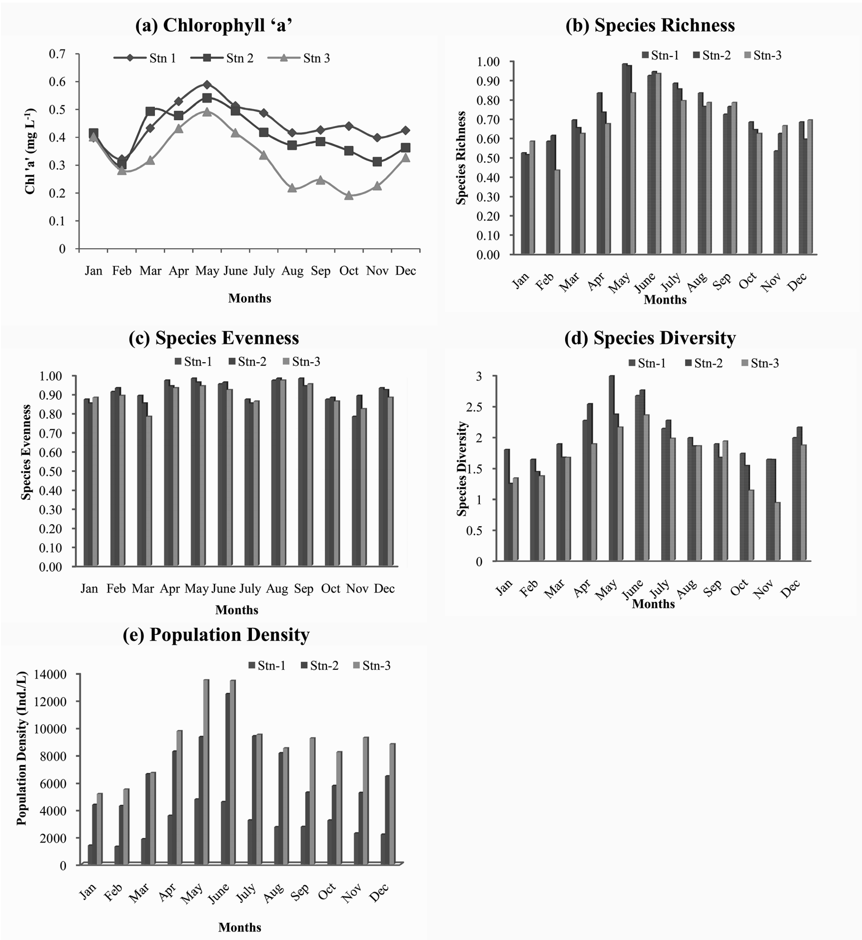


Fig. 4a-e. Biological characteristics of Nagore coastal waters.

nitrite recorded in November 2016 at Station 2 and the maximum during June 2016 at Station 1. Nitrite, the intermediate oxidation state between ammonia and nitrate, can emerge as a transient species by the oxidation of ammonia or by the reduction of nitrate (Sathpathy et al. 2010, Dinesh Kumar et al. 2017).

Most of the estuarine waters in general have relatively low values of dissolved inorganic phosphorus and nitrogen. The phosphate content was recorded between 5.35 and 13.14 µmol/l. The minimum value was recorded during April 2016 at Station 3 and maximum value during September 2016 at Station 1. The recorded reactive silicate concentration was varied from 24.54 to 131.64 µmol/l. The low value was recorded during January 2016 at Station 2 whereas the high value recorded during October 2016 at Station 1. The higher concentration during the rainy season could be attributed to the fresh water interference into the coastal waters and similar milieu had been reported in different coastal environments (Burton 1970). The major contribution of ammonia input into the coastal waters could be from land runoff, zooplankton excretion, or demineralization of organic matter (Srinivasan et al. 2013, Sridhar et al. 2006). The ammonia values ranged from 0.03 to 0.32 µmol/l. The maximum values were observed during August 2016 at Station 1 and minimum values during March 2016 at Station 3. The chlorophyll a values ranged from 0.19 to 0.58 mg/m^3. The maximum chlorophyll

Table 2. Correlation matrix among the physico-chemical and biological characteristics of Nagore coastal waters (Station–1). RF-Rainfall, SL-Salinity, AT-Atmospheric Temperature, ST-Surface Temperature, PD-Population Density, SD-Species Diversity, SR-Species Richness, SE-Species Evenness.

