Diversity of macrobenthic community in the Negombo estuary, Sri Lanka with special reference to environmental conditions

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Abstract

Benthic animals are generally considered to be good indicators of environmental conditions of aquatic ecosystems. The present study was undertaken to study the spatial variation of macrobenthic community in Negombo estuary (7^0 6' $- 7^0$ 12' N; 79^0 49' $- 79^0$ 53' E), which is subjected to a variety of anthropogenic activities. Benthic samples were obtained from 25 randomly selected sites in Negombo estuary in March 2003 and the macrobenthos were separated by wet sieving and identified as much as possible. The diversity of macrobenthos was determined using Shannon-Wiener index and the similarities among the macrobenthic communities at different sites were determined using Bray-Curtis similarity coefficient. Seventy-six species of benthic invertebrates belonging to 41 families were recorded during the study. Of the gastropods, those belonging to families Assimineidae, Cerithiidae, Haminoeidae and Hydrobiidae were the most abundant. The most abundant polychaete families were Pilargidiidae and Heterospionidae. Among amphipods, aorids were recorded in most of the sampling sites. The sampling sites were separated into several clusters based on the diversity of macrobenthos. The major environmental factors that influenced the separation of these clusters appeared to be salinity, presence of mangroves and soil texture.

Introduction

Benthic macrofauna plays an important role in aquatic ecosystems as primary and secondary consumers. Benthic invertebrates, specially benthic worms, are very important as a food resource for a large number of predators including commercially important benthic fish and as primary material exchangers across sediment-water interface (Popchenko 1971; Bouguenec & Gaini 1989). Survival, distribution and abundance of macrobenthos depend on the characteristics of their environment such as salinity, organic mater content, soil texture, sediment particles and the ability to construct permanent burrows in the substratum (Perkins 1974).

Estuarine areas have long been subjected to industrialization and urbanization. The response by benthos to natural and anthropogenic perturbations is especially important because of their ability to integrate over time with changes to the water column and sedimentary regime (Elliott & Taylor 1989). Published research on diversity indices of benthic communities and use of macrobenthos, as indicator organisms of environmental conditions are rare in Sri Lanka. Costa et al. (1997) have studied the abundance of oligochaetes in Colombo Lake, Sri Lanka in relation to environmental parameters. Gamlath and Wijeyaratne (1997) have identified gastropod and oligochaete species indicative of environmental condition in a lotic water body in Sri Lanka. Weerasundara et al. (1999, 2000) have related the species composition and densities of oligochaetes to environmental parameters in some fresh water lakes in Sri Lanka. Pathiratne and Weerasundara (2004) have used benthic oligochaetes for bioassessment of inland water bodies in Sri Lanka. However, there is no published research on the diversity of macrobenthos in brackish water environments of Sri Lanka in relation to environmental conditions. Therefore, the 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 anthropogenic activities.

Materials and Methods

Benthic samples were collected from 25 randomly selected sites in the Negombo estuary (Fig. 1) in March 2003 using a Peterson grab and immediately fixed using 1% Rose Bengal. The approximate surface area sampled at each sampling site was 250 cm^2. At each sampling site, the depth and salinity were measured and the presence of sea grasses and mangroves was recorded. 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 and Weil (1999).
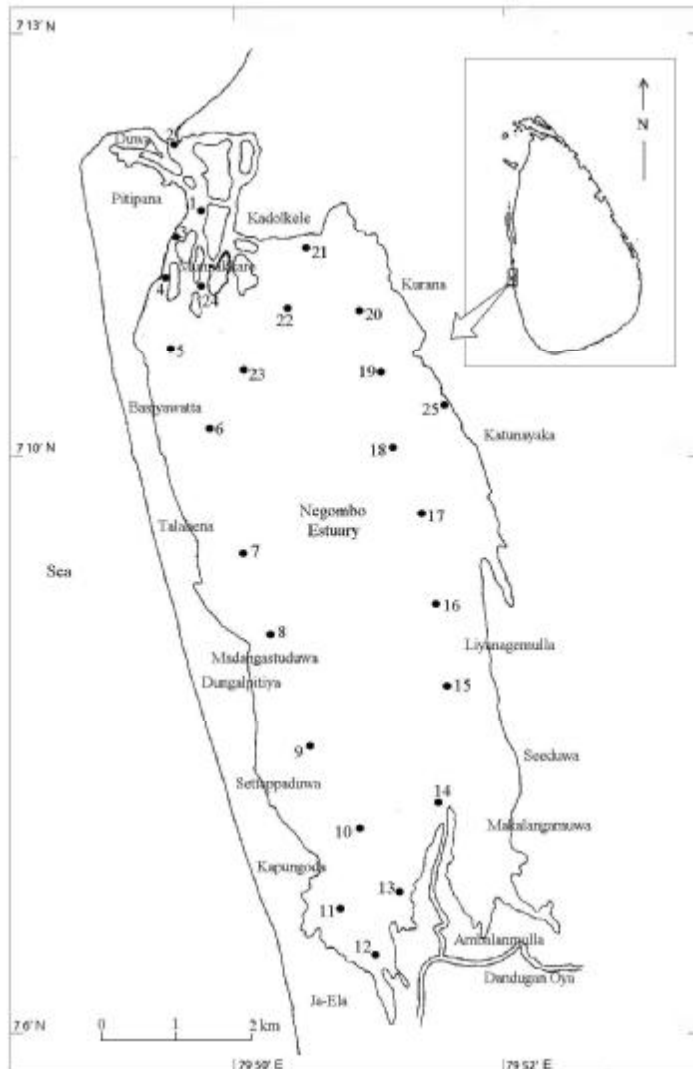

