ISSN 2348-313X (Print)
International Journal of Life Sciences Research ISSN 2348-3148 (online)
Vol. 7, Issue 2, pp: (425-432), Month: April - June 2019, Available at: www.researchpublish.com

Diversity of macrobenthos in the estuaries of south Tamil Nadu

P. Selvaraj[1], M. Muniasamy[2], P. Murugesan[1]

[1]Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, Parangipettai – 608 502, Tamil Nadu – India

[2]Department of Environmental Sciences, Bharathiar University,

*Corresponding author Email: pmurugesaan74@gmail.com

Abstract: **Distribution of macrobenthic organisms in estuaries are mainly based on the optimal physico-chemical nature of the estuaries. The nature of estuaries is being modified by the climatic changes and also the manmade activities. In the presents study, the distribution and seasonal variations of macrobenthic faunal composition in 5 different major estuaries were assessed from South east Coast of Tamilnadu (Manakkudi estuary, Thengaipattinam estuary Rajakkamangalam estuary, Punnaikayal estuary and Vembar estuary). Totally 64 species of macrofaunal species have been recorded in various estuaries. Among the benthic groups, polychaetes were the most dominant group in the present study followed by other faunal groups. The maximum diversity (H') value (4.12) was observed in (st-1) Manakkudi estuary during summer season compared to other estuaries and the minimum diversity value (1.53) was recorded in (st-3) Rajakkamangalam estuary during monsoon season. BIO-EN method proved the salinity, DO, silt, clay, TOC and total phosphorous as the major environmental variables influencing the faunal distribution.**

***Keywords*: Macrobenthos, Polychaetes, Community structure, Estuaries, Diversity.**

1. INTRODUCTION

Estuaries are home to a variety of animals and plants (Pritchard, 1967). The benthic substrate has the important role in the marine environment and provides home for many sessile, burrowing, crawling and even swimming organisms and it acts as a store house of organic matter and inorganic nutrients. Benthic fauna in marine sediments play an important role in ecosystem processes such as nutrient cycling, pollutant metabolism, dispersion and burial and secondary production (Snelgrove, 1998). Among the benthic fauna, polychaetes, by virtue of their numerical abundance and diversity, widespread presence, diversity of feeding modes, differential tolerance to environmental imbalances and limited motility, have been used in many studies as markers of environmental health (Tomassetti and Porrello, 2005; Chollet and Bone, 2007; Hughes *et al*., 2009).

Therefore, benthos can give reliable information on the water quality. Due to their differential tolerance, they have been considered as the best indicators of anthropogenic perturbations. Further, their long life cycles allow studies conducted by aquatic ecologists to determine any decline in environmental quality. In the past two decades, estuary and other backwaters have been used as the dumping yard for anthropogenic, industrial and domestic loading (Balachandran e*t al*., 2005). Knowing the spatial distribution of benthos, their relative levels in distribution is the first step in understanding the human impacts on the polychaetes of macrobenthic community. Global climate change, for example, may be adversely affecting the benthos of a particular region. This cannot be proven unless there is an understanding of the current scenario of benthos in the estuaries of Tamilnadu, which can, in future, be compared in terms of temporal and spatial distributions of benthic organisms.

Taking cognizance of the facts elaborated above, in the present study an extensive seasonal survey was made with a view to map out benthic biodiversity with special reference to polychaete diversity in the selected estuaries along the south Tamil Nadu.

ISSN 2348-313X (Print)
International Journal of Life Sciences Research ISSN 2348-3148 (online)
Vol. 7, Issue 2, pp: (425-432), Month: April - June 2019, Available at: www.researchpublish.com

2. MATERIALS AND METHODS

For the present study five major estuaries have been studied. The seasonal wise survey was conducted from April 2012 to March 2013 and three replicate samples were collected in each estuary. The description and geographical locations of each estuary are given below (Fig. 1):

