



Research Article

SEASONAL VARIATIONS OF ZOOPLANKTON DIVERSITY IN MUTHUPET ESTUARY, SOUTH EAST COAST OF INDIA

¹Kothandapani, S., ¹Sukumaran, M. and ^{*2}Muthukumaravel, K.¹Department of Zoology, Rajah Serfoji Government Arts College, Thanjavur-613 005, Tamil Nadu, India²Department of Zoology, Khadir Mohideen College, Adirampattinam-614 701, Tamil Nadu, India**Article History:** Received 13th July 2016; Accepted 29th August 2016; Published 20th October 2016

ABSTRACT

The seasonal variations of primary and net production were studied during July 2014 to June 2015 in Muthupet mangroves (Lat. 10° 46' N; Long. 79° 51' E) south east coast of India. Throughout the study period, a total of 17 species of zooplankton in Muthupet estuary were identified. The copepods constituted the major component of the zooplankton population throughout the study period. The cladocerans like *Daphnia sp.* and *Monia sp.* were recorded during the monsoon and post monsoon periods in Muthupet estuary. In the present study, *Acrocalanus gracilis*, *Acartia kemp*, *Microsetella sp.*, *Paracalanus parvus*, *Tintinnopsis phillipensis*, *T. tocantinnensis*, *Daphnia sp.*, *Monia sp.*, *Brachionus sp.*, *Keretella*, *Lucifer hansen*, nauplii of copepods, veliger of gastropods, zoea of crabs, eggs of fishes, *Acartia erthrea* and *Dictyocysta eseshaiyai* were found in Muthupet estuary. The population density in Muthupet estuary ranged from a minimum of 8690 individuals/m³ in November 2014 to the maximum of 79950 individuals/m³ in June 2015. Annual average population densities of zooplankton were higher in Muthupet estuary. In general, the seasonal mean population density was maximum during summer and pre monsoon periods. Minimum population density was found during monsoon period.

Keywords: Seasonal variations, Zooplankton, Diversity, Muthupet estuary.

INTRODUCTION

Zooplankton are tiny animals found in all aquatic ecosystems, particularly the pelagic and littoral zones in the ocean, also in ponds, lakes, and rivers. They are classified by size and/or by developmental stage. According to size, they are picoplankton < 2 µm, nanoplankton 2-20 µm, microplankton 20-200 µm, mesoplankton 0.2-20 µm, macroplankton 20-200 µm, and megaplankton >200 µm. Zooplankton are primary consumer which constitute a fundamental step in the marine food web as they transfer energy from the lower trophic levels to the higher trophic levels. Zooplankton plays an important role in aquatic food webs as a resource for consumers on higher trophic levels (including fish) and as a conduit for packaging the organic material in the biological pump.

Studies on zooplankton species composition and seasonal variations in an estuarine environment are very much essential for predicting the productivity of the area and also its fisheries potential. The estuarine zooplankton and their composition, seasonal distribution, abundance and

interrelationship have been worked out in detail. The seasonal variations of zooplankton in Vasishta Godavari estuary were carried out by Sai Sastry and Chandramohan (1995). Copepods abundance and their distribution in the Hooghly estuary were documented by Sarkar *et al.* (1986). In Mandovi-Zuari estuarine system of Goa, Padmavati and Goswami (1996) carried out detailed study on the abundance, distribution and ecology of zooplankton. Studies on zooplankton composition in relation to environmental parameters in Point Calimere coastal waters were carried out by Damotharan *et al.* (2010).

Distribution and diversity of zooplankton in the Parangipettai coastal waters were observed by Santhanam and Perumal (2003). Govindasamy and Kannan (1996) have studied the ecology of rotifers of Pichavaram mangroves. Godhantaraman (2001) has worked on the species composition, abundance and biomass of tintinnids of estuarine and mangrove waters of Parangipettai. Effect of pollution on the distribution and abundance of copepods in Thane Creek-Basin creek, Bombay was studied by

* Corresponding Author: Assistant Professor, PG and Research Department of Zoology, Khadir Mohideen College, Adirampattinam - 614 701, Tamilnadu, India, Email kumar_phd_2003@yahoo.co.in, Mobile: +91 9791387363.

Ramaiah and Vijayalakshmi Nair (1997). Shanmugam *et al.* (1986) have studied the biomass and composition of zooplankton in Pichavaram mangroves. Abundance and seasonal variations of zooplankton in mangroves of Gulf of Kachchh-Gujarat was made by Saravanakumar *et al.* (2007).

