Available online at www.elixirpublishers.com (Elixir International Journal)

Bio Diversity

Elixir Bio Diver. 75 (2014) 27765-27770

ISSN: 2229-712X

Hydrographic conditions, composition and distribution of zooplankton in relation to potential resources of muthupettai mangrove environment, Palk Strait, southeast coast of India

M.M. Karthikeyan[1,*] and G. Ananthan[2]

[1]Department of Zoology, Pachaiyappas college for men, Kanchipuram- 631 501, Tamil Nadu, India.
[2]Centre of Advanced Study in Marine Biology, Annamalai University, India.

ARTICLE INFO

Article history:
Received: 8 April 2013;
Received in revised form:
27 September 2014;
Accepted: 20 October 2014;

Keywords
Hydrobiology,
Zoolpankton,
Mangrove environment,
Palk Strait.

ABSTRACT

The present study was carried out to determine on hydrography; composition and community structure of zooplankton at the Muthupettai mangrove environment, Palk Strait (Southeast coast of India), during February 2006 to January 2007. Physico-chemical parameters and nutrients such as air temperatures, surface water temperatures, salinity, pH, light extinction coefficient (LEC), dissolved oxygen , nitrite, nitrate, inorganic phosphate and silicate were at the ranges of 21-32.8ºC, 23- 31.0°C, 14.5- 34‰,7.4-8.3, 0.21- 0.83, 3.01 to 5.33mg/1, 0.122 to 2.08µM, 0.911 to 6.00µM, 1.03 to 2.98µM and 30.21 to 102.21µM, respectively. The maximum density was found during summer season coinciding with the stable hydrographical conditions. Totally 92 species of zooplankton besides 18 larvae were recorded and the foraminifera and copepods formed the dominant group. Higher values of zooplankton density and species diversity were found during premonsoon and summer seasons and which showed positive correlation with salinity. The seasonal distribution and abundance of plankton are discussed in relation to hydrographical parameters.

Introduction

The physico-chemical characteristics are said to play a significant role in the distribution of organisms such as reproduction, feeding *etc.* Various physico-chemical and biological processes in the mangals make it a habitat for vast array of organisms, leading to rich biodiversity (Balasubrananian, 2000) but seasonal variation and anthropogenic pressures bring about a lot of changes in physical-chemical characteristics, which affect the biotic elements of the mangals system. The most important variables which influence the mangrove are temperature, salinity, tides, rainfall and wind. Survival and development of regeneration and recruitment classes depend on salinity and solar radiation (Kathiresan *et al.*, 1996). Temperature and salinity determine the species composition, distribution and zonation. Tidal amplitude with topography structure regulates the landward extension of the mangroves. Many studies related to hydro biological parameters were carried out in Indian coastal waters. Of which, Menon *et al*. (2000) studied the hydrobiology of the Cochin backwaters, south west coast of India. The physico chemical characteristics of Pichavaram mangroves, south east coast of India by Kathiresan *et al.*, 1996; Rajendran, 1997 and Kathiresan, 2000.

Water quality assessment generally involves analysis of physico-chemical, biological and microbiological parameters and reflects on abiotic and biotic status of the ecosystem (IAAB, 1998; Mulani *et al.*, 2009). In ecologically, zooplankton are one of the most important biotic components influencing all the functional aspects of an aquatic ecosystem, such as food chains, food webs, energy flow and cycling of matter (Sinha and Islam, 2002; Park and Shin, 2007). The distribution of zooplankton community depends on a complex of factors such as, change of climatic conditions, physical and chemical parameters and vegetation cover (Neves *et al.*, 2003). The rate of zooplankton production can be used as a tool to estimate the exploitable fish stock of an area (Tiwari and Nair, 1991).

Zooplankton provides an important food source for larval fish and shrimp in natural waters. It has been reported that in many countries the failure of fishery was attributed to the reduced zooplankton especially copepod population (Stottrup, 2000). Information on species diversity, richness, evenness and dominance evaluation on the biological components of the ecosystem is essential to understand detrimental changes in environs (Krishnamoorthy and Subramanian, 1999). Some studies (Oswin and Rahman, 1997) are available on the Muthupettai mangroves of this region. Most of the species of planktonic organisms are cosmopolitan in distribution (Mukherjee, 1997). Therefore, the present investigation attempts to study the zooplankton species richness, diversity and evenness in relationship between physico-chemical parameters in Muthupettai mangrove environment, Palk Strait, Southeast coast of India.