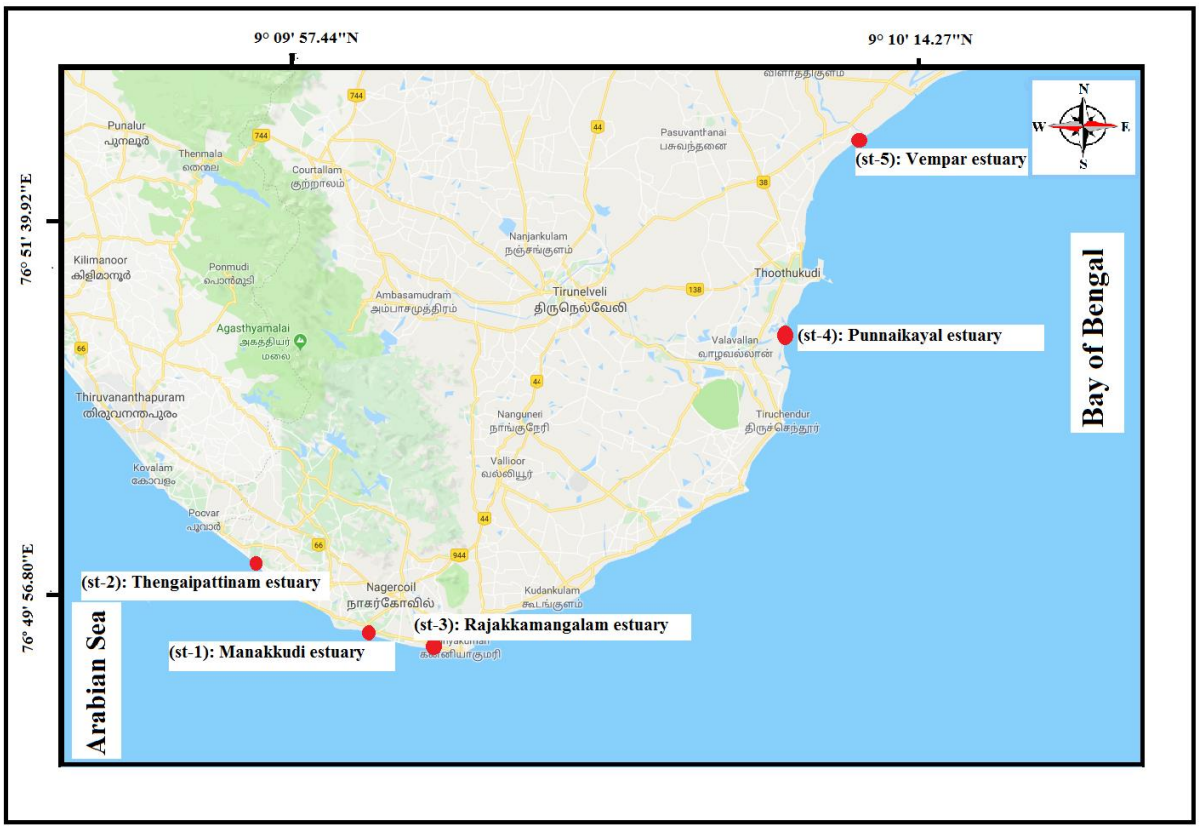

Fig. 1. Map showing the study area

A) **Station 1 (st-1)**: Manakkudi estuary which is situated in the coastline of Kanyakumari (Lat. 08° 06' 503"N Long. 077°28' 503" E).

B) **Station 2 (st-2)**: Thengaipattinam estuary is situated in Kanyakumari district (Lat. 08º 14' 402"N Long. 77º 10' 084"E).

C) **Station 3 (st-3)**: Rajakkamangalam estuary, situated in Kanyakumari district (Lat. 08º 07' 080"N Long. 77º 22' 233"E).

D) **Station 4 (st-4)**: Punnaikayal estuary is situated in Thothukudi district (Lat. 08º 38' 205"N Long. 078º 07' 415"E).

E) **Station 5(st-5)**: Vempar estuary is situated in Thoothukudi district (Lat. 09º 05' 368"N Long. 78º 21' 787"E).

Water temperature was measured using a standard thermometer with +0.5^{o}C accuracy. Salinity was measured using a Hand Refractometer (Atago co. Ltd., Japan). The water pH was measured using a battery operated pH pen (Eutech Instrument Singapore). Dissolved oxygen was analyzed following the Winkler's method (Strickland and Parsons, 1986). For the analysis of TOC (mgC/g), the shade dried sediment samples were treated with 0.4 N Chromic acid and the resulting solution was titrated against 0.2 N Ferrous ammonium sulphate using 0.025 N Ferrous Phenanthroline as indicator (Elwakeel and Riley, 1956). Total nitrogen and total phosphorous was measured by following the method of Grasshoff *et al*. (1983). The percentage composition of sand, slit and clay was worked out by the pipette method as proposed by Krumbein and Pettijohn (1938).