	RF	pH	SL	AT	ST	DO	PO_4	NO_2	NO_3	NH_3	SiO_3	Chl-*a*	PD	SD	SR	SE
RF	1															
pH	0.65	1														
SL	0.07	-0.02	1													
AT	0.58	0.65	0.06	1												
ST	0.47	0.72	0.00	0.84	1											
DO	-0.66	-0.23	0.25	-0.33	-0.31	1										
PO_4	0.73	0.52	-0.04	0.32	0.21	-0.27	1									
NO_2	0.62	0.46	0.09	0.30	0.24	-0.49	0.45	1								
NO_3	-0.10	0.10	-0.21	0.42	0.66	-0.21	-0.45	-0.16	1							
NH_3	0.21	0.66	-0.07	0.14	0.27	0.15	0.21	0.27	-0.02	1						
SiO_3	0.45	0.49	-0.05	0.63	0.72	-0.34	0.01	0.26	0.52	0.33	1					
Chl-*a*	0.30	0.44	-0.08	0.49	0.68	-0.62	-0.11	0.37	0.64	-0.01	0.35	1				
PD	0.54	0.60	0.11	0.62	0.81	-0.62	0.05	0.52	0.60	0.20	0.63	0.90	1			
SD	0.23	0.39	-0.05	0.51	0.78	-0.40	-0.18	0.19	0.82	0.02	0.45	0.90	0.86	1		
SR	0.37	0.68	-0.01	0.71	0.91	-0.38	0.02	0.21	0.70	0.32	0.55	0.84	0.88	0.87	1	
SE	0.02	0.45	0.36	0.64	0.67	0.28	-0.16	-0.05	0.46	0.09	0.29	0.44	0.46	0.59	0.65	1

was obtained during May 2016 at Station 1 and minimum during October 2016 at Station 3.

Copepods, being the dominant component of any given zooplankton community, their species diversity is used as an index in all biological monitoring studies to characterize the quality of a certain water body (Gajbhiye et al. 1981). Copepods are known to select preferred habitats and hence their distribution may vary with species as well as seasonal fluctuations (Lalli and Parsons 1997). During the 1 year study, a total of 27 species of copepods were recorded, in which the calanoida being the most dominant order in all the Stations followed by harpacticoida and cyclopoida. Copepods species such as *Labidocera pavo, Labidocera minuta, Candacia braydi, Acartia spinicauda, Pontella danae, Pseudodiaptomus annandalei, Nitrokra affinis, Euterpina acutifrons,*

Table 3. Correlation matrix among the physico-chemical and biological characteristics of Nagore coastal waters (Station–2). RF- Rainfall. SL-Salinity, AT-Atmospheric Temperature, ST-Surface Temperature, PD-Population Density, SD-Species Diversity, SR-Species Richness, SE-Species Evenness.

	RF	pH	SL	AT	ST	DO	PO_4	NO_2	NO_3	NH_3	SiO_3	Chl-*a*	PD	SD	SR	SE
RF	1.00															
pH	-0.16	1.00														
SL	0.48	0.06	1.00													
AT	0.48	-0.39	0.33	1.00												
ST	0.12	-0.35	0.22	0.68	1.00											
DO	-0.56	0.08	0.00	-0.25	0.07	1.00										
PO_4	0.76	-0.34	0.31	0.18	0.02	-0.30	1.00									
NO_2	0.62	0.13	0.38	0.18	-0.06	-0.05	0.45	1.00								
NO_3	-0.10	0.09	0.11	0.43	0.73	-0.08	-0.49	-0.28	1.00							
NH_3	0.22	0.26	0.35	-0.37	-0.04	0.14	0.31	0.03	-0.07	1.00						
SiO_3	0.62	0.17	0.33	0.39	0.29	-0.16	0.21	0.73	0.25	0.20	1.00					
Chl-*a*	-0.22	-0.05	-0.04	0.59	0.63	-0.03	-0.50	-0.09	0.67	-0.48	0.14	1.00				
PD	0.29	-0.24	0.39	0.74	0.85	-0.19	0.02	0.01	0.69	0.04	0.49	0.62	1.00			
SD	0.22	-0.29	0.49	0.63	0.79	-0.08	0.04	0.19	0.53	0.00	0.44	0.66	0.90	1.00		
SR	0.49	-0.07	0.36	0.68	0.83	-0.24	0.15	0.24	0.70	0.18	0.64	0.55	0.86	0.77	1.00	
SE	0.17	0.07	0.50	0.28	0.56	0.49	0.08	0.51	0.35	0.17	0.58	0.16	0.40	0.47	0.51	1.00

Table 4. Correlation matrix among the physico-chemical and biological characteristics of Nagore coastal waters (Station–3). DF-Rainfall, SL-Salinity, AT-Atmospheric Temperature, ST-Surface Temperature, PD-Population Density, SD-Species Diversity, SR-Species Richness, SE-Species Evenness.