Fig.1. Map of the Negombo estuary showing sampling sites

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 4th 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.

Results

Seventy-six species of invertebrates belonging to 41 families were recorded in the benthic samples during the present study. Among them were 23 species of polychaetes, 24 species of gastropods, 16 species of bivalves and 13 species of crustaceans (Tables 1-3). Assimineids, Cerithiids, Haminoeids and Hydrobiids were the most abundant gastropods while Pilargidiids and Heterospionids were the most abundant polychaetes. Among amphipods, Aorids were the most abundant.

The highest number of species, which was 28, was recorded at the sampling site 23 while no macrobenthos were recorded at the sampling site 25. High values for species richness, which were above 20, were recorded for sampling sites 2, 6, 7, 20, 22 and 23 (Table 4). The sampling site 2 was located at the sea mouth and the others were located in the northern part of the basin segment of the estuary. The lowest values for species richness, which were less than 10, were recorded at sampling sites 4, 12, 14 and 21. Of these, sampling sites 12 and 14 were located close to freshwater inlets of the estuary while site 21 was located in an area where water circulation is poor. However, the sampling site 4 was located in the canal segment of the estuary.

The high values for species diversity, which were above 2.50 were recorded at sampling sites 2, 6, 7, 16, 17, 18, 20 and 23 (Table 4). Of these, the sampling sites other than the site 2 were located in the mid basin part of the estuary. The low values for species diversity were recorded at sampling sites 4, 12, 13, 14 and 15 (Table 4). The sites 12-15 were located in the southern part of the estuary close to freshwater inlets (Fig. 1). Sampling site 4 as indicated earlier is located in the canal segment of the estuary.

Table 1. Abundance of different species of polychaetes recorded at each sampling site of Negombo estuary in March 2003

Family/Species	Sampling site																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Class: Polychaeta																									
Order: Errantia																									
Eunicidae																									
Eunice sp	-	-	-	*	-	*	-	-	-	-	-	-	-	-	-	-	*	-	*	*	-	-	-	-	-
Goniadidae																									
Goniadid sp 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-
Lumbrineridae																									
Lumbrinerid sp 1	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nephtyidae																									
Nephtys sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**	**	*	*	-	-	-	-	-	-
Nephtyidae sp 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-
Nereididae																									
Nereidid sp 1	-	-	-	-	-	-	*	-	-	-	-	**	-	-	-	*	-	*	*	-	*	-	-	-	-
Nereidid sp 2	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pilargidiidae																									
Pilargidiid sp 1	**	-	*	-	**	*	**	*	*	*	-	*	-	-	-	-	**	-	**	*	-	**	-	-	-
Pilargidiid sp 2	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	*	-	**	*	-	*	-	-	-
Pilargidiid sp 3	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-
Sphaerodoridae																									
Sphaerodorid sp1	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Un. Errantia sp 1	-	-	*	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-
Un.Errantia sp 2	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-
Un. Errantia sp 3	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Un. Errantia sp 4	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-
Order: Sedentaria																									
Heterospionidae																									
Heterospionid sp 1	-	-	*	-	-	*	**	-	-	**	***	**	**	*	-	**	*	*	**	*	-	-	-	*	-
Sabellariidae																									
Sabellariid sp 1	-	-	-	-	-	**	-	-	-	-	**	-	-	-	-	-	-	-	-	*	-	-	**	-	-
Sabellidae																									
Sabellid sp 1	-	-	-	-	-	*	**	-	*	-	**	-	-	*	-	*	*	*	-	**	-	*	**	-	-
Spionidae																									
Spionid sp 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-
Syllidae																									
Syllid sp 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	*	-	-	-
Un.Sedenteria sp 1	*	-	-	-	-	*	*	-	**	***	-	**	-	*	**	*	*	-	-	-	-	**	*	-	
Un.Sedenteria sp 2	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-
Un.Sedenteria sp 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	*	-	-	-	-	-	-