The sediment sample for the quantitative analysis of benthic fauna collected using a Peterson grab. The grab employed was found to take a sample covering an area of 0.1m^2. The procedure adopted for sampling was following the method of Mackie (1994). After collecting samples, they were emptied into a plastic tray. The larger organisms were handpicked

ISSN 2348-313X (Print)
International Journal of Life Sciences Research ISSN 2348-3148 (online)
Vol. 7, Issue 2, pp: (425-432), Month: April - June 2019, Available at: www.researchpublish.com

immediately from the sediments and then sieved through 0.5mm mesh screen. The organisms retained by the sieve were placed in a labeled container and fixed in 5-7% formalin. Subsequently, the organisms were stained with Rose Bengal solution (0.1g in 100 ml of distilled water) for greater visibility during sorting (Plate-I). All the species were sorted, enumerated and identified to the advanced level possible with the consultation of available literature. The works of Fauvel (1953), Day (1967) were referred for polychaetes; Barnes (1980) and Lyla *et al*. (1999) for crustaceans; Subba Rao *et al*. (1991) and Ramakrishna (2003) for molluscs.

Further, the data were approached to various statistical methods namely Univariate, and multivariate methods available in PRIMER (ver. 7.) statistical software (Clarke and Gorley, 2015).

3. RESULTS AND DISCUSSION

Environmental characteristics

As regards environmental entities, temperature is known to influence the chemical characteristics of interstitial waters and thereby determining the occurrence and distribution of benthic organisms. In the present study the water temperature (°C) in various stations varied from 27 to 36.3 with minimum in St-4 (monsoon) due to heavy rain and maximum in St-1 (summer) which might be due to high intensity of solar radiation and evaporation. Present finding are in harmony with the studies of Joydas and Damodaran, (2009); Bolam *et al*., (2010). Like temperature, the salinity is the major influencing factor and considered to be the basic as well as the prime factor among the environmental variables in the estuarine environment. The Salinity (PSU) level was ranged from 4 to 41.8 with minimum in St-2 during monsoon period due to downpour and inflow of fresh water from the land and maximum in St-5 during summer season due to the evaporation and less tidal action with decreased freshwater inflow and the minimum during monsoon due to downpour and inflow of fresh water from the land. Water pH was in the range of 6.3 to 8.2 with minimum value in St-2 (monsoon) and maximum value in St-5 (summer) which might be due to the utilization of carbon dioxide in the photosynthetic process. The present findings are in agreement with that of Mondal (2009); Kundu (2009). The dissolved oxygen is an important factor influencing the productivity of the marine environment. In the present study, the level of Dissolved Oxygen (mg/l) in various stations varied from 2.44 to 4.2 with minimum level recorded in St-3 during summer period by the fact that the higher salinity and temperature and maximum level recorded in St-5 during monsoon period, which could be attributed to high inflow of freshwater from the terrestrial area. The trend noticed in the present study is in conformity with the findings of Upadhayay (1988), Mitra *et al.* (1990).

Table. 1. Seasonal variations in the physico-chemical parameters in water and sediment samples collected in various estuaries

		Water temperature (°C)	Salinity (PSU)	Water pH	DO (mg/l)	Sediment pH	TOC (mg C/g)	TP (µg/g)	TN (µg/g)
St-1	**Summer**	36.3	24	6.9	5.21	7.2	6.4	12.2	12.22
	Premonsoon	31.4	18.3	7.2	3.69	7.6	3.85	10	10.11
	Monsoon	28.7	4.4	6.9	4.25	7.3	4.76	12.49	13.82
	Postmonsoon	26.2	28.2	8.1	4.5	8.5	3.82	12.2	12.24
St-2	**Summer**	26.9	7	8.1	5.1	8.6	5.55	8.15	8.2
	Premonsoon	31.4	4.3	6.8	3.2	7.4	2.86	12.2	12.44
	Monsoon	26.4	4	6.3	3.5	6.6	5.89	9.1	9.76
	Postmonsoon	28.3	6.9	7.8	4.25	8.2	4.34	9.2	9.5
St-3	**Summer**	27.6	14.2	7.4	3.15	7.9	4.65	10.2	10.24
	Premonsoon	27.8	12.3	7.9	2.44	8.3	5.45	9.9	9.2
	Monsoon	24.1	10.5	6.8	2.9	8.2	4.5	2.75	4.32
	Postmonsoon	26.1	12.5	7.3	2.85	7.9	6.29	6.8	6.82
St-4	**Summer**	27.2	38.5	7.9	3.8	8.3	6.56	7.2	6.45
	Premonsoon	27	27.5	8	3.9	8.4	3.35	10.1	10.27
	Monsoon	26.1	31.9	7.1	3.43	7.6	4.02	9.78	10.1
	Postmonsoon	31.1	29.8	7.7	4.2	8.1	2.77	8.2	8.5
St-5	**Summer**	29.9	41.3	6.2	4.75	7	6.67	12.65	12.45
	Premonsoon	27.3	41.8	7.3	3.95	7.9	2.2	4	4.24
	Monsoon	27.9	9.8	7	6.2	7.5	2.5	7.25	7.75
	Postmonsoon	30.2	40.1	8.2	3.5	8.6	6.84	5.6	5.2