Materials and Methods

Description of the study site: Muthupettai mangroves (Lat.10º25'N;Long.79º39'E) situated 400km south of Chennai lies on the southern part of cavery delta region along the South East coast of India. It spreads to an area of about 6800 ha in which two specialized habitats are noted viz. Mangrove and lagoon. *Avicennia marina* is the dominant mangrove species in Muthupettai and accounts for nearly 95% of vegetative cover. Besides these native species *Rhizophora mucronata, Rhizophora apiculate* and *Ceriops decandra* have been successfully

Tele:
E-mail addresses: karthikasci@gmail.com

introduced in Muthupettai. The sampling areas of Station 1(Sea mouth region) and Station 2 (Lagoon) were selected for the present study (Fig.1).

Physico-chemical analysis: Monthly samplings were made in the two stations for a period of one year from February 2006 toJanuary 2007. Field data like temperature, salinity, dissolved oxygen and pH were measured during morning to noon. Atmospheric and surface water temperatures were measured using standard mercury filled centigrade thermometer. Light penetration in the water column was measured with the help of a Secchi disc and the light extinction coefficient (LEC) was calculated using the Pool and Atkins (1929). Salinity was estimated with the help of a hand refractometer (Atago, Japan) and pH was measured using Elico pH meter (Model LC- 120). Dissolved oxygen and all nutrients (inorganic phosphate, nitrate, nitrite, reactive silicate and ammonia) were estimated by the modified Winkler's method (Strickland and Parsons, 1972).

Biological analysis: Samplings of zooplankton were carried out from the surface water, by towing the zooplankton nets (mouth diameter 0.35 m) made up of bolting silk cloths (No. 10, Mesh size 158 µm), for half an hour. The collected samples were preserved in 5% neutralized formalin for further analysis. Zooplankton species identification was done with the help of standard references (Alfred *et al.,* 1973). Species diversity index (H') was calculated using the formula of Shannon and Weaver (1949). Species richness (SR) was calculated as described by Simpson (1949). Species evenness (J') was calculated by formula of Pielous (1966). Correlation coefficients (r) were calculated for zooplankton density and physico-chemical parameters and the Analysis of Variance (F) tests were made for hydrological parameters in relation to stations and seasons.

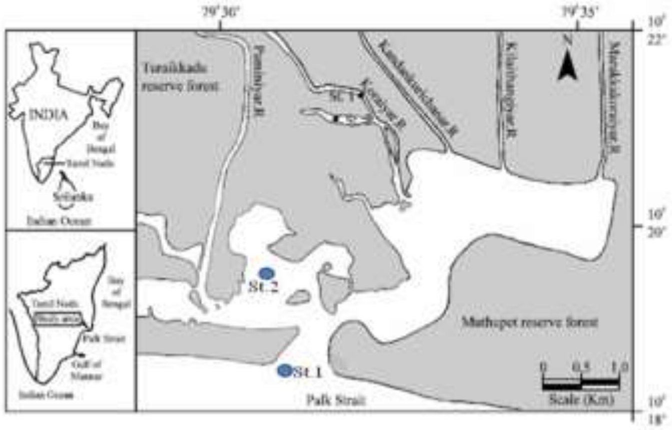

Fig.1. Map of Muthupettai mangrove environment showing different locations

Results and Discussion

Hydrography: Atmospheric temperature varied from 21ºC to 32.8ºC with the minimum (21.0ºC) during the monsoon season and the maximum (32.8ºC) during the summer season. The maximum surface water temperature (31.0^{o}C) was recorded during the summer season and the minimum (23.0^{o}C) was recorded during the monsoon season (Table 1). The surface water temperature showed an increasing trend from December through April and was influenced by the intensity of solar radiation, evaporation, freshwater influx and cooling and mix up with ebb and flow from adjoining neritic waters. The observed low value of November was due to strong land sea breeze and precipitation and the recorded high value during summer could be attributed to high solar radiation (Govindasamy *et al.,* 2000).

Light extinction co-efficient (LEC) varied from 0.21 to 0.83 with the maximum during the monsoon and minimum during the summer seasons (Table 1). Salinity ranged between 14.5 and 34.0‰ recording the maximum during the summer season and the minimum during the monsoon season (Table 1). The recorded high monsoon value could be due to the low intensity of solar radiation and higher concentration of dissolved organic matter and suspended sediments. The observed low summer value could be due to the higher solar penetration, clean water condition and low runoff (Kannan and Kannan, 1996), as has been supported by the positive correlation between light extinction coefficient and rainfall.

