Benthic invertebrates of a tropical estuary in the western coast of Sri Lanka

D.D.G.L. Dahanayaka[1*], S.C. Jayamanne[1] and M.J.S. Wijeyaratne[2]
[1] National Aquatic Resources Research and Development Agency, Crow Island, Colombo 15, Sri Lanka
[2] Department of Zoology, University of Kelaniya, Kelaniya, Sri Lanka
[*]Corresponding author. Phone: +94 112 521000, Fax: +94 112 521005
Email: ddgldahanayaka@gmail.com

ABSTRACT
Spatial distribution, diversity of macrobenthos and their relationships between physico-chemical parameters of the water and sediments were studied in the Negombo estuary (7°6' – 7°12'N, 79°49' – 79°53'E), western coast of Sri Lanka from January to December 2005. Benthic samples were taken from 37 sampling sites scattered over the estuary using van Veen grab sampler. The depth, pH, temperature, salinity, dissolved oxygen content, nitrate nitrite phosphate contents in the water, sea grass biomass, abundance of mangroves and sediment texture were determined at each sampling site. The similarities among the macrobenthic communities at different sampling sites were determined using Bray-Curtis similarity coefficient and ordinations of Non-metric Multidimensional Scaling (MDS). A total of 9062 benthic invertebrates consisting of 36 species of polychaetes, 24 species of gastropods, 16 species of bivalves and 13 species of crustaceans were recorded. The ranges of Species richness, Shannon Weiner (diversity) index (H'), Simpson index (J') and Pielou's index of the sampling sites were 0-27, 0-2.85, 0-0.95 and 0-0.87 respectively. Low or zero diversity was recorded from deeper areas and high abundance and diversity were noted at the marginal areas of the estuary. Significance differences between groups of sampling sites which were clustered together with the 30% similarity level of the Bray Curtis similarity analysis were noted. The ordinations of Non-parametric Multidimensional Scaling (MDS) indicated that the clustering of sites which were located in the northern region of the estuary was based on the abundance of polychaetes. Spearman rank correlation coefficients for permutations of environmental variables indicated that the combination of salinity, depth, nutrient contents of water and sea grass biomass mostly affect the abundance and diversity of macrobenthos in the Negombo estuary.

Keywords: diversity, macrobenthos, Negombo estuary, Sri Lanka.

1. INTRODUCTION

The Negombo estuary (7°6' – 7°12'N, 79°49' – 79°53'E) is a shallow basin estuary in the Western Coastal region of Sri Lanka. The surface area of the estuary is 3502 ha (CEA/Euroconsult, 1994). The estuary is considerably chocked on tidal frequencies because of a narrow entrance. The exchange mechanisms maintain the salinities, the siltation rates, the pollution transport and the biological productivity within the estuary (Rajapaksha, 1997). The seasonal fluctuations in species diversity, narrow opening of the estuary to the sea, distribution pattern of mangrove vegetation around the estuary and the salinity distribution pattern of the lagoon has resulted a greater niche diversification within the estuary leading to a high species diversity (Jayakody & Dahanayaka, 2005).

Survival, distribution and abundance of the macrobenthos depend on the characteristics of their environment. Benthic community structure depends on environmental factors such as salinity, organic mater content, soil texture, sediment particles and the ability of constructing permanent burrows in sand etc. Different macrobenthos communities are associated with different qualities of the sediment. Since most of the macrobenthos are detritivores the amount of organic matter in the sediment also affects their community structure. Therefore, any form of anthropogenic input which increases the organic matter content may also decide the community composition of the macrobenthos in aquatic environments (Perkins, 1974). Use of some types of fishing gear such as push nets, trawl nets and encircling nets can adversely affect the macrobenthic community structure by destroying the sea grass beds which are one of their most favoured habitats (Amarasinghe *et al*., 1993). Estuarine areas have long been subjected to industrialisation and urbanisation. It is only recently that the biological functioning of those areas been studied in relation to anthropogenic threats. In particular, because of ability to integrate over time changes to the water column and sedimentary regime, the response by the benthos to natural and anthropogenic perturbations is especially important (Elliott & Taylor, 1989). Since the composition and abundance of benthic organisms in aquatic environment are closely related to the water quality (Mackenthum, 1966), the benthic organisms are considered as good indicators of past and present conditions of water and the composition of benthic communities is found to be closely related to environmental pollution (Bruse *et al.*, 1975). The information on changes in species composition, species diversity and the relative abundance of constituent species can be useful in measuring the nature and extent of environmental impacts on that community (Herricks & Cairns, 1982; Westman, 1985; Smith *et al.*, 1988).