ISSN 2348-313X (Print)
International Journal of Life Sciences Research ISSN 2348-3148 (online)
Vol. 7, Issue 2, pp: (425-432), Month: April - June 2019, Available at: www.researchpublish.com

Studies on the sediment composition also important factor influencing the benthic diversity (Gray, 1981). From the soil texture analyses, the 5 stations could be categorized in to (a) Silt loam, Sand (St-1, St-2), (b) Silt loam, sand and Sandy loam (St-3), (c) Silt loam, Loamy sand, Sand (St-4), (d) Sandy loam, Sand, Loamy sand (St-5) (Table. 2). The soil texture varied significantly between the seasons and stations. Similarly, Woodruff et al. (2001) stated that the nature of the sediments are being modified by seasonally through erosion-deposition, rather than input of sediments from watershed; Total organic carbon is the essential nutrient for the benthic organisms (Garcia-Arberas & Rallo, 2002).

Table. 2. Seasonal variations of soil classes recorded in various estuaries

Stations	Summer	Premonsoon	Monsoon	Postmonsoon
St-1	Silt Loam	Sand	Sand	Sand
St-2	Silt Loam	Sand	Sand	Sand
St-3	Silt Loam	Sand	Sand	Sandy Loam
St-4	Silt Loam	Loamy Sand	Sand	Loamy Sand
St-5	Sandy Loam	Sandy Loam	Sand	Loamy Sand

The level of Total Organic Carbon (mgC/g) ranged from 2.16 to 6.84 with minimum value was found in St-2 during monsoon season due to high flow of water in the estuary and maximum values were in St-5 during postmonsoon, which could be attributed to settling of organic matter in the form of small particles. (Fig.6). Similarly, the minimum TOC was recorded during monsoon and maximum in summer which is in good agreement with the results of Nair *et al.* (1983) and Chandran (1987) in Vellar estuary who studied the benthic diversity in relation to TOC; Total phosphorus and total nitrogen are said to be the two most important sediment nutrients, which determines the productivity of marine environment. Total Phosphorous (µg/g) level ranged from 2.75 to 12.65 with minimum level was in St-3 during monsoon and maximum level was observed in St-5 during summer season. Total Nitrogen (µg/g) level varied from 6.6 to 8.6 with minimum level was observed in St-2 during monsoon and maximum was in St-5 during postmonsoon. Similarly, Manikoth and Salih (1974) reported high nitrogen concentration during monsoon season in the Vembanad estuarine system, southwest coast of India. Seasonal variations of the physico-chemical parameters recorded in both water and sediment samples in various estuaries are given in Table. 1.

Biological entities

In the present study, organisms of the following five animal taxa such as Polychaetes, Crustaceans, Bivalves, Gastropods and "Others" were recorded in the benthic samples collected.

Totally 67 macro benthic species were recorded in various stations (Estuaries) of Tamil Nadu. Of these, 49 were polychaetes, 8 were bivalves, and four each were crustaceans and gastropods, and two species of "others". The dominant polychaetes in the present study were *Arcidea* sp., *Capitella capitata*, *Armandia longicaudata*, *Euclymene* sp., *Chone collaris*, *Nephtys* sp., *Branchiomaldane vincenti*, *Neries* sp., *Notomastus latericeus*, *Ophelia* sp., *Polydora* sp., *Polyophthalmus pictus*, *Potamilla* sp., *Platyneries* sp. and *Prionospio* sp. Bivalves formed second dominant group which comprised of *Anadara* sp. *Katelysia opima*, *Paphia* sp., *Perna indica*, *Meretrix meretrix* and *Meretrix casta*. In gastropod, *Cerithedia cingulata*, *Turritella* sp. and *Bullia* sp., were the common species and one species belonged to the "others".