	RF	PH	SL	AT	ST	DO	PO_4	NO_2	NO_3	NH_3	SiO_3	Chl-*a*	PD	SD	SR	SE
RF	1.00															
pH	-0.10	1.00														
SL	0.66	0.10	1.00													
AT	0.47	0.04	0.37	1.00												
ST	0.17	0.08	-0.05	0.74	1.00											
DO	-0.63	-0.15	-0.10	-0.05	0.11	1.00										
PO_4	0.63	0.07	0.32	0.17	-0.12	-0.64	1.00									
NO_2	0.46	-0.19	0.90	0.12	-0.21	0.11	0.12	1.00								
NO_3	-0.03	0.23	-0.08	0.52	0.87	0.30	-0.42	-0.23	1.00							
NH_3	0.28	-0.21	0.15	-0.16	-0.24	-0.02	0.46	0.11	-0.26	1.00						
SiO_3	0.32	0.00	0.51	0.77	0.53	0.20	-0.02	0.33	0.50	0.07	1.00					
Chl-*a*	-0.33	0.16	-0.25	0.32	0.60	0.29	-0.54	-0.24	0.69	-0.65	0.10	1.00				
PD	0.57	0.13	0.57	0.69	0.65	-0.13	0.09	0.39	0.61	-0.09	0.67	0.43	1.00			
SD	0.18	0.35	0.14	0.78	0.85	0.07	0.12	-0.08	0.68	-0.18	0.49	0.57	0.66	1.00		
SR	0.62	0.31	0.51	0.82	0.67	-0.30	0.37	0.19	0.52	-0.14	0.66	0.28	0.86	0.76	1.00	
SE	0.22	-0.52	0.05	0.65	0.68	0.23	0.14	0.09	0.38	-0.01	0.50	0.24	0.41	0.55	0.44	1.00

Metis jousseaumei, Dioithona rigida, Oncaea minor, Oncaea venusta were recorded almost in all the seasons in appreciable numbers might be due to their high reproduction potential and their adaptation to widely changing environmental conditions (Rezai et al. 2004). In the present study, the calanoida was the dominant order and their population density was high in all the Stations. Similar results were obtained by several authors; Saravanakumar et al. (2007) have recorded 33 species of copepods from the Gulf of Kachchh, Gujarat coast. Vengadesh Perumal et al. (2009) reported 43 species of copepods from the Kaduviyar estuary. Recently, Santhosh Kumar and Perumal (2011) have recorded 24 species of copepods in the Ayyampattinam coast and Santhi and Ramanibai (2011) recorded 35 species of copepods from Chennai coast. Santhanam et al. (2012), Rajasegar et al. (2000) recorded 85 species of copepods from Vellar estuary. Madhupradap and Haridas (1986) have also reported that the east coast of India receives huge amount of sewage and industrial wastes and as a result the plankton diversity was decreased in the near shore coastal waters. Nearly 80 species of copepod were recorded by Santhanam et al. (2019), Prasath et al. (2019) in Muthupettai mangrove waters.

Copepod population density ranged from 1282-13465 ind./l. Maximum population density was recorded in Station 3 in May 2016 and the minimum population density was recorded in Station 1 in Feb 2016 (Fig. 4a-e). The high population densities recorded might be due to the rationally balanced environmental condition, which occurred during those seasons and great neritic elements presence from the adjacent sea could have also contributed to the maximum density of copepods. Salinity is also a major factor influencing the distribution and abundance of zooplankton (Padmavathi and Goswami 1996, Vijayakumar et al. 2000). Copepods species diversity was ranged from 0.92-2.97. Maximum species diversity was recorded in Station 1 in May 2016 and the minimum species diversity was recorded in Station 3 in Nov 2016. Species richness was found to be ranged between 0.43 and 0.98. Maximum species richness was recorded in Station 1 in May 2016 and the minimum richness was recorded in Station 3 in Feb 2016. Species evenness ranged from 0.78-0.98. Maximum evenness was recorded at Station 1 in Sep 2016 and the minimum evenness was recorded at Station 3 during Mar 2016. The recorded low species diversity in monsoon season could be attributed to the freshwater influx and decreased salinity.

The correlation maximum results between the physico-chemical and copepods were shown in Tables 2, 3 and 4. The strong positive correlation were found between rainfall and pH, atmosphere temperature, phosphate, nitrate and salinity; strong negative correlation were recorded between dissolved oxygen and rainfall as Station 1 (Table 2). Atmosphere and surface water temperature has been positively correlated with copepod population density, copepod diversity, copepod richness and copepod evenness at Station 2 (Table 3). The same trend has been observed in Station 3 also (Table 4). Inorganic nutrient phosphate negatively correlated with nitrate and dissolved oxygen in Station 3.

Conclusion

As the estuaries have been called as the Nurseries of the Sea, the proper monitoring of diversity and ecology of copepod fauna in Vettar estuary is essential in oder to enrich many species of fishes, benthos and birds that depend on this estuary for food and nesting areas. Further long term monitoring and evaluation studies are required to know the role of seasonal variation on diversity and ecological abundance of marine copepods. Hence the present study establishes a highlight towards conducting the future research on diversity, ecology, taxonomy and conservation of estuarine copepod species in Vettar estuary.

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