* Less than 100 individuals m^{-2} ** 100 to 1000 individuals m^{-2}
 *** above 1000 individuals m^{-2},   - Absence   Un.- Unidentified Species

Table 2. Abundance of different species of crustaceans recorded at each sampling site of Negombo estuary in March 2003.

Family/Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Class: Crustacea																									
Order: Amphipoda																									
Ampeliscidae																									
Ampeliscid sp 1	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-
Aoridae																									
Aorid sp 1	-	-	-	-	-	-	**	**	-	*	-	*	-	**	**	**	**	*	*	-	**	-	**	-	-
Aorid sp 2	-	-	-	-	-	*	**	***	-	**	**	-	**	*	**	***	*	-	-	**	-	**	-	-	-
Gammaridae																									
Gammarid sp 1	-	-	-	-	-	-	*	**	-	-	*	-	-	-	-	**	**	**	-	**	-	-	*	-	-
Gammarid sp 2	-	-	-	-	-	-	-	***	-	-	-	-	**	-	-	**	**	-	**	-	-	-	-	-	-
Gammarid sp 3	-	-	-	-	-	-	-	-	**	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-
Order: Isopoda																									
Cirolanidae																									
Cirolanid sp 1	-	-	-	-	-	-	-	**	-	-	-	-	*	*	*	*	-	-	-	*	-	-	-	-	-
Order: Decapoda																									
Atyidae																									
Caridina sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-
Coenobitidae																									
Eupagurus sp	-	*	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Penaeidae																									
Penaeus sp	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	*	-
Other Crustaceans																									
Balanidae																									
Balanus sp	-	-	-	-	**	-	*	-	-	-	-	-	*	-	-	-	-	-	*	-	**	*	**	-	-
Un. Crustacean sp 1	-	-	-	-	-	-	-	-	-	-	**	-	-	-	-	-	**	**	-	-	-	-	-	-	-
Un.Crustacean sp 2	-	-	-	-	-	-	**	-	**	*	-	-	*	-	**	***	**	**	-	**	-	**	-	-	-

* Less than 100 individuals m^{-2} ** 100 to 1000 individuals m^{-2}
*** above 1000 individuals m^{-2}, - Absence   Un.- Unidentified Species

Table 3. Abundance of different species of gastropods and bivalves recorded at each sampling site of Negombo estuary in March 2003.

Family/Species	Sampling site																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Class: Gastropoda																									
Acmaeidae																									
Acmaeid sp 1	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Assimineidae																									
Assimineid sp 1	**	**	**	*	***	**	**	**	-	**	**	-	*	-	-	*	-	**	*	-	*	**	**	***	***
Cerithiidae																									
Cerithidea cingulata	**	**	**	-	**	**	**	**	**	**	**	-	-	*	**	**	**	**	**	**	***	**	-	-	
Dentaliidae																									
Dentalium sp	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	**	-	-
Haminoeidae																									
Haminoeid sp 1	**	*	*	-	**	***	-	-	**	**	*	**	*	-	-	**	**	**	-	**	*	**	***	***	-
Haminoeid sp 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-	
Haminoeid sp 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	***	-	-	
Hydrobiidae																									
Hydrobiid sp 1	**	**	-	**	***	**	**	**	***	***	**	***	**	-	**	**	**	**	-	**	**	**	***	**	
Hydrobiid sp 2	**	-	-	-	**	**	**	**	*	**	**	-	-	-	-	-	-	-	-	-	-	**	**	-	
Littorinidae																									
Littorinid sp 1	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nassariidae																									
Nassariid sp 1	-	-	*	*	*	**	-	*	*	-	-	*	-	-	-	-	-	-	-	-	**	**	**	-	-
Naticidae																									
Naticid sp 1	-	*	*	-	**	*	*	*	-	-	-	-	-	-	-	-	*	-	-	*	**	**	-	-	
Naticid sp 2	-	*	-	-	*	*	*	*	-	-	-	-	-	-	-	-	-	-	-	-	***	-	-		
Naticid sp 3	-	-	-	-	-	**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-		
Neritidae																									
Neritid sp 1	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Planorbidae																									
Planorbid sp 1	-	-	-	-	*	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-
Potamididae																									
Terebralia palustris	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
Terebridae																									
Terebrid sp 1	*	*	-	-	-	**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	
Thiaridae																									
Faunus ater	-	-	-	-	*	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-
Thiarid sp 1	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thiarid sp 2	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Un.Gastropod sp 1	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Un.Gastropod sp 2	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Un.Gastropod sp 3	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Less than 100 individuals m^{-2} ** 100 to 1000 individuals m^{-2}