Population density

The population density of macrofauna is governed by various environmental variables such as temperature, salinity, sediment type, organic carbon level in the sediment and tidal action (Maurer *et al.* 1978). The density of macro fauna was varied from 650 to 4340 nos. /m^{-2} with minimum in St-3 during monsoon and maximum population in St-1 during summer season (Fig. 2) and the summer maxima is in agreement with the studies of Denadai *et al.* (2000); Dauvin *et al.* (2010).

ISSN 2348-313X (Print)
International Journal of Life Sciences Research ISSN 2348-3148 (online)
Vol. 7, Issue 2, pp: (425-432), Month: April - June 2019, Available at: www.researchpublish.com

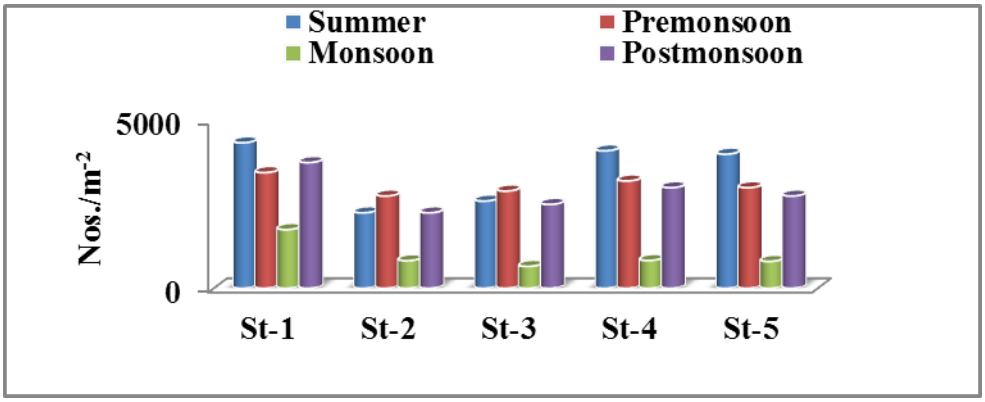

Fig. 2. Seasonal variations in the Population density of macrobenthic fauna in various stations

Percentage composition of macrofauna

Species composition of the benthic macrofauna in the present observation showed in the order of polychaetes, crustaceans, bivalves, gastropods and groups 'others'. The dominance of polychaetes in terms of density and species composition in diverse ecological niches is due to their high degree of adaptability to a wide range of environmental factors. Such a preponderance of polychaetes in the benthic communities was reported earlier by Kundu *et al.* (2009) and Murugesan *et al.* (2011) in Parangipettai coastal waters. (Fig. 3)