The abundance, distribution and biomass of zooplankton in the Cochin backwaters have been described by several authors. Madhupratap and Haridas (1975) studied composition and variations in the abundance of zooplankton of backwaters from Cochin to Alleppey. Madhupratap (1979) investigated distribution, community structure and species succession of copepods in Cochin backwaters, Kerala. Seasonal changes in the zooplankton population in the same backwater were observed by Wellereshaus (1974). Shanmugan *et al.* (1986) investigated on the biomass and composition of Zooplankton in Pichavaram mangroves. Seasonal abundance of copepods was observed by Sarkar and Singh (1986) in Hooghly estuary, West Bengal. The distribution and abundance of zooplankton in Poombukar, Pazhayar and Pichavaram coastal waters were investigated by Varatharajan and Soundarapandian (2013) and they recorded 26 species belonging to 7 families. Studies on seasonal variation, abundance and food web relationship of micro zooplankton in estuarine mangrove waters of Parangipettai region were carried out by Godhantaraman (2001). Eswari and Ramanibai (2004) observed the estuarine copepod abundance and diversity in relation to environmental variables. Seasonal variations in species composition, abundance, biomass of tintinnids at estuarine and mangrove waters of Parangipettai have been reported by Godhantaraman (2001). Diversity of zooplankton in Vellar estuary and Portonovo coastal waters, southeast coast of India was studied by Prabhakar *et al.* (2011). Karuppasamy and Perumal (2000) carried out studies on biodiversity of zooplankton at Pichavaram mangroves. Jeyaraj *et al.* (2016) studied abundance and diversity of zooplankton along the Gulf of Mannar region, Southeast coast of India. In the present study has been undertaken to study the zooplankton diversity and density at Muthupet estuary for a period of one year from July 2014 to June 2015.

MATERIALS AND METHODS

Study area

Muthupet mangroves (Lat. 10° 46' N; Long. 79° 51' E) is located at the southern end of the Cauvery river delta of Tamil Nadu on the Bay of Bengal, covering an area of approximately 6,803.01 ha of which only 4% is occupied by well-grown mangroves. The rivers Paminiyar, Koraiyar, Kilaitthankiyar, Marakkakoraiyar and other tributaries of the river Cauvery flow through Muthupet and adjacent villages. At the tail end, they form an estuary before meeting the sea.

Collection and estimation of plankton samples

Zooplankton samples were collected at monthly intervals from the surface waters by horizontal towing of

plankton net(0.35 mouth diameter), made up of blotting silk(cloth No. 10, mesh size 158 μ m) for 20 minutes. These samples were preserved in 5% formalin and used for qualitative analysis. For the quantitative analysis of zooplankton, a known quantitative of water (200L) was filtered through a bagnet of same mesh size and the numerical plankton analysis was carried out using a binocular microscope. The zooplankton were identified using standard study of Davis (1955), Kasturirangan (1963) and Perumal *et al.* (1998).

Quantitative analysis was made using a plankton counting plastic slide (Sedgewick rafter). The capacity of the counting chamber in the slide is 1 ml. This counting chamber is divided into 100 small squares. First, the preserved samples of plankton collected from 200 litres of water were diluted to 100 ml of distilled water. Then from this 1 ml was transferred to counting chamber to observe under the microscope. The phytoplankton components were counted in all the small squares and calculated the numbers per M³ of water filtered.

RESULTS AND DISCUSSION

Species composition

Throughout the study period, a total of 17 species of zooplankton in Muthupet estuary were identified. The copepods constituted the major component of the zooplankton population throughout the study period. The cladocerans like *Daphnia sp.* and *Monia sp.* were recorded during the monsoon and post monsoon periods in Muthupet estuary.

In the present study, *Acrocalanus gracilis*, *Acartia kemp*, *Microsetella sp.*, *Paracalanus parvus*, *Tintinnopsis phillipensis*, *T.tocannitinensis*, *Daphnia sp.*, *Monia sp.*, *Brachionus sp.*, *Keretella sp.*, *Lucifer hansen*, nauplii of copepods, veliger of gastropods, zoea of crabs, eggs of fishes, *Acartia erethrea* and *Dictyocysta eseshaiyai* were found in Muthupet estuary.

Population density

The population density in Muthupet estuary ranged from a minimum of 8690 individuals / m³ in November 2014 to the maximum of 79950 individuals / m³ in June 2015 (Table 1 and Figure 1). Annual average population densities of zooplankton were higher in Muthupet estuary. In general, the seasonal mean population density was maximum during summer and pre monsoon periods. Minimum population density was found during monsoon period.

Species diversity

The species diversity (H¹) of zooplankton in Muthupet estuary fluctuated between 2.55 in August 2015 to 2.816 in November 2014 (Table 2). It can be seen that the diversity indices from phytoplankton was high in monsoon period when compared to other seasons.

Table 1. Seasonal variations of Zooplankton (individuals / m³) in Muthupet estuary.