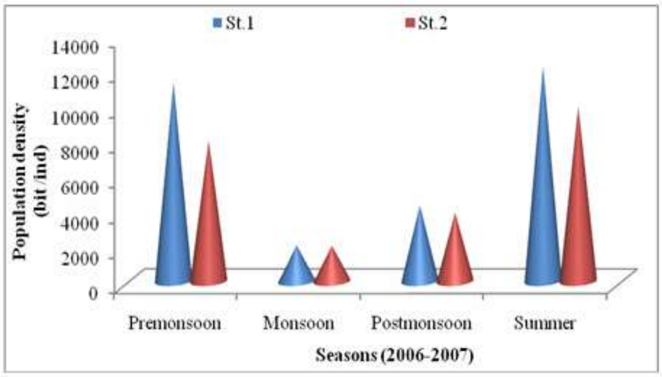

Fig.2. Seasonal variations of zooplankton population density recorded during 2006 to 2007

The maximum (8.3) hydrogen-ion concentration (pH) was recorded during the summer season and the minimum (7.4), during the monsoon season (Table 1). The recorded high summer pH might be due to the influence of seawater penetration and high biological activity (Das *et al.,* 1997). The statistical analysis also revealed that salinity show highly significant negative correlation with rainfall. Dissolved oxygen content varied from 3.01 to 5.33 ml l^{-1} with the minimum during the summer season and the maximum during the monsoon season (Table 1). It is well known that the temperature and salinity affect the dissolution of oxygen (Vijayakumar *et al.,* 2000). In the present investigation, higher values of dissolved oxygen were recorded during monsoon months at all the stations.

Nutrients are considered as one of the most important parameters in the estuarine environment influencing growth, reproduction and metabolic activities of living beings. Distribution of nutrients is mainly based on the season, tidal conditions and freshwater flow from land source. The recorded higher nitrite values during monsoon season(2.082 µM) could be due to the increased phytoplankton excretion, oxidation of ammonia and reduction of nitrate and by recycling of nitrogen and also due to bacterial decomposition of planktonic detritus present in the environment (Govindasamy *et al.,* 2000). The recorded low nitrite value (0.122 µM) during postmonsoon season may be due to less freshwater inflow and high salinity (Murugan and Ayyakkannu, 1991) (Table 1).

The recorded highest nitrates value (6.007 µM) during monsoon season could be mainly due to the organic materials received from the catchment area during ebb tide (Das *et al.,* 1997) (Table 1). The increased nitrates level was due to fresh water inflow, mangrove leaves (litter fall) decomposition and terrestrial run-off during the monsoon season (Karuppasamy and Perumal, 2000; Santhanam and Perumal, 2003). Further, significant inverse relationship between rainfall and nutrients indicated that freshwater flow constituted the main source of the nutrients in the estuaries.

The recorded high concentration of inorganic phosphates (2.980 µM) during monsoon season might possibly be due to intrusion of upwelling seawater into the creek, which in turn increased the level of phosphate (Nair *et al.,* 1984) (Table 1). Further, regeneration and release of total phosphorus from bottom mud into the water column by turbulence and mixing also attributed to the higher monsoonal values (Chandran and Ramamoorthy, 1984). The low summer value (1.03 µM) could be attributed to the limited flow of freshwater, high salinity and utilization of phosphate by phytoplankton (Rajasegar, 2003). The silicate content was higher than that of the other nutrients (NO3, NO2 and PO4) and the recorded high monsoon values (102.21 µM) may be due to heavy inflow of monsoonal freshwater derived from land drainage carrying silicate leach out from rocks. Further, due to the turbulent nature of water, the silicate from the bottom sediment might have been exchanged with overlying water in this estuarine environment (Govindasamy and Kannan, 1996). The observed low post-monsoonal values (30.21 µM) could be attributed to uptake of silicates by phytoplankton for their biological activity (Rajasegar, 2003) (Table 1).