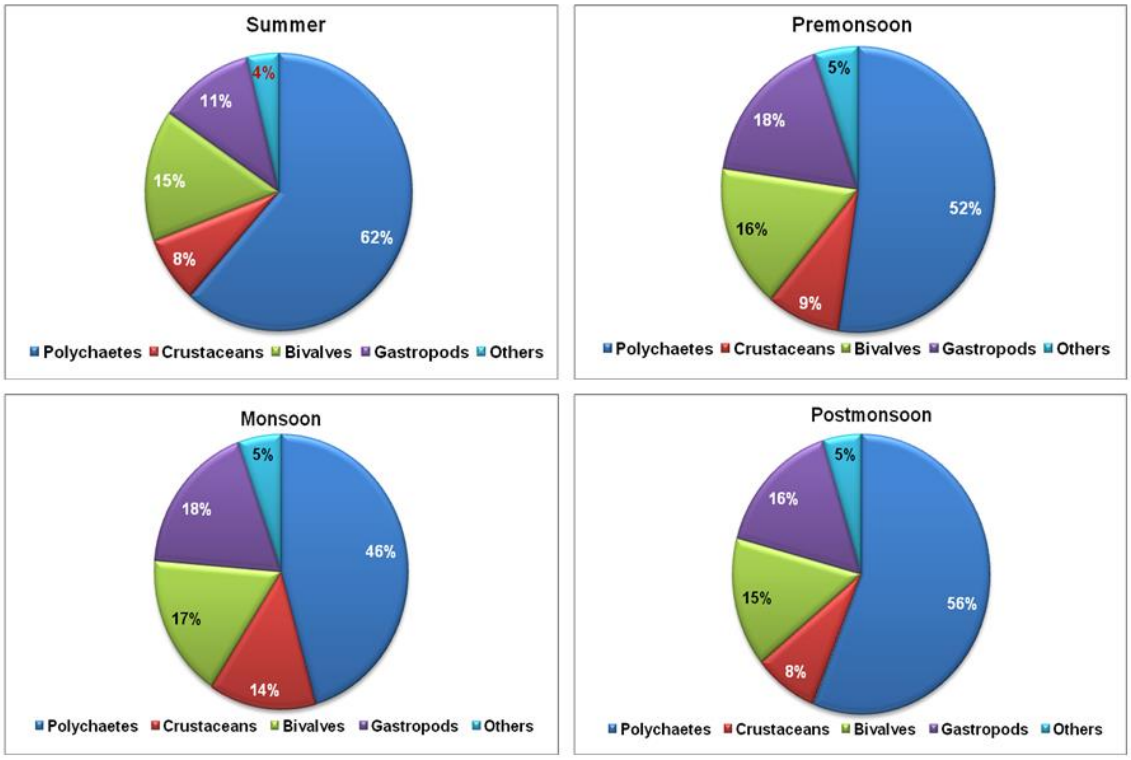

Fig.3. Seasonal variations in the percentage composition of macro faunal groups

Species diversity (H')

Diversity is a measure of the complexity of the community structure and it increases (or) decreases due to physical, chemical and biological factors. High diversity generally indicates a balanced, stable and responsive community. Low diversity occurs in an area where the community is dominated by a few species. The species diversity in various stations fluctuated between 1.53 and 4.12 (H') with minimum in St-3 during monsoon period and maximum in St-1 during summer period (Fig. 11). Similar range of diversity values was also recorded earlier by Murugesan (2002) in Vellar estuary.

ISSN 2348-313X (Print)
International Journal of Life Sciences Research ISSN 2348-3148 (online)
Vol. 7, Issue 2, pp: (425-432), Month: April - June 2019, Available at: www.researchpublish.com

Margalef index (d) (Species richness)

As in the species diversity, species richness values were also low (1.65) during monsoon in station 3 and high (3.52) during summer months in station 1. The reason is, such that it is easier to tolerate high salinities at high temperatures than at low temperatures (Sanders, 1968) and as a result more marine forms are able to flourish in tropical estuaries (Panikker, 1940). Hence, the high species richness noticed during summer and postmonsoon seasons might be ascribed to the entry of marine forms into the estuary and the low values could be attributed to the drastic change in salinity during monsoon season. The trend with respect to richness values of the present study is in harmony with the studies made by Sebastin Raja (1990) in Sunnambar estuary.

Pielou's evenness index (J')

The evenness value in various stations was found to range from 0.99 to 0.76 (J') with minimum value in St-3 during monsoon season and maximum value was recorded in St-1 during summer season.

Table. 3. Seasonal variations in the diversity (H'), richness (d) and evenness (J') recorded in various estuaries

		Species diversity (H')	Species richness (d)	Species evenness (J')
St-1	**Summer**	4.12	3.52	0.96
	Premonsoon	3.55	3	0.9
	Monsoon	2.98	2.43	0.88
	Postmonsoon	3.32	3.13	0.91
St-2	**Summer**	2.1	2.13	0.86
	Premonsoon	3.21	2.8	0.81
	Monsoon	2.12	2.1	0.78
	Postmonsoon	2.2	2.32	0.78
St-3	**Summer**	2.11	2.1	0.87
	Premonsoon	2.43	2.53	0.8
	Monsoon	1.53	1.65	0.76
	Postmonsoon	2.22	2.14	0.79
St-4	**Summer**	3.1	3.11	0.99
	Premonsoon	2.94	2.89	0.91
	Monsoon	1.98	2	0.87
	Postmonsoon	2.98	3	0.88
St-5	**Summer**	2.98	2.53	0.95
	Premonsoon	2.54	2.63	0.88
	Monsoon	2	1.99	0.82
	Postmonsoon	2.55	2.65	0.87

BIO-ENV

The BIO-ENV yielded the combinations of five environmental entities (salinity–DO–silt–clay–TOC–total phosphorous) as best match 'defining' the faunal distributions. The associated coefficient of environmental to biotic similarity was 0.90. Following this, DO, sand, Temperature, pH and total nitrogen were also manifested as important variables influencing the faunal distribution. True to this, in a study made by Murugesan (2002) reported the similar combinations of environmental variables influencing the faunal distribution.