*** above 1000 individuals m^{-2} - Absence   Un.- Unidentified Species

Table 3. Continued

Family/Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Class: Bivalvia																									
Arcid sp 1	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-
Cardiidae																									
Cardiid sp 1	-	*	-	-	*	**	*	*	-	-	-	-	-	-	-	-	-	-	*	-	-	-	*	**	-
Limidae																									
Limid sp 1	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mytilidae																									
Mytilid sp 1	-	**	-	-	-	-	**	***	-	-	-	-	***	***	**	**	-	-	-	*	*	*	-	-	-
Mytilid sp 2	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solenidae																									
Solenid sp 1	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	*	-	-	-	-	-	*	-
Tellinidae																									
Tellinid sp 1	-	**	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Veneridae																									
Meretrix casta	*	-	-	*	*	-	-	-	-	-	*	*	*	*	-	***	**	-	-	*	*	-	*	**	-
Venerid sp 1	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Venerid sp 2	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Un.Bivalve sp 1	**	-	**	*	-	*	*	-	-	-	-	-	**	**	-	-	-	-	-	*	*	-	**	**	-
Un.Bivalve sp 2	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	***	**	-
Un.Bivalve sp 3	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	***	*	-
Un.Bivalve sp 4	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-
Un.Bivalve sp 5	-	**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	-
Un.Bivalve sp 6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	***	-	-

* Less than 100 individuals m^{-2} ** 100 to 1000 individuals m^{-2}
*** above 1000 individuals m^{-2} - Absence   Un.- Unidentified Species

The values for the physico-chemical parameters of water and sediments at different sampling sites are given in Table 5. Salinity of water ranged from 8 to 30 g kg^{-1} and the water depth ranged from 0.5 m to 2 m. The maximum depth and the maximum salinity were recorded at the mouth of the estuary (Site 2). As expected, the salinity was high in the northern part of the estuary, which is close to the sea mouth, and low in the southern part where the freshwater inflow takes place. The organic matter content of the bottom sediments ranged from 0.8 to 12%, the sand content from 0 to 98% and the silt content from 0 to 98%. The organic matter content in the bottom sediments was high at sampling sites 10, 11 and 12, which were located in the southern part of the estuary. High silt contents in the bottom sediments were recorded at sampling sites 8, 9, 10 and 12, where no sand was recorded (Table 5). These sites were located in the southwestern part of basin segment of the estuary.   No silt was recorded in the sampling sites located near the sea mouth and the mouth of the main canal (sites 2 & 24). The clay content was always < 12.8% and in many sites, it was < 5%.

Table 4. Shannon – Wiener index (H') and species richness of macrobenthic invertebrates recorded at dfferent sampling sites of Negombo estuary.

Sampling site	H'	Species richness
1	2.11	10
2	3.72	26
3	2.24	13
4	1.42	8
5	2.36	14
6	2.62	24
7	2.87	22
8	2.15	15
9	2.43	13
10	2.38	14
11	2.35	13
12	1.39	8
13	1.92	13
14	1.20	8
15	1.55	11
16	2.76	18
17	3.33	19
18	2.63	16
19	2.48	14
20	3.05	22
21	2.37	9
22	2.29	20
23	3.20	28
24	2.05	14
25	0.00	0

The sea grasses showed a patchy distribution in the estuary and these were abundant at sampling sites 5, 13, 14, 16, 19, 21 and 23. Mangroves were abundant at sampling sites 13, 14 and 24 (Table 6). Brush piles were found near all sampling sites except for sites 2 and 4 and those located in the southern part of the estuary. Encircling nets are operated in the areas of the sampling sites 6, 9-11, 17-20, 22 and 23. No operation of encircling nets was observed in the southeastern part of the estuary. In the canal segment also, encircling nets are not operated. Disposal of sewage was noted at the sampling sites 1, 3, 7, 8, 12, 16, 18-20 and 25.