Zooplankton	2014						2015						Total	Percentage
	July	August	September	October	November	December	January	February	March	April	May	June		
Copepods	6250	4010	2215	1125	970	885	1750	1875	2165	2560	4670	5760	34235	13.15
<i>Acrocalamus gracilis</i>														
<i>Acartia erythrea</i>	5915	4215	1920	1050	875	890	1625	1700	1850	2145	4670	6375	33230	12.76
<i>A.kempi</i>	6920	4324	2150	975	630	550	1810	1950	1810	2220	4310	7200	34849	13.38
<i>Microtella</i> sp.,	7500	5100	2250	1025	610	835	2110	2050	2315	2585	4430	8100	38910	14.94
<i>Paracalanus parvus</i>	8170	5180	2500	1215	725	810	1950	2135	2350	2725	4930	9315	42005	16.13
Ciliates	4230	2025	1420	575	325	550	1210	1430	1250	1310	5810	4810	24945	9.58
<i>Dictyocysta seshaiyai</i>														
<i>Tintinnopsis phillipensis</i>	5015	2210	1250	630	250	425	1310	1715	1775	1420	2725	5125	23850	9.16
<i>T.tocantinsensis</i>	5930	2125	1415	810	625	610	1215	1410	1460	1610	2870	6100	26180	10.06
Cladocera	-	-	-	125	350	215	115	95	-	-	-	-	900	0.35
<i>Daphnia</i> sp.,														
<i>Monia</i> sp.,	-	-	-	160	480	350	180	85	-	-	-	-	1255	0.48
Rotifers	-	-	-	130	375	150	-	-	-	-	-	-	655	0.25
<i>Brachionus</i>														
<i>Keratella</i>	-	-	-	175	410	225	-	-	-	-	-	-	810	0.31
Decadpod	4310	2125	1225	475	410	625	1150	1200	1175	1310	2910	4825	21740	8.35
<i>Lucifer hansenii</i>														
Copepod nauplii	5115	3110	1995	850	575	720	1225	1310	1450	1880	3985	5325	27540	10.58
Velier of gastropod	6210	3510	1200	550	325	575	950	1415	975	1187	3300	6950	27147	10.43
Zoea of crabs	3965	2100	1700	750	410	550	1180	1125	1110	1105	2700	4250	20945	8.04
Fish eggs	5614	3225	1630	520	345	475	375	1300	1575	1680	2910	5815	25464	9.78
Total Population	75144	43259	22870	11140	8690	9440	18155	20795	21260	23737	50220	79950	384660	-
Density														

Table 2. Shannon and Weiner Diversity Index of Zooplankton.

Month	S	N	d	J'	H'(loge)	1-Lambda'
Jul-2014	13	983	1.742	0.9978	2.559	0.9232
Aug-2014	13	739	1.817	0.9943	2.55	0.9221
Sep-2014	13	541	1.907	0.9971	2.557	0.9236
Oct-2014	17	415	2.655	0.9803	2.777	0.9375
Nov-2014	17	378	2.696	0.9938	2.816	0.9415
Dec-2014	17	391	2.681	0.9905	2.806	0.9406
Jan- 2015	15	498	2.254	0.9789	2.651	0.9287
Feb-2015	15	534	2.229	0.9774	2.647	0.9288
Mar-2015	13	521	1.918	0.9964	2.556	0.9234
Apr-2015	13	549	1.902	0.9956	2.554	0.923
May-2015	13	802	1.795	0.9968	2.557	0.923
Jun-2015	13	1013	1.734	0.9977	2.559	0.9231