4. CONCLUSION

To conclude, the present survey yielded good amount of information on the benthic diversity in the estuaries of south Tamilnadu. As the studies of yesteryears in the estuaries are fragmentary in nature, the findings of the present study form comprehensive one with detailed account on the benthic biodiversity in general and polychaete taxonomy in particular. Further, the present study also shed light on the physico – chemical characteristics of the estuaries of south Tamilnadu as the environmental parameters are known to influence the distribution of benthic organisms. Therefore, the information generated during the study would be of great help to those who intend to work in this line.

ACKNOWLEDGEMENT

The authors are thankful to the Director and Dean, CAS in Marine Biology, Annamalai University for the support.

REFERENCES

[1] Balachandran, K. K., C. Lalu Raj, M. Nair, M. Joseph, T. Sheeba and P. Venugopal, 2005. Heavy metal accumulation in a flow restricted, tropical estuary. *Estuar. Coast. Shelf Sci*., 65: 361-370.

[2] Barnes, R. D., 1980. *Invertebrate Zoology*. Saunders College, Philadelphia. 108pp.

[3] Bolam, S. G., C. R. S. Barrio-Frojan, and J. D. Eggleton, 2010. Macrofaunal production along the UK continental shelf. *J. Sea Res.*, 64: 166-179..

[4] Chandran, R., 1987. Hydrobiological studies in the gradient zone of the Vellar estuary. I Physicochemical parameters. *Mahasagar – Bull. Natn. Inst. Oceanogr*., 17: 69– 78.

[5] Chollet I. and David Bone, 2007. Effects of heavy rainfall on polychaetes. Differential spatial patterns generated by a large-scale disturbance. *J. Exp. Mar. Biol. Ecol*., 340: 113-125.

[6] Clark, K.R., Gorley, R.N., 2015. PRIMER V7: User Manual/Tutorial. PRIMER-E: Plymouthp. 3-296.

[7] Dauvin, J. C., S. Alizier, C. Vallet and T. Ruellet, 2010. Does the Port 2000 harbour construction have an effect on the Seine estuary suprabenthic community? *Estuar. Coast. Shelf Sci*., 86(1): 42-50.

[8] Day, J. H., 1967. *A Monograph on the Polychaeta of Southern Africa part I Errantia.* Trustees of the British Museum (Natural History) London VI-XXIX: 1-458.

[9] Denadai, M. R., A. C. Z. Amaral and A. Turra, 2000. Annual variation of the malacofauna in two intertidal sandy substrates with rock fragments in South-eastern Brazil. *Rev. Bras. Oceanogr*., 48: 141-150.

[10] El Wakeel, S. K. and J. P. Riley, 1956. The determination of organic carbon in marine muds.

[11] Fauvel, P., 1953. The Fauna of India including Pakistan, Ceylon, Burma and Malaya. Annelida: Polychaeta, Allahabad. 507pp.

[12] Garcıa-Arberas, L. and A. Rallo, 2002. The intertidal soft-bottom infaunal macrobenthos in three Basque estuaries (Gulf of Biscay): a feeding guild approach. *Hydrobiologia*, 475–476: 457–468.

[13] Grasshoff, K., M. Ehrhardt and K. Kremling, 1983. *Methods of Seawater Analysis.* Verlag Chemie., Germany, 1-419

[14] region along the west coast of India. *Indian J. Mar. Sci*., 9(2): 106-110.

[15] Hughes, D. J., P. A. Lamont, L. A. Levin, M. Packer, K. Feeley and J. D. Gage, 2009. Macrofaunal communities and sediment structure across the Pakistan margin oxygen minimum zone, Northeast Arabian sea. *Deep Sea Res*., 56: 434-448.

[16] Joydas, T. V. and R. Damodaran, 2009. Infaunal macrobenthos along the shelf waters of the west coast of India. *Indian J. Mar. Sci.*, 38(2): 191-204.

[17] Krumbein, W. C. and F. J. Pettijohn, 1938. *Manual of Sedimentary Petrology*. New York, Appleton, Century and Crofts, lnc., 549 pp.

[18] Kundu, S., Nityananda Mondal, P. S. Lyla and S. Ajmal Khan, 2009. Biodiversity and seasonal variation of macro-benthic infaunal community in the inshore waters of Parangipettai Coast. *Environ. Monit. Assess.,* 163: 67-79.