Table 5. Physico-chemical parameters of water and sediments at different sampling sites of Negombo estuary in March 2003.

Sampling site	Depth (cm)	Salinity (g kg^{-1})	Organic matter content (%)	Soil Texture		
				Sand (%)	Silt (%)	Clay (%)
1	42.0	29	3.08	82.6	13.0	4.3
2	197.0	30	0.78	97.7	0.0	2.3
3	47.0	29	3.03	83.3	12.5	4.2
4	46.0	28	1.65	85.0	10.0	5.0
5	97.0	26	4.48	71.4	23.8	4.8
6	128.0	24	2.24	87.0	8.7	4.3
7	69.0	24	1.58	76.9	20.5	2.6
8	61.5	17	2.04	0.0	98.4	1.6
9	128.0	10	7.75	0.0	96.4	3.6
10	125.5	10	11.92	0.0	97.9	2.1
11	123.0	10	8.17	58.3	37.5	4.2
12	105.0	8	11.41	0.0	97.3	2.7
13	64.0	10	1.47	62.5	33.3	4.2
14	89.5	8	1.91	70.2	28.1	1.8
15	112.5	16	3.93	58.6	32.8	8.6
16	89.5	14	3.76	59.0	31.1	9.8
17	151.0	19	6.77	59.1	36.4	4.5
18	184.5	24	4.65	51.1	36.2	12.8
19	171.5	23	1.67	77.6	12.2	10.2
20	115.0	25	2.06	79.4	17.6	2.9
21	105.0	27	2.19	69.6	21.7	8.7
22	123.0	26	2.97	65.2	32.6	2.2
23	110.0	28	3.27	72.0	16.0	12.0
24	151.0	30	0.96	95.5	0.0	4.5
25	92.0	24	1.27	67.3	28.8	3.8

The results of the present study indicated that a gammarid species was the most abundant in the sample sites, which are closer to the human dwellings (Table 2). This species was less abundant in other areas of the estuary. However, this species could not be identified to species level due to unavailability of keys. Further, the gastropods, which were abundant in other areas, were not found at these sites. At the sample site closer to the fiber mill (Site 8), the abundance of mytilids was high. In the sample site closer to the effluent discharge point of the shrimp farm, the species richness as well as the abundance of polychaetes, gastropods and bivalves were low. Further, the amphipods and isopods, which were abundant in other parts of the estuary, were absent at this site.

Table 6. The anthropogenic activities and presence of sea grasses and mangroves at the 25 sampling sites of the Negombo estuary.

Sample site	Presence of sea grasses	Presence of Mangroves	Brush piles	Encircling Nets	Disposal of Sewage
1	-	Low (3)	+	-	+
2	-	-	-	-	-
3	Moderate (4)	Low (2)	+	-	+
4	-	Moderate (5)	-	-	-
5	High (7)	-	+	-	-
6	Moderate (6)	-	+	+	-
7	Moderate (4)	-	+	-	+
8	Moderate (4)	Moderate (5)	-	-	+
9	-	-	-	+	-
10	-	-	-	+	-
11	-	-	-	+	-
12	-	-	-	-	+
13	High (9)	High (9)	-	-	-
14	High (8)	High (9)	-	-	-
15	-	-	-	-	-
16	High (8)	-	-	-	+
17	-	-	+	+	-
18	-	-	+	+	+
19	High (9)	-	+	+	+
20	Moderate (5)	-	+	+	+
21	High (7)	-	+	-	-
22	-	-	+	+	-
23	High (7)	-	+	+	-
24	-	High (7)	+	-	-
25	-	-	+	-	+

Presence of sea grasses and mangroves indicated according to an arbitrary scale (Low: 1-3; Moderate : 4-6; High: 7-9), + Presence, - Absence