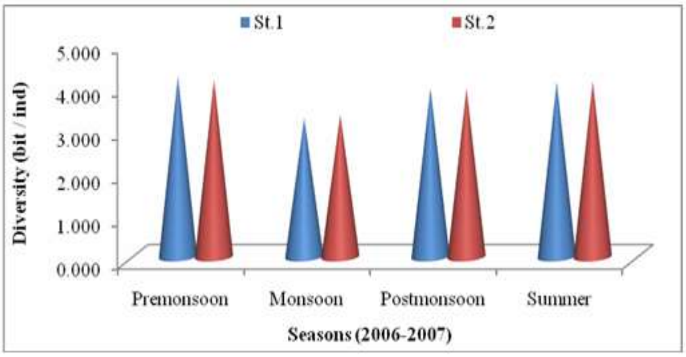

Fig.3. Seasonal variations of zooplankton diversity recorded during 2006 to 2007

Composition and community structure of zooplankton: A total of 102 zooplankton including 14 larvae belonging to diverse groups viz., foraminifera (12), hydrozoa (1), Pteropoda (1), cladocera (3), rotifera (5), chaetognatha (3), copepoda (54), decapoda (3), Doliolida (4), appendicularia (2) and larvae (14) were recorded. At Station 1, 102 forms of zooplankton were recorded, the majority was formed by copepoda (54), followed by 14 forms of larvae, foraminifera (12), rotifera (5), doliolida (4), 3 each to cladocera, chaetognatha and decapoda, appendicularia (2), 1 each to hydrozoa and pteropoda. At station 2, 98 zooplankton were represented by copepoda (52), foraminifera (12), larvae (12), rotifera (5), doliolida (4), 3 each to cladocera, chaetognatha and decapoda, appendicularia (2), 1 each to hydrozoa and pteropoda *(*Table-2). The percentage compositions of zooplankton were dominantly occupied by copepods followed by other groups at both the stations. Presently recorded zooplankton consisted of 102 forms including 102 larvae from both the stations. The descending order of abundance of the various groups of zooplankton is as follows: Copepoda > Larvae > Foraminifera > Rotifera > Doliolida > Cladocera > Chaetognatha > Decapoda Appendicularia > Hydrozoa > Pteropoda.

Studies on zooplankton communities, especially copepods are very important in assessing the health of coastal ecosystems (Ramaiah and Nair, 1997). Among the 3 sub orders of the order-copepoda, the sub-order calanoida represented by the bulk of the copepods with 26 species. This may be due to their continuous breeding behaviour, quick larval development and that they adopt well to the widely changing environmental conditions of the estuary. Further, among the calanoids, Acartia spp. dominated the other forms throughout study period (Madhupratap, 1987) and that of *Oithona* spp. among cyclopoid was noticed (Mckinnon and Klumpp, 1998). Similar findings were earlier reported in Parangipettai coastal waters by Santhanam and Perumal (2003) who have pointed out that the abundance of *Oithona* spp was mainly due to its high reproductive capacity. The abundance of copepods steadily increased at both the stations from March to June with rising trend of salinity. With the onset of southwest monsoon (July-December), salinity dropped down and the population density also declined (Bhunia and Choudhury, 1982).

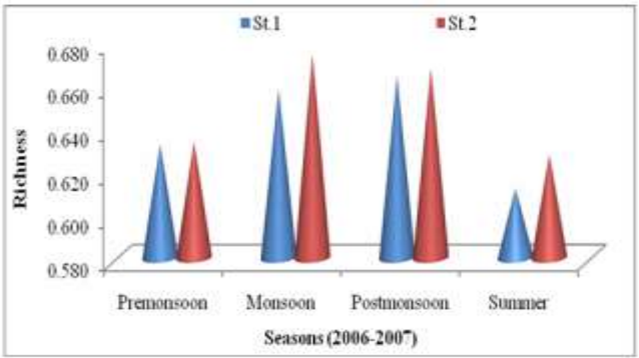

Fig.4. Seasonal variations of zooplankton richness recorded during 2006 to 2007

Among the microzooplankton-*Tintinnids*, the genus, *Tintinnopsis* was the most abundant one with 8 species viz., *Tintinnopsis cylindrica, T. beroidea, T. butschi, T. tocantinensis, T. tubulosa* and *T. mortensenii, Favella philippinensis* and *F. brevis.* Their predominance could be due to their high reproductive capacity and euryhaline nature (Govindasamy and Kannan, 1991). Similar observations were made by Godhantaraman (1994) in the Pichavaram mangroves. One of the characteristic features of the present observation was the relatively large occurrence of copepod nauplii, which could be attributed to high density of older stage copepods (Uye *et al.*, 2000). Among the rotifers, *Brachionus* was the most abundant genus with 3 species (*B. calyciflorus*, *B. Rubens* and *B. plicatilis*) and to lesser extent by *Keretella sp* as they are least tolerant to higher salinity. Similar observations have been made earlier from Pichavaram mangroves (Govindasamy and Kannan, 1991).