[19] Lyla, P. S., S. Velvizhi and S. Ajmal Khan. 1999. *A Monograph on the Amphipods of Parangipettai Coast.* Annamalai University, India. 78pp.

[20] Mackie. S. Y., 1994. A dercodon pleijeli gen. Et sp. nov. (Polychaeta: Ampharetidae) from the Mediterranean Sea. In: J.-C. Dauvin, L. Laubier & D.J. Reish (Eds), *Actes de la 4eme Conf. Int. Polychetes. Memoires du Museum National d'histoire Naturelle,* 162: 243-250.

[21] Manikoth, S. and K. Y. M. Salih, 1974. Distribution characteristics of nutrients in the estuarine complex of Cochin. *Indian J. Mar. Sci.,* 3: 125-130.

[22] Mitra, A., K. C. Patra, R. C. Panigrahy, 1990. Seasonal variations of some hydrographical parameters in tidal creek opening into the Bay of Bengal. *Mahasagar- Bull. Natn. Inst. Oceanogr.*, 23(1): 55- 62.

[23] Mondal, N., 2009. Biodiversity of meiobenthos in the inshore waters off Parangipettai coast (Southeast coast of India) and its use as a pollution indicator. *Ph.D., Thesis, Annamalai University*, India, 221pp.

[24] Murugesan, P., 2002. Benthic biodiversity in the marine zone of Vellar estuary (Southeast Coast of India). *Ph. D., Thesis Annamalai University*, India, 359 pp.

[25] Murugesan, P., M. Muniasamy, V. Muthuvelu, S. Vijayalakshmi and T. Balasubramanian, 2011. Utility of benthic diversity in assessing the health of an ecosystem. *Indian J. Mar. Sci.*, 40: 783-793.

[26] Nair, N. B., P. K. Abdul Azis, K. Dharmaraj, M. Arunachalam, K. Krishna Kumar and N. K. Balasubramanian, 1983. Ecology of Indian estuaries: Part- I – Physico chemical features of water and sediment nutrients of Ashtamudi estuary. *Indian J. Mar. Sci*., 12: 143- 150.

[27] Panikkar, N. K., 1940. Influence of temperature on osmotic behaviour of some crustacea and its bearing on problems of animal distribution. *Nature*, 146: 366.

[28] Pritchard, D. W., 1967. What is an Estuary? Physical viewpoint. In Estuaries. *Publication AAAS*, Washington, D. C pp. 83.

[29] Ramakrishna, D. A., 2003. *Manual on identification of schedule molluscs from India*. 40pp.

[30] Sanders, H. L., 1968. Marine benthic diversity: A comparative study. *American Naturalist*, 102: 243-282.

[31] Sebastin Raja, S., 1990. Studies on the ecology of benthos in Sunnambar estuary, Pondicherry, Southeast coast of India. *Ph.D. Thesis, Annamalai University*, India.

[32] Sivadas, S., B. Ingole and M. Nanajkar, 2010. Temporal variability of macrofauna from a disturbed habitat in Zuari estuary, west coast of India. *Environ. Monit. Ass*. 10661-010-1371.

[33] Snelgrove, P. V. R. 1998. The biodiversity of macro-faunal organisms in marine sediments. *Biodiversity and Conservation, 7*, 1123-1132.

[34] Strickland, J. D. H. and T. I. Parsons, 1986. A manual of sea water analysis, (2Ed.) *Bull. Fish. Res. Can.*, 167: 310pp.

[35] Subba Rao N. V., K. V. Surya Rao S. Maitra, 1991. *Marine molluscs. State Fauna Series 1, Part 3. Fauna of Orissa*. *Zoological Survey of India*, Kolkata, 1–175.

[36] Tomassetti, P. and S. Porrello 2005. Polychaetes as indicators of marine fish farm organic enrichment. *Aquacult. Int*., 13: 109-128

[37] Upadhyay, S., 1988. Physico- chemical characteristics of the Mahanadi estuarine ecosystem, East coast of India. *Indian J. Mar. Sci*., 17: 19- 23.

[38] Woodruff, J.D., Geyer, W.R., Sommerfield, C.K. and Driscoll, N.W., 2001. Seasonal variation of sediment deposition in the Hudson River estuary. *Marine Geology, 179*; 105-119.