Present study was carried out to investigate the spatial variation of macrobenthic diversity in the Negombo estuary, which is subjected to variety of anthropogenic activities (Samarakoon & van Zon, 1991). An attempt was also made to find out how their distribution is affected by the environmental factors such as depth, pH, temperature, salinity, dissolved oxygen content, nitrate nitrite phosphate contents in the water and the presence of sea grasses and mangroves.

2. MATERIALS AND METHODS

Benthic samples were collected from 37 sites in the Negombo estuary (Fig. 1) western coast of Sri Lanka from January to December 2005 using a Peterson grab and immediately fixed using 1% Rose Bengal. The approximate surface area sampled at each sampling site was 0.025 m^2. At each sampling site, depth, pH, temperature, salinity, dissolved oxygen content, nitrate nitrite phosphate contents in the water were measured and the presence of sea grasses and mangroves was recorded using an arbitrary scale. The anthropogenic activities that are carried out at each sampling site such as disposal of sewage and fishing were also noted. The benthic samples were subjected to wet sieving through 4 mm, 2 mm, 1 mm and 500 μm mesh sieves to separate the benthic fauna from the substrate (Sutherland, 1997). The organisms retained in each sieve were collected, preserved in 10% formalin and identified as much as possible using Needham & Needham (1962), Fauchald (1977), Kirthisinghe (1978), Fernando (1990) and Robertson et al. (1997). The number of organisms of each species was also recorded. The organic matter content of the benthic sediments at each site was determined using the method described by Williams (2001). Soil texture was determined as the approximate proportions of sand, silt and clay, using the method described by Brady & Weil (1999).

The diversity of macrobenthos in each site was estimated using Shannon-Wiener index (H') (Zar, 1984; Krebs, 1999) and the similarities of benthic communities among sampling sites were determined using Bray-Curtis similarity coefficient (Bray & Curtis, 1957). In this analysis, the 4^{th} root transformation was used to increase the influence by rare species. Ordinations of Non-metric Multidimensional Scaling (MDS) of sampling sites were determined based on the Bray-Curtis similarity matrix (Clarke & Warwick 2001) using PRIMER-5 software package (Version 5.2.2). The BIO-ENV function in PRIMER-5 package was used to relate the multivariate community structure to environmental variables and to determine the most responsible variables for the inter-site variability of the benthic community.

3. RESULTS AND DISCUSSIONS

A total of 9062 benthic invertebrates consisting of 36 species of polychaetes, 24 species of gastropods, 16 species of bivalves and 13 species of crustaceans were recorded. Of the gastropods, belonging to families Assimineidae, Atyidae, Cerithiidae and Hydrobiidae were the most abundant. The most abundant bivalve families were Mytilidae and Veneridae. Among amphipods, Aorids and Gammarids were recorded in most of the sampling sites. A total of 862 polychaetous annelids representing 16 families and 36 species (Erantia 22 spp.; Sedeteria 14 spp.) were identified. The polychaetes constituted 40% of the total macrofauna. Families with highest species richness were Nereididae (7 spp.), Pilargidiidae (3 spp.), and Spionidae (3 spp.). Pilargidiids and Heterospionids were dominated in most of the sampling sites. The ranges of the values calculated for Species richness, Shannon Weiner (diversity) index (H'), Simpson index (J') and Pielou's index of the sampling sites were 0-27, 0-2.85, 0-0.95 and 0-0.87 respectively (Table 1). Low or zero diversity recorded from deeper areas of middle region of the estuary. High abundance and diversity were noted at the marginal and inner regions. Results of physico-chemical parameters of water and sediments at different sampling sites of Negombo estuary given in Table 2. The analysis of similarities permutation test (ANOSIM) indicate that there was a significance differences between groups of sampling sites which was clustered together with the 30% similarity level of the Bray Curtis similarity analysis. The clustering of Bray-Curtis similarity analysis and ordinations of Non-parametric Multidimensional Scaling (MDS) (Fig. 2) indicated the clustering of sites which were located in the northern region of the estuary based on the abundance polychaetes. Results of the Spearman rank correlation coefficients for permutations of environmental variables indicated that the combination of salinity, depth, nutrient contents of water and sea grass biomass mostly affected the abundance and diversity of macrobenthos in the estuary.

Table 1:
Results of Diversity indices and species richness of macrobenthic invertebrates recorded at different sampling sites of Negombo estuary.