The sampling site 25 was excluded from the study of Non-metric MDS and Bray- Curtis similarity, as no macrobenthos were present at this site. When the Bray-Curtis similarity index based on the abundance of macrobenthos is considered, the sampling site 14, which was located at the freshwater inlet of the Dandugan Oya, was separated from other sampling sites at about the 22% level of similarity (Fig. 2). This sampling site was clearly separated from other sampling sites in the MDS ordination too, based on the abundance of macrobenthos also (Fig. 3). Of the 7 species of

macrobenthos found at this sampling site, one species of polychaetes (Order: Errantia) was recorded only at this site. Other polychaetes, which were widely distributed in the estuary such as pilargidiids and some sedentarians, were not found at this site. Further, no gastropods were present at this site although they were abundant at other areas of the estuary. There may have contributed to the separation of site from other sites at 22% level of similarity in Bray-Curtis similarity analysis and in the MDS ordination. This site was not found to be perturbed by any anthropogenic activity, was rich in seagrasses and was located close to mangrove habitats. However, the salinity at this site was low compared to other sites because of the close location to freshwater inflow (Fig. 1).

Sampling site 19, which was located at the North-East part of the basin segment of the estuary, was separated from other sites at about 24% level of similarity in the Bray-Curtis analysis based on the abundance of macrobenthos (Fig. 2). It was also clearly separated from other sampling sites in the MDS ordination (Fig. 3).

Sampling site 2, which was located at the sea mouth of the estuary, was separated from other sites at about 26% level of similarity in the Bray-Curtis analysis (Fig. 2). It is also clearly separated from other sampling sites in the MDS ordination (Fig. 3). There were no polychaete, amphipod or isopod species at this sample site. However, 13 species of gastropods and 12 species of bivalves were recorded (Tables 1-3). One species of Acmeid, one species of Littorinid, 3 unidentified species of gastropods and the decapod *Eupagurus* sp were recorded only at this sample site. Further, of the bivalves, one species of family Limidae, one species of family Mytilidae and two species of family Veneridae were recorded only in this sampling site.

Table 7. Statistically significant values for Spearman Rank Correlation Coefficient (p<0.05) for permutations of environmental variables in Negombo estuary.

Correlation Coefficient	Environmental Variables
0.423	2,4,8
0.420	4,8
0.418	1,2,4,8
0.416	1,2,4,6,8
0.415	2,4,6,8
0.410	1,4,8
0.406	4,6,8
0.405	1-3,4,8
0.402	1,4,6,8
0.401	2,3,4,8

Variables:1- depth, 2- salinity, 3- organic mater content (%), 4- sand (%), 5- silt (%), 6- clay (%), 7- abundance of seagrasses, 8- abundance of mangroves.
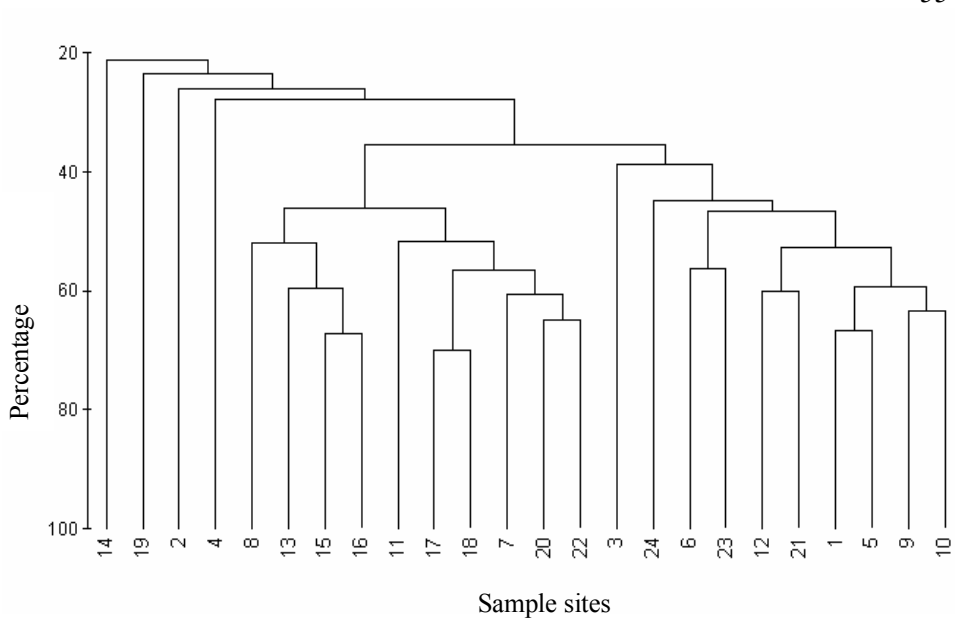
Fig. 2: Dendrogram of the Bray- Curtis similarity index for the sampling sites of Negombo estuary based on the abundance of macrobenthic invertebrates.