The ranges of population densities (org. l-1) of zooplankton were: 2042- 12218 and 2017- 9951 at Station 1 and 2 respectively (Fig. 2). The density of the zooplankton was comparatively high at Station 1. In the present study, minimum population density recorded during the monsoon seasons at station 2 and the maximum population density recorded during summer at station 1.

The recorded high densities might be due to the relatively stable environment condition, which prevailed during those seasons and great neritic elements presence from the adjacent sea could have also contributed to the maximum density of zooplankton. Further, salinity is the key factor influencing the distribution and abundance of zooplankton (Padmavathi and Goswami, 1996). The salinity showed positive correlation with zooplankton density (r=0.416 at Station 1 and r=0.742 at Station 2).

Table - 1: Physico-chemical characteristics of the Muthupettai mangrove (Southeast coast of India) during (February 2006 to January 2007)

Parameters	St.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Mean±Sd
A.Temp.(°C)	S1	24.5	24.7	31.2	32.8	30.9	29.6	28.3	27.7	25.5	23.2	21.0	23.5	±2.5
	S2	25.4	24.0	31.5	32.0	31.1	29.1	29.1	28.8	26.1	22.7	20.4	23.0	±2.0
W.Temp. (°C)	S1	27.5	28.9	29.3	30.4	28.8	27.4	26.7	26.0	27.5	25.0	23.5	25.0	±1.5
	S2	28.0	28.6	29.7	31.0	30.2	28.2	26.3	26.9	27.5	24.4	23.0	25.5	±1.0
Salinity (‰)	S1	29.0	31.0	33.0	34.0	33.0	32.0	32.0	31.0	24.5	22.0	18.0	20.0	±2.0
	S2	28.0	30.0	31.0	33.0	33.0	32.0	31.0	29.0	24.0	21.5	14.5	20.5	±1.5
pH	S1	8.1	8.1	8.2	8.3	8.2	8.1	8.2	8.0	7.8	7.5	7.6	7.9	±0.5
	S2	8.0	8.0	8.1	8.2	8.1	8.0	8.1	7.9	7.9	7.5	7.4	7.8	±1.0
Light extinction coefficient	S1	0.32	0.24	0.21	0.28	0.35	0.36	0.41	0.51	0.54	0.63	0.76	0.72	±1.5
	S2	0.31	0.26	0.25	0.31	0.33	0.4	0.43	0.49	0.57	0.64	0.83	0.78	±2.0
DO(mg/1)	S1	4.65	4.1	3.97	4.28	4.55	4.23	4.99	5.11	5.33	4.99	4.77	4.88	±1.0
	S2	4.35	4.04	3.18	3.01	3.537	4.34	4.57	4.87	5.03	4.2	4.61	4.43	±1.5
NO2 (μM)	S1	0.122	0.751	0.156	0.16	0.258	0.77	0.816	1.203	0.752	2.082	1.263	0.838	±0.5
	S2	0.378	0.845	0.243	0.128	0.273	0.891	0.923	1.143	0.992	1.944	1.784	1.232	±0.6
NO3 (μM)	S1	3.181	2.266	1.115	0.911	1.102	3.111	4.121	5.975	4.298	6.007	5.133	4.994	±1.9
	S2	2.31	2.433	1.89	1.151	1.286	4.01	4.231	4.295	4.231	5.783	5.873	5.03	±2.5
IP (μM)	S1	1.65	1.81	0.885	0.275	0.436	0.515	0.988	0.67	0.745	1.14	2.62	1.19	±1.0
	S2	1.76	1.64	1.03	0.321	0.523	0.765	0.832	0.719	0.872	1.231	2.98	1.32	±1.5
SiO3 (μM)	S1	30.23	35.36	32.12	30.21	44.26	42.733	52.92	61.25	102.21	68.21	56.26	48.15	±8.5
	S2	35.432	31.32	30.43	38.9	40.1	45.12	51.21	60.15	60.9	60.23	55.89	34.89	±4.0

Table - 2: List of zooplankton species recorded of the Muthupettai mangrove (Southeast coast of India) during (Feb. 2006 to Jan.2007)