Sampling Site	Species richness	J' (Pielous Index)	H' (Shannon Weiner index)	1-lambda (Simpson Index)
1	27	0.86503002	2.850997832	0.9518698
3	13	0.717744528	1.840978365	0.7778519
4	7	0.78623612	1.529944846	0.8230519
5	9	0.838249073	1.841821464	0.8302216
6	14	0.694889522	1.833853287	0.7909549
7	14	0.656841274	1.733441778	0.7401203
8	17	0.673503426	1.908178895	0.7415145
9	22	0.808951451	2.500503277	0.9048092
10	22	0.62605016	1.935147623	0.7966148
11	10	0.692437254	1.594395699	0.7233278
12	1	0	0	0
13	14	0.72518166	1.913795976	0.8252117
14	24	0.640487047	2.035502313	0.8235158
15	11	0.689054463	1.65228044	0.7743051
17	16	0.802787113	2.225798495	0.8693904
18	1	0	0	0
19	22	0.789019221	2.438891909	0.8864488
20	8	0.77895449	1.619790326	0.7863053
21	8	0.583588774	1.21353874	0.6152737
22	19	0.858771871	2.528601371	0.9093956
23	15	0.566792091	1.534901437	0.7189615
24	9	0.764975289	1.680822505	0.7882386
25	5	0.846545994	1.362463218	0.7081388
26	11	0.727319367	1.744035671	0.7876899
27	13	0.730044922	1.872528253	0.8139367
28	5	0.80385894	1.293761054	0.7046085
29	9	0.853130108	1.87451844	0.8254688
30	14	0.710254869	1.874403317	0.7709517
31	6	0.764244761	1.369342788	0.7024313
32	11	0.86793444	2.08121589	0.8629151
33	13	0.794190204	2.037057653	0.8360082
34	13	0.758365862	1.945170031	0.7859818
35	8	0.847373398	1.762063445	0.8091475
36	8	0.533982244	1.110384861	0.5157819
37	7	0.736842453	1.433829208	0.7291038

Table 2:
Physico-chemical parameters of water and sediments at different sampling sites of Negombo estuary in year 2005.

Site	pH	Temp (^0C)	DO (mg/l)	Salinity (g/kg)	Depth (cm)	abundance of seagrass	abundance of mangrove	Nitrate (mg/l)	Nitrite (mg/l)	Phosphate (mg/l)
1	8.3	28.6	7.02	30	200	0	0	3.5	0.0072	0.893
2	8.2	29.4	6.19	30	150	0	7	3.2	0.0142	1.04
3	8.3	28.7	6.96	27	90	0	0	3.4	0.0121	0.367
4	8.2	29.2	6.06	30	45	0	5	2.8	0.0079	0.957
5	8.5	28.7	10.6	16	75	9	0	1.9	0.0002	0.479
6	8.2	28.8	6.22	25	60	0	0	0.6	0.0098	0.044
7	8.1	29.1	5.91	23	30	5	0	4.1	0.0052	0.613
8	8.2	32.4	7.42	12	135	2	0	1.8	0.0218	0.49
9	8.9	29.9	14	11	45	7	6	0	0.0174	0.879
10	8.1	28.7	6.18	25	75	0	2	1.6	0.0207	0.274
11	8.1	29.2	6.57	20	135	0	0	2.4	0.0112	0.595
12	8.2	30.4	8.09	25	135	0	0	3.3	0.0012	2.23
13	8.1	29	6.43	13	140	0	0	3.3	0.0081	0.688
14	8.1	29.1	7.7	21	75	4	3	3.5	0.0012	2.27
15	8	28.8	6.37	17	135	0	0	1.7	0.0231	0.251
16	8.2	30.1	8.2	24	180	0	0	3.7	0.0144	0.437
17	7.9	29.1	6.45	15	150	0	0	2.2	0.0171	0.989
18	8	30	6.8	14	45	5	5	4.1	0.0342	1.529
19	8.2	30.8	7.08	25	150	0	0	1.5	0.0105	1.21
20	8.1	30.4	7.11	22	150	0	0	3.9	0.0019	0.605
21	8	29.3	6.75	16	150	0	0	1.8	0.018	2.531
22	8.2	30.2	8.2	15	90	0	0	1.7	0.021	0.824
23	8.2	31.1	8.7	26	90	1	4	2.8	0.0049	0.626
24	8	30.8	6.89	17	150	0	0	0.8	0.0226	1.224
25	8.2	29.1	7.65	20	165	0	0	2.4	0.0138	0.568
26	8.2	30.1	8.3	9	60	0	0	2.9	0.0422	0.628
27	8	31	6.9	16	120	0	0	3.2	0.0095	1.306
28	8	29.4	7	15	75	0	0	1.8	0.018	2.531
29	7.8	30.2	7.72	11	75	0	0	2.3	0.006	0.517
30	8	30.6	8	16	135	0	0	3.2	0.0169	1.301
31	8	29.7	6.8	17	135	0	0	2.4	0.0198	0.665
32	8	29.9	6.96	10	105	0	0	2.5	0.009	2.237
33	7.8	31.2	8.4	14	90	1	7	0.7	0.0092	0.393
34	8	30.4	6.7	15	105	0	0	2.6	0.019	0.558
35	7.9	30.5	6.77	8	105	0	9	1.6	0.0206	0.943
36	7.8	31.3	6.43	7	105	0	7	1.8	0.0142	0.712
37	8	31.6	7.32	9	75	0	8	1.5	0.0123	2.241