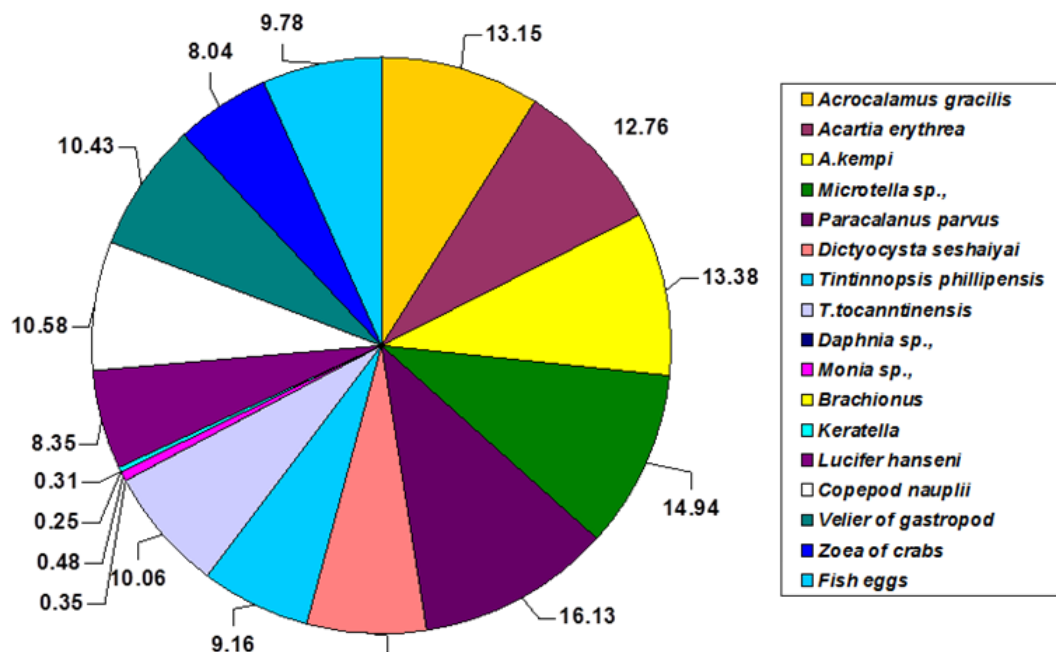


Figure 1. Percentage composition of zooplankton in Muthupet estuary.

Species richness

The species richness (d) in Muthupet estuary ranged from a minimum of 1.734 in June 2015 to a maximum of 2.696 in November 2014 (Table 2). In general the high species richness was coincided with monsoon followed by post monsoon period. The low species richness was recorded during summer, followed by pre monsoon period.

Species evenness

Species evenness in Muthupet estuary recorded a low value (0.9774) in February 2015 to a high value (0.9978) in July 2014.

In Muthupet estuary a total of 17 species of zooplankton were identified throughout the study period. The copepods constituted the major component of the zooplankton population and the cladocerans like *Daphnia sp.* and *Moina sp.* were recorded during the monsoon and post monsoon periods in Muthupet estuary.

In the present study, *Acrocalanus gracilis*, *Acartia kemp*, *Microtella sp.*, *Paracalanus parvus*, *Tintinnopsis philipensis*, *T. tocannitensis*, *Daphnia sp.*, *Moina sp.*, *Brachionus sp.*, *Keratella*, *Lucifer hanseni*, nauplii of copepods, Veliger of gastropods, zoea of crabs, eggs of fishes, *Acartia erythrea* and *Dictyocysta seshaiyai* were found in Muthupet estuary.

Considerable information is available on the density of zooplankton and copepods in Indian estuaries such as in Porto Novo waters (Subbaraj and Krishnamurthy, 1972) and in Agniar estuary (Habib Mohamed and Abdul Rahaman, 1987). The zooplankton in Muthupet estuary showed marked seasonal fluctuations. Studies by several authors in different Indian estuaries have revealed that

plankton differs considerably both in quality and quantity from place to place and also from time to time. The zooplankton showed a considerable increase when the estuary was influenced by neritic waters with moderate salinity (34.2‰) in the month of May. Observations of Ganapathi and Subba Rao (1958) in Waltair coast, Qasim *et al.* (1969) in Cochin backwaters, Subbaraju and Krishnamurthy (1972) and Ramadhas (1977) in estuarine water of Porto Novo showed that maximum zooplankton would occur during the high salinity period.

A definite seasonal pattern is clearly visible with respect to copepod population with more abundance during the period of moderate salinity. The peak periods of copepods were recorded in the month of June and July when salinity was 28.5‰ and 30.5‰ respectively. But during the period of low salinity the copepods were comparatively lesser in numbers. But the observation recorded in the Agniar estuary (Habib Mohamed and Abdul Rahaman, 1987) showed that the copepod population was more during the high saline period and less during the low saline period.

Copepods occupied a major portion of the zooplankton population in the present study and similar observation was recorded in Vellar estuary (Subbaraju and Krishnamurthy, 1972), in Ashtamudi estuary (Divakaran *et al.*, 1982) and in Agniar estuary (Habib Mohamed and Abdul Rahaman, 1987). The copepod Nauplii were present throughout the study period and they were abundant in the months of May, June and July and very low in the month of November. In the present study peaks in copepod nauplii coincided with the phytoplankton peaks. Similar observation was made by In Vellar estuary the maximum of copepod Nauplii in July coincided with the secondary peak in diatom numbers,

whereas the secondary maximum in June coincided with the primary peak of diatoms occurring in April (Ramadhas, 1977). Thus a relationship between the availability of food and the breeding of copepods was noticed. In the Muthupet estuary the total yield of fish catches found to be greater when copepods were most abundant. Similar observation was made in Porto Novo waters (Subbaraju and Krishnamurthy, 1972).

The abundance of rotifers and cladocerans during monsoon period only, showed that the rotifers were brought to the estuary by the river discharge and their adaptability to the less saline water. Tintinnids were present throughout the study period indicating their tolerance to salinity fluctuations. In the estuary, the larval forms except copepod nauplii and veliger were found in lesser numbers. Thus the occurrence, distribution and the nature of zooplankton population in Muthupet estuary were influenced by salinity, temperature, rainfall, food (phytoplankton) and the ability to survive under the widely fluctuating conditions of the environment.