Foraminifera	***B.plicatilis***	***C.aurivilli***	***C.vitrea***	Larval forms
Globigerina rubescense	***Keretella sp.***	***Euchaeta marina***	***Bomolochus sp.***	Crustacean nauplii
G.bulloides	Sagittoida	***E.concinna***	Harpacticoida	Copepod nauplii
Tintinnopsis cylindrica	***Sagittta sp.***	***Labidocera pavo***	***Longipedia sp.***	Barnacle nauplii
T.tubulosa	***S.enflata***	***L.acuta***	***L.weberi***	Shirmp zoea
T.mortensenii	***S.bifunctata***	***L.pectinata***	***Miracia effereta***	Mysis larvae
T.butschii	Copepoda	***L.minuta***	***Euterpina acutiforns***	Euphasid zoea
T.tocantinensis	***Calanus sp.***	***Acartia spinicauda***	***Microsetella sp.***	Crab zoea
T.beroidea	***Rhincalanus sp.***	***A.clausi***	***M.norvegica***	Polychaete larvae
Eutintinnus tennuis	***Nanocalanus minor***	***A.danae***	***M.rosea***	Ophiopluteus larvae
Codenellopsis sp.	***Eucalanus elongatus***	***A.centrura***	***Macrosettella sp.***	Gastropod veliger
Favella philipiensis	***E.monachus***	***A.southwelli***	***Metis jousseaumei***	Bivalve veliger
F.brevis	***Paracalanus parvus***	***A.erythraea***	***Clytemmnestra scutella***	Echinoderm larvae
Hydrozoa	***Acrocalanus gracilis***	***A.sewelli***	Decapoda	Fish eggs
Obelia sp.	***A.gibber***	Cyclopoida	***Acetes sp.***	Fish larvae
Pteropoda	***Pontella sp.***	***Oithona rigida***	***Lucifer sp***	
Cresis sp.	***Temoro turbinata***	***O.brevicornis***	***L.hanseni***	
Cladocera	***T.styliferra***	***O.similis***	Doliolida	
Evadne sp.	***T.discaudata***	***O.spinirostris***	***Salpa sp.***	
Penilia sp.	***Pseudodiaptomus serricaudatus***	***Oncaea venusta***	***S.fusiformis***	
Daphina sp.	***P.aurivilli***	***Corycaeus catus***	***Doliolum sp.***	
Rotifera	***Canthocalanus pauper***	***C.danae***	***D.coioides***	
Brachionus sp.	***Centronages tenuremis***	***C.speciosus***	Appendicularia	
B.calyciflorus	***C.furcatus***	***Sapphirina sp.***	***Oikopleura sp.***	
B.rubens	***Calamooia minor***	***Copilia sp.***	***Oikopleura parva***	

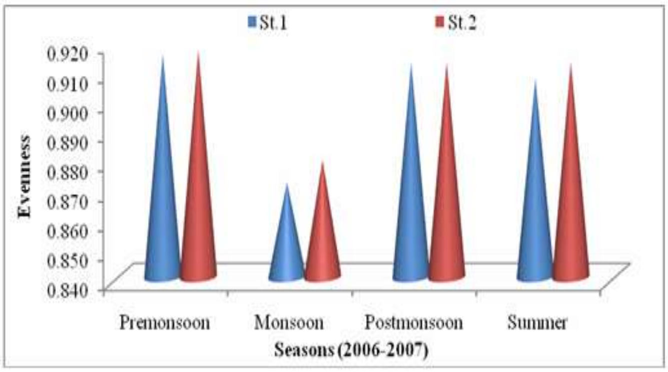

Fig.5. Seasonal variations of zooplankton evenness recorded during 2006 to 2007

Species diversity variations were: 3.22- 4.202 (Station 1) and 3.307- 4.124 (Station 2) (Fig. 3). Species richness ranges were: 0.612 - 0.664 and 0.627- 0.674 at Station 1 and 2 respectively (Fig. 4). The ranges of species evenness were: 0.872- 0.915 and 0.879- 0.916 at Stations 1 and 2 respectively (Fig. 5). The recorded high premonsoonal species diversity values may be due to the high zooplankton density that also indicated the stable high salinity values. The low species diversity was observed monsoon season, which could be attributed to heavy freshwater influx and low salinity (Govindasamy and Kannan, 1991; Godhandaraman, 1994). This is supported by the obtained statistically significant r values between diversity and density (r=0.343 at Station 1 and r=0.712 at Station 2).