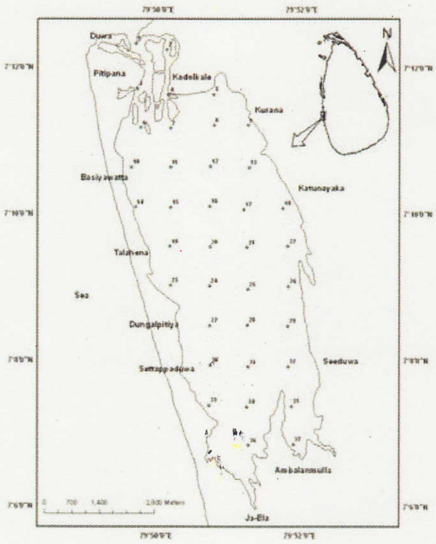

Figure 1: Map of the Negombo estuary showing sampling sites

(a)

(b)

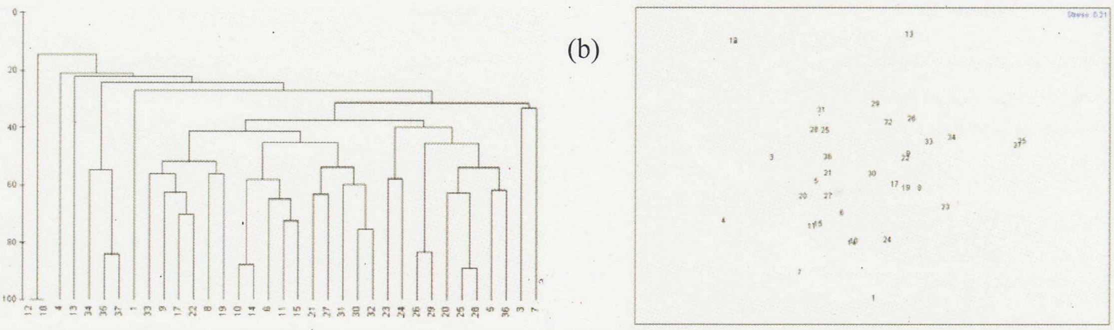

Figure 2: (a) Dendrogram of the Bray- Curtis similarity index and (b) Two-dimensional MDS ordination of sampling sites of Negombo estuary based on the abundance of macrobenthic invertebrates.

4. CONCLUSION

Low or zero diversity of polychaetes recorded from the mouth region and deeper areas of middle region of the estuary. High abundance and diversity were noted at the marginal and inner regions. The species richness of gastropods and bivalves is high and that of amphipods and polychaetes is low at the sampling sites located at the canal segment. Perkins (1974) has reported that the amphipods and polychaetes are an important constituent of macrobenthic communities of the inner areas of estuaries, which are associated with the finer sediments. The sampling sites at the canal segment are rich with sand, and therefore associated with coarser sediments than other sampling sites. Hence, this may be the reason for low abundance of amphipods and polychaetes at these sampling sites. Polychaete abundance decreased with increasing depth and their diversity changed with the salinity.

The results of the present study indicate that the biodiversity of macrobenthos in the Negombo estuary is very high. Further, some of the species recorded in the present study, such as some amphipods and polychaetes have not been reported in Sri Lanka in previous studies. Most of the species recorded in the present study could not be identified beyond the family level. Therefore it is necessary to carry out a detail taxonomic study of the benthic fauna of the Negombo estuary relating the macrobenthic community structure to water quality parameters and resource use patterns.