The study of several authors have revealed that the plankton differs considerably both in quality and quantity from place to place and from time to time. The zooplankton distribution in Muthupet estuary was similar with regard to high numerical abundance during the high saline summer and pre monsoon period to that of Vellar estuary (Santhanam *et al.*, 1975; Chandran, 1982 and Thangaraj, 1984), Cochin backwaters (Silas and Pillai, 1975; Madhupratap, 1978; Nair *et al.*, 1984) and Coleroon estuary (Prabha Devi, 1986). In Ashtamudi estuary, a major peak was observed during monsoon and a minor peak during post monsoon period (Divakaran *et al.*, 1982). However, in Veli lake, a backwater adjacent to the Kadinamkulam, peak incidence was observed during the premonsoon and Postmonsoon periods in the upper reaches (Arunachalam *et al.*, 1982).

Throughout the year, the ciliates namely *Dictyocysta seshaiyai*, *Tintinnopsis phillipensis* and *T. tocanntinensis* occurred frequently. Out of which *Tintinnopsis tocanntinensis* found to be dominant form among ciliates. Reports from vellar and Coleroon estuary stated that tintinnids were the dominant taxa among microzooplankton both in species composition and in abundance (Damodara Naidu, 1980; Chandran, 1982; Thangaraj, 1984; Prabha Devi, 1986). In addition to earlier reports from Vellar estuary (Damodara Naidu *et al.*, 1977; Sivakumar, 1982) confirmed that *Tintinnopsis* sp. and *Favella* sp. were

common in occurrence. Sivakumar (1982) has also observed that these two species prefer moderate salinity (15%-30%). This perhaps may be the reason for such common occurrence of *Tintinnopsis* sp. in Muthupet estuary. The perennial occurrence and summer abundance of tintinnid populations in these waters were mainly due to the abundance of photosynthetic dinoflagellates, upon which the tintinnids mostly depend for their food.

The rotifers *Brachinous* sp. and *Keratella* sp. appeared during monsoon months. Devassy and Gopinathan (1970)

from Cochin backwater, Chandran (1982) from vellar estuary and Prabha Devi (1986) from Coleroon estuary reported the occurrence of rotifers during monsoon periods, which are in conformity with the observations of present study.

Among the 17 species of zooplankton recorded, copepods constitute major portion with 5 species followed by 3 species of Tintinnids and 2 species rotifers. Copepods were the dominant forms throughout the study period. This observation in this study is in conformity with the earlier reports of Dwivedi *et al.* (1974) and Goswami and Singbal (1974) from Mandovi and Zuari estuaries, Madhupratap *et al.* (1977) and Madhupratap (1978 and 1979) from Cochin backwaters; Divakaran *et al.* (1982) from Ashtamudi estuary; Arunachalam *et al.* (1982) from Veli lake. In Vellar estuary, Porto Novo, copepods constituted maximum per cent of the zooplankton population (Subbaraju and Krishnamurthy, 1972). Plankton studies in Nethravati-Gurupur estuary also revealed that copepods and copepodites together formed the bulk of zooplankton (Bhat and Gupta, 1983). This supports the present findings in Muthupet estuary.

The abundance of copepod was maximum during summer and pre monsoon dominance of copepod was also reported from Mandovi-Zuari estuaries (Goswami and Singbal, 1974), Cochin backwaters (Madhupratap *et al.*, 1977); Purari estuary (Bayly, 1980), Vellar estuary (Chandran, 1982 and Thangaraj, 1984 and Coleroon estuary (Prabha Devi, 1986).

Generally, estuarine zooplankton is volumetrically abundant but limited in species composition. In the present study, population density was high during summer and pre monsoon and low during monsoon and postmonsoon periods. During summer and pre monsoon period the entire water column shows stable and uniform hydrographic conditions and the estuary becomes virtually an extension of the adjoining sea with high salinity and temperature values. Heavy rainfall during the monsoon period has significant effect on the zooplankton distribution of Muthupet estuary since the dominant species constituting the bulk of the heavy rainfall and the resultant large influx of freshwater to the estuarine system many marine organisms migrate from the environment following the monsoonal decline of marine components gradually get established in the estuarine system during the post monsoon period. A gradual rise in salinity was noted during this period and was reflected in the biomass distribution of zooplankton. The average population density was maximum during summer and minimum during monsoon period. This may be explained that the high density of zooplankton in the estuary is mainly due to the addition of zooplankton by the adjacent water. The high density of both phytoplankton and zooplankton production in the tropical estuaries is mainly influenced by high salinity (Pillai *et al.*, 1973; Rao *et al.*, 1975; Madhupratap *et al.*, 1977, Madhupratap, 1978; Nair *et al.*, 1984) followed by high dissolved oxygen content and temperature

(Madhupratap *et al.*, 1977). The present finding agrees with the earlier observations.