Presently maximum species richness was recorded during the premonsoon season. During this season, population density of the zooplankton also increased with increasing species richness (Santhanam and Perumal, 2003). Maximum evenness was recorded during the premonsoon season and low evenness was observed during the monsoon season. Population density, species diversity and species richness values were high during premonsoon along with high values of evenness index, suggesting the equal distribution of species during this season (Karuppasamy and Perumal, 2000). The statistical correlation values of evenness showed positive correlation with species richness and species diversity at both the stations. The results of analysis of variance (ANOVA) for the difference in zooplankton distribution between the stations are significant at 0.05% level.

In the present investigation, the increase or decrease of salinity in the water column exerts either a direct or an indirect effect in the appearance or disappearance of some forms and replacement by others. The second effect is probably due to the migration of some species from one station to another to avoid either low or high salinity. The indirect effect might be due to the scarcity of food caused by the fluctuations of salinity in the waters ultimately affecting the population abundance of zooplankton. The present investigations of zooplankton distribution and abundance would form a useful tool for further ecological assessment and monitoring of these mangroves ecosystems of Muthupettai lagoon.

Acknowledgments

The authors are thankful to Prof. T. Balasubramanian, Dean of the Center of Advanced Study in Marine Biology, for encouragement and the authorities of Annamalai University for provided facilities and to the UGC, New Delhi, SSCP-Lab, DCI and SCL for financial assistance.

Reference

Alfred, J.R.B., S. Bricice, M.L. Issac, R.G. Michael, M. Rajendran, J.P. Royan, V. Sumitra and J. Wycliffe,1973. A guide to the study of freshwater organisms. J. Madras Univ. Suppl., 1:103-151.

Balasubramaniam, T. S., 2000. Modifications of craft and gear in diversified tuna fishery undertaken at Tharuvaikulam, Gulf of Mannar, India. Mar. Fish. Infor. Serv., T&E Ser., No. 164: 19-.

Bhunia, A.B. and A. Choudhury., 1982. Some ecological consideration for zooplankton production in Chemaguri Creek, Sagar Island (South) Sundarbans. Mahasagar Bull. Natl. Inst. Oceanogr., 15:247-252.

Chandran, R. and K. Ramamoorthy, 1984. Hydrobiological studies in the gradient zone of the Vellar estuary-Nutrients. Mahasagar Bull. Natl. Inst. Oceanogr., 17:133-140.

Das, J., S.N. Das and R.K. Sahoo, 1997. Semidiurnal variation of some physicochemical parameters in the Mahanadi estuary, East coast of India. Ind. J. Mar. Sci., 26:323-326.

Godhantaraman, N., 1994. Species composition and abundance of tintinnids and copepods in the Pichavaram mangroves (South India). Ciencias Marinas, 20:371-391.

Govindasamy, C. and L. Kannan, 1996. Ecology of rotifers of Pichavaram mangroves, Southeast coast of India. Ind. Hydrobiol., 1:69-76.

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

IAAB.,1998. Methodology for water analysis, IAAB Editorial Board, Hyderabad.

Kannan, R. and L. Kannan, 1996. Physico-chemical characteristics of seaweed beds of the Palk bay. Southeast coast of India. Indian J. Mar. Sci., 25:358-362.

Karuppasamy, P.K. and P. Perumal, 2000. Biodiversity of zooplankton at Pichavaram mangroves, South India. Ad. Biosci., 19:23-32.

Kathiresan, K., 2000. A review of studies on Pichavaram mangroves, South east coast of India. Hydrobiology, 430: 185-205.

Kathiresan, K., N. Rajendran and G. Thangadurai, 1996. Growth of a mangrove seedlings in the intertidal area of Vellar estuary, Southeast coast of India. Indian J. Mar. Sci., 25: 240-243.

Krishnamoorthy .K. and P. Subramanian, 1999. Organisation of commercially supporting meroplankton in Palk Bay and Gulf of Mannar biosphere reserve areas, Southeast coast of India. Indian J. Mar. Sci., 28:211-215.

Madhupratap, M., 1987. Status and strategy of zooplankton of tropical Indian estuaries. A review. Bull. Plankton. Soc. Jap., 34:65-87.

McKinnon, A.D. and D.W. Klumpp, 1998. Mangrove zooplankton of North Queensland, Australia. I. Plankton community st ruc ture and environment. Hydrobiologia, 362: 127-143.