5. REFERENCES

Amarasinghe, U.S., Kitsiri, H.M.P., Chandrasekera, W.U., Dissanayake, D.M.A. & Ranasinghe, J.M. (1993). An analysis of the impact of the fishing on the seagrass beds in Negombo Lagoon, University of Kelaniya, Sri lanka.

Brady, N.C. & Weil, R.R. (1999). The Nature and Properties of Soils. (Twelfth edition), pg 137. Prientice-Hall, Inc.: New Jersey.

Bray, J.R. & Curtis, J.T. (1957). An ordination of the upland forest communities of Southern Wisconsin. Ecological Monographs, 27: 325-349.

Bruse, C.C., Craing, W.D. & Robert, C.A. (1975). A synoptic study of the limnology of lake Thonotosassa, Florida: Part 1. Effects of primary treated sewage and citrus wastes. Hydrobiologia, 46: 301-345.

CEA. (1994). Conservation Management Plan: Muthurajawela Marsh and Negombo Lagoon. Wetland Conservation Project, Central Environmental Authority and Euroconsult, Colombo, pp 129.

Clarke, K.R. & Warwick, R.M. (2001). Changes in Marine Communities: An Approach to Statistical Analysis and Interpretation (2nd Edition), pg 91. Primer-E Ltd,

Elliott, M. & Taylor, C.J.L. (1989). The Production Ecology of the Subtidal Benthos of the Forth Estuary, Scotland. In: Topics in Marine Biology. (S.D Ros ed.), pg 531-541.

Fauchald, K. (1977). The Polychaete Worms: Definitions and Keys to the Orders, Families and Genera. Natural History Museum of Los Angeles County, pg 173.

Fernando, C.H. (1990). The Freshwater Fauna and Fisheries of Sri Lanka, Natural Resources, Energy and Science Authority of Sri Lanka, pg 276.

Herricks, E.E. & Cairns, J. (1982). Biological monitoring, Part III. Receiving system methodology based on community structure. In: Biological monitoring in water pollution; J. Cairns (ed), pg 141-153.Pergamon: Oxford.

Jayakody, D.S. &. Dahanayaka, D.D.G.L (2005). Diversity of Fishing Practices and Resources Conservation in Negombo Lagoon, Sri Lanka Naturalist, Vol. Vii, No. 01-02, Young Zoologists' Association of Sri Lanka, pg 29-31.

Kirthisinghe, P. (1978). Seashells of Sri Lanka, pg 202. Charles E. Tuttle Company Inc. of Rutland, Vermant & Tokyo: Japan.

Krebs, C.J. (1999). Ecological Methodology (2nd edition), pg 620. Addison-Welsey Educational Publishers Inc.: USA,

Mackenthum, K.M. (1966). Biological evaluation of polluted streams. Journal of Water Pollution Control Federation, 38: 241-247.

Needham, J.G. & Needham, P.R. (1962). A Guide to the Study of Fresh Water Biology (5th edition), pg 108. Holden-Day Inc.: San Francisco

Perkins, E.J. (1974). The Biology of Estuaries and Coastal waters, pg 78. Academic Press Inc.: London.

Rajapaksha, J.K. (1997). Low-frequency tidal response and water exchange in a restricted lagoon. Rep. B73 Earth Sciences Centre, Gothenberg University, Sweden.

Robertson, M.R., Moore, D.C. & Ekaratne, S. (1997). Taxonomy of marine Polychaetes, Amphipodes and Isopodes. Marine Laboratory, Aberdeen, Scotland/ University of Colombo, Sri Lanka, pp 70.

Samarakoon, J.I. & Van Zon (1991). Environmental Profile of Muthurajawela and Negombo lagoon, Greater Colombo Economic Commission, Euroconsult, The Netherlands, pp 173.

Smith, R.W., Bernstein, B.B. & Cimberg, R.L. (1988). Community-environmental relationships in the benthos: applications of multivariate analytical techniques. In: Marine organisms as indicators; D.F. Soule & G.S. Kleppel (eds) , pg 247-326. Springer: Berlin.

Sutherland, W.J. (1997). Ecological Census Techniques (A hand book), pg 336, Cambridge University Press.

Westman, W.E., (1985). Ecology, Impact Assessment and Environmental Planning, pg 532. Wiley: New York,

Williams, I. (2001). Environmental Chemistry, a Modular Approach, pp 139-146. John Wiley & Sons Ltd: England

Zar, J.H. (1984). Biostatistical Analysis (2nd edition), pg 718. Prentice-Hall Inc.:Englewood. Cliff , New Jersey.