A direct relationship between zooplankton and gross and net primary production was observed in the present study, whereas Nair *et al.* (1984) in Asthamudi estuary recorded an inverse relationship between zooplankton and primary production.

The observation made by Kumar (1991), Rajasegar *et al.* (2000) and Santhanam and Perumal (2003) from Vellar estuary, Jegadesan (1986) from Coleroon estuary, Ambikadevi (1993) and Saraswathi (1993) from Arasalar and Kaveri estuaries, Sai Sastry and Chandramohan (1995) from Godavari estuary, Padmavathi and Goswami (1996) in Mandovi-Zuari estuaries, Krishnakumari and Nair (1988) in Vashisti estuary, Damotharan *et al.* (2010) in Point Calimere coastal waters are in agreement with the present findings.

Further, the higher population densities of zooplankton observed during summer were coincided with the peak of phytoplankton density. The phytoplankton density showed positive correlation with zooplankton density. It is supported from the earlier observations of Govindasamy and Kannan (1991) in Pichavaram Mangroves, Jegadesan (1986) in Coleroon estuary and Murugan and Ayyakannu (1993) from Uppanar backwaters.

In the present study, a major (summer) and a minor (monsoon) peak of zooplankton population density was observed. Similar observation was made from Vellar estuary (Krishnamurthy, 1967; Subbaraju and Krishnamurthy, 1972; Santhanam *et al.*, 1975) and Mandovi estuary (Dehadrai, 1970). Seasonal average species diversity was maximum during summer and premonsoon. Similarly, high species diversity indices of zooplankton during summer months was reported by Ramadhas (1977) in Vellar estuary, Goswami and Selvakumar (1977) in Cochin backwater and Madhupratap (1978 and 1979) in Mandovi and Zuari estuaries.

ACKNOWLEDGEMENT

The author (Dr. M. Sukumaran) expresses his gratitude to UGC, Government of India, New Delhi for financial assistance through Major Research Project.

REFERENCES

- Ambikadevi, P., 1993. Studies on zooplankton in Arasalar and Kaveri estuaries, south east coast of India, Ph.D., Thesis, Annamalai University, India.
- Arunachalam, M., Divakaran, O., Nalt, N.B. and Balasubramanian, N.K., 1982. Seasonal variation of zooplankton of the Veli lake. South West coast of India. *Arch. Hydrobiol.*, 93, 358-374.
- Bayly, I.A.E., 1980. A Preliminary report on the Zooplankton of the Purari estuary. Aquatic ecology of the Purari river Catchment. T.Petr. ed. *Environ. Stud.*, 11, 7-11.
- Bhat, B.V and T.R.C. Gupta, 1983. Zooplankton distribution in Nethravati Gurupur estuary, Mangalore. *Indian J.Mar. Sci.*, 12, 36-42.
- Chandran, R., 1982. Hydrobiological studies in the gradient zone of the Vellar estuary. Ph.D., Thesis, Annamalai University, India.
- Damodara Naidu.W. 1980. Studies on Tintinnids (Protozoa Ciliate) of Porto Novo region. South India. Ph.D. Thesis. Annamalai University. 281 pp.
- Damodara Naidu, W., R. Santhanam, K. Krishnamurthy and R. Natarajan, 1977. The species biomass and the seasonal composition of Tintinnids (Protozoa – Ciliate). *Proc. Symp. Warm water Zooplankton, Spl. Pul. UNESCO – NIO*, 5, 520 -527.
- Damotharan, P., Vengadesh Perumal N. and Arumugam, M., 2010. Studies on zooplankton ecology from Kodiakkarai (Point Calimere) coastal waters (South east coast of India). *Res. J. Biol. Sci.*, 5(2), 187-198.
- Davis, C.C., 1955. The marine and freshwater plankton. Michigan State University Press, Michigan, USA. pp.562.
- Dehadrai, P.V., 1970. Changes in environmental features of Zuari and Mandovi estuaries in relation to tides. *Proc. Indian Acad. Sci.*, 72, 68-80.
- Devassy, V.P. and Gopinathan, C.K., 1970. Hydro biological features of the Kerala uring premonsoon and monsoon months. *Fish. Technol.*, 7, 20-25.
- Divakaran, O., M. Arunachalam, N.B. Nair and N.K. Balasubramanian, 1982. Distribution and seasonal variation of the zooplankton of Ashtamudi lake, South-West Coast of India. *Mahasagar. Bull. Natn. Inst. Oceanogr*, pp.15-43.
- Dwivedi, S.N., Bhargava, R.M.S., Parulekar, A.M., Selvakumar, R.A., Singbal, S.Y.S., and Sankaranarayan, V.N., 1974. Ecology and environmental monitoring of Mandovi, Zuari and Camburjua canal complex during monsoon months. *J. Ind. Fish Assn.* 3, 113-130.
- Eswari, Y.N.K., and Ramanibai, R. 2004. Estuarine copepod abundance and diversity in relation to environmental variables, South east coast of India. *J. Mar. Biol. Ass. India*, 46, 10-20.
- Ganapathi, P.N. and Subba Rao, D.V., 1958. Quantitative study of plankton off lawson's Bay Waltair. *Proc. Indian Acad. Sci.*, 48,189-209.
- Godhantaraman, N., 2001. Seasonal variations in taxonomic composition, abundance and food web relationship of micro zooplankton in estuarine and mangrove waters, Parangipettai region, South East Coast of India. *Indian J. Mar. Sci.*, 30, 151-160.
- Goswami, S.C. and R.A. Selvakumar, 1977. Plankton studies in the estuaries of Goa. *Proc. Symp. Warm*