Menon, N.N., A.N. Balchand and N.R. Menon, 2000. Hydrobiology of the Cochin backwater System - A review. Hydrobiologia, 130(1-3): 149-183.

Mukherjee, B., 1997. Environmental Biology, Tata McGraw Hill Publishing Company Limited, New Delhi.

Mulani, S.K., M.B. Mule and S.U. Patil, 2009. Studies on water quality and zooplankton community of the Panchganga river in Kolhapur city. J. Environ. Biol., 30:455-459.

Murugan, A. and K. Ayyakannu, 1991. Ecology of Uppanar backwater, Cuddalore. I. Physico-chemical parameters. Mahasagar-Bull. Natl. Ins. Oceanogr., 24, 31-38.
Nair, P.V.R., C.P. Gopinathan, V.K. Balachandran, K.J. Mathew, A. Regunathan, D.S. Rao and A.V.S. Murty., 1984. Ecology of mud banks: Phytoplankton productivity I Alleppey mudbank. Bull. Cent. Mar. Fish. Res. Inst., 31:28-34.
Neves, I.F., O. Recha, K.F. Roche and A.A. Pinto, 2003. Zooplankton community structure of two marginal lakes of the river Cuiaba (Mato Grosso, Brazil) with analysis of Rotifera and Cladocera diversity. Braz. J. Biol., 63:1-20.
Oswin, D. and A.A. Rahman, 1997. Impact of aquaculture effluents on mangroves. In: Procedings of the national seminar on water quality issues in aquaculture systems (Eds: R. Santhanam, V. Ramadhas, and P. Gopalakrishnan). Fisheries College, Tuticorin. pp:15-22.
Padmavathi, G. and S.C. Goswami, 1996. Zooplankton ecology in the Mandovi- Zuari estuarine system of Goa, west coast of India. Ind. J. Mar. Sci., 25:268-273.
Park, K.S. and H.W. Shin, 2007. Studies on phyto-and-zooplankton composition and its relation to fish productivity in a west coast fish pond ecosystem. J. Environ. Biol., 28: 415-422.
Pool, H.H. and L.R.G. Atkins, 1929. Photoelectric measurements of submarine illumination throughout the year. J. Mar. Biol. Ass. UK., 16:297-324.
Rajasegar, M., 2003. Physico-chemical characteristics of the Vellar estuary in relation to shrimp farming. J. Environ. Biol., 24:95-101.
Rajendran,, N., 1997. Studies on mangrove associated prawn seed resources of the Pitchavaram, southeast coast of India. Ph.D. Thesis, Annamalai University, India, pp: 131.
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. Ind. J. Mar. Sci., 26:20-25.
Santhanam, P. and P. Perumal, 2003. Diversity of zooplankton in Parangipettai coastal waters, southeast coast of India. J. Mar. Biol. Ass. India, 45:144-151.
Shannon, C.E. and W. Weaver, 1949. The mathematical theory of communication (University of Ilinois press, Urbana), pp:117.
Sinha, B. and M.R. Islam, 2002. Seasonal variation in zooplankton population of two lentic bodies and Assam State Zoo cum Botanical garden, Guwahati, Assam. Eco. Environ. Cons., 8:273-278.
Simpson, E.H., 1949. Measurement of diversity. Nature, 163: 688.
Stottrup, J.G., 2000. The elusive copepods: Their production and suitability in marine aquaculture. Aquaculture Res., 31:703-711.
Strickland, J.D.H. and T.R. Parsons,1972. A practical handbook of seawater analysis. Bull. Fish. Res. Bd., Canada, 167:311.
Tiwari, L.R. and V.R. Nair, 1991. Contribution of zooplankton to the fishery of Dharamtar creek, adjoining Bombay harbour. J. Indian. Fish. Ass., 21:15-19.
Uye, S., T. Shimazu, M. Yamamuro, Y. Ishitobi and H. Kamiya, 2000. Geographical and seasonal variations in mesozooplankton abundance and biomass in relation to environmental parameters in Lake shinji-Ohashi River- Lake Nakaumi brackish-water system. Japan. J. Mar. Syst., 26:193-207.
Vijayakumar, S., K.M. Rajan, R. Mridula, Mendon and Hariharan,2000. Seasonal distribution and behavior of nutrients with reference to tidal rhythm in the Mulki estuary, southwest coast of India. J. Mar. Biol. Ass. India, 42:21-24.