- water Zooplankton. Spl. Publ. UNESCO/NIO, 226- 241.
- Goswami, S.C. and Singbal, S.Y.S. 1974. Ecology of Mandovi and Zuari estuaries. Plankton community in relation to hydrographic conditions during monsoon months. *Indian J. Mar. Sci.*, 3, 51-57.
- Govindasamy, C. and Kannan, L., 1991. Rotifers of the Pitchavarm mangroves (Southeast west of India). A hydrobiological approach. Manasagar. *Bull. Natl. Inst. Oceanogr.*, 23, 55-62.
- Govindasamy, C., and Kannan, L., 1996. Ecology of rotifers of Pichavaram mangroves, South east coast of India. *Indian. J. Hydrobiol.*, 1, 69-76.
- Habib Mohamed, T.A.M., and A. Abdul Rahman, 1987. Seasonal distribution of plankton in Agnira estuary. *J. Mar. Biol. Ass. India*, 29 (1 and 2), 273-279.
- Jegadeesan, P., 1986. Studies on environmental inventory of the marine zone of Coleroon estuary and inshore waters of Pазhayaru, southeast coast of India. Ph.D Thesis, Annamalai University, pp. 277.
- Jeyaraj N., Ravikumar, S., Rajthilak, C., Kumar, S.P. and Santhanam, P., 2016. Abundance and diversity of zooplankton along the Gulf of Mannar Region, Southeast coast of India. *Int. J. Mar. Sci.*, 6(28), 1-9.
- Karuppasamy, P.K. and P. Perumal, 2000. Biodiversity of zooplankton at Pichavaram mangroves, south east coast of India. *Adv. Bio Sci.*, 19, 23-32.
- Kasturirangan, L.R., 1963. A key for the more common Planktonic copepods of the Indian waters. CSIR Publication, New Delhi.
- Krishnakumari, L. and V.R. Nair, 1988. Biomass, organic carbon and calorific content of zooplankton from the Arabian sea of central west coast of India. *Indian J. Mar. Sci.*, 17, 78-80.
- Krishnamurthy, K., 1967. Seasonal variation in the plankton of Porto Novo back waters (India). *Hydrobiol.*, 39, 226-238.
- Kumar, K., 1991. Studies on copepods occurring in coastal waters of Parangipettai. Ph.D. Thesis, Annamalai University, India.
- Madhu Prata, P.M., 1978. Studies on the ecology of zooplankton of Cochin backwaters. Mahasagar. *Bull. Natn. Inst. Oceanogr.*, 11, 45- 56.
- Madhupratap, M., 1979. Distribution, Community Structure and species succession of copepods from Cochin backwaters, *Indian J. Mar. Sci.*, 8, 1-8.
- Madhupratap, M. and Haridas, P., 1975. Composition and variations in the abundance of zooplankton of backwaters from Cochin to Alleppey. *Indian J. Mar. Sci.*, 4, 77-85.
- Madhupratap, M., Rao, T.S.S. and P. Haridas, 1977. Secondary Production in Cochin backwaters, a tropical monsoonal estuary. *Proc. Symp. Warm water Zooplankton. Spl. Publ. UNESCO/NIO*, 515-519.
- Murugan, A. and K. Ayyakannu, 1993. Studies on the ecology of phytoplankton in Cuddalore Uppanar back water, South east coast of India. *Indian J. Mar. Sci.*, 22(2), 135-137.
- Nair, N.B., Abdul Azis, P.K., Dharmaraj, K., Arunachalam, M., Krishnakumar, K. and Balasubramanian, N.K., 1984. Ecology of Indian estuaries : Part V : Primary productivity of Ashtamudi estuary, South West Coast of India. *Proc. Indian Acad. Sci. (Anim. Sci.)*, 93(1), 2-23.
- Padmavathi, G. and Goswami, C., 1996. Zooplankton ecology in the Mandovi-Zuari estuarine system of Goa, West coast of India. *Indian J. Mar. Sci.*, 25, 268-273.
- Perumal, P., Sampathkumar, P. and Santhanam, P. 1998. Zooplankton of Parangipettai coastal Waters. Monograph series, Vol. I. UGC-SAP, CAS in Marine Biology, Annamalai University, Parangipettai, pp. 31.
- Pillai, P.P., 1973. Tidal, influence on the diel variations of zooplankton with special reference to copepods in the Cochin backwater. *J. Mar. Biol. Ass. India*, 15(1), 411-417.
- Prabha Devi, L., 1986. Hydrobiological studies in tidal zone of the Coleroon estuary. Ph.D. Thesis, Annamalai University, pp. 241.
- Prabhakar, C., Saleshrani, K. and Tharmaraj, K., 2011. Hydrobiological investigations on the planktonic diversity of Vellar river, Vellar estuary and Portonovo coastal water, south east coast of India. *IJ PBP*, 2(6), 1699-1704.
- Qasim, S.Z., Wellershaus, S., Bhattathiri, P.M.A. and Abidi, S.A.H., 1969. Organic production in a tropical estuary. *Proc. Indian. Acad. Sci.*, 69B, 51-94.
- Rajasegar, M., Srinivasan, M. and Rajaram, R. 2000. Phytoplankton diversity associated with the shrimp farm development in Vellar estuary, South India. *Seaweed . Res. Util.*, 22, 125-130.
- Ramadas, V., 1977. Studies on phytoplankton, nutrients and some trace metals in Porto Novo water. Ph.D. Thesis, Annamalai University, pp. 135.
- Ramaiah, N. and Vijayalakshmi Nair, 1997. Distribution and abundance of copepods in the pollution gradient zones of Bombay harbour – Thane creek–Basin creek, West Coast of India. *Indian J. Mar. Sci.*, 26, 20-25.
- Rao, T.S.S., Madhupratap, M. and Haridas, P., 1975. Distribution of Zooplankton in Space and time in a tropical estuary. *Bull. Dept. Mar. Sci., Univ. Cochin.*, 7, 695-704.
- Sai Sastry, A.G.R.S. and Chandramohan, P. 1995. Zooplankton of Visishta Godavari estuary, a pre

- pollution status survey. *J. Mar. Biol. Ass. India*, 37, 249-258.
- Santhanam, P. and Perumal, P., 2003. Diversity of zooplankton in Parangipettai coastal waters, South east coast of India. *J. Mar. Ass. India*, 45(2), 144-151.
- Santhanam, R., Krishnamurthy, K. and Raju, R.C.S., 1975. Zooplankton of Portonovo, South India. *Bull. Department Mar. Sci.*, 7, 899- 911.
- Saraswathi, R., 1993. Hydrobiology of two estuarine systems (Arasalar and Kaveri) of the southeast coast of India with special reference to plankton. Ph.D. Thesis, Annamalai University, India.
- Sarvanakumar, A., Rajkumar, M., Sesh Serebiah, J. and Thivakaran, G.A., 2007. Abundance and seasonal variations of zooplankton in the arid zone mangroves of gulf of Kachchh- Gujarat. West coast of India. *Pak. J. Biol. Sci.*, 10, 3525-3532.
- Sarkar, S.K. and Singh, B.N., 1986. The ecology of copepods from Hoogly estuary, West Bengal, India, Mahasagar. *Bull. Nat. Inst. Oceanogr.*, 19, 103-112.
- Shanmugam, A., Kasinathan, R. and Maruthamuthu, S. 1986. Biomass and composition of zooplankton from Pichavaram mangroves, south east coast of India. *Ind. J. Mar. Sci.*, 15, 111-113.
- Silas, E.G. and Pillai, P.P., 1975. Dynamics of zooplankton in a tropical estuary (Cochin backwaters) with a view on the plankton fauna of the environment. *Bull. Dept. Mar. Sci. Univ. Cochin*, 7, 329-335.
- Sivakumar, V., 1982. An environmental inventory of the tidal zone of the Vellar estuary. Ph.D. Thesis, Annamalai University, pp.195.
- Subbaraju, R.C. and Krishnamurthy, K., 1972. Ecological aspects of plankton production. *Mar. Biol.*, 14, 25-31.
- Thangaraj, G.S., 1984. Ecobiology of the marine zone of the Vellar estuary. Ph.D. Thesis, Annamalai University, pp. 192.
- Varadharajan, D. and Soundarapandian, P., 2013. Distribution and abundance of zooplankton along Tamilnadu coastal waters India. *Ecosyst. Ecograp.*, 3(4), 1-4.
- Whitfield, A.K., 1980. Factors influencing the recruitment of juvenile fishes into the Mhlamba estuary. *S. Afr. J. Zool.*, 15(3), 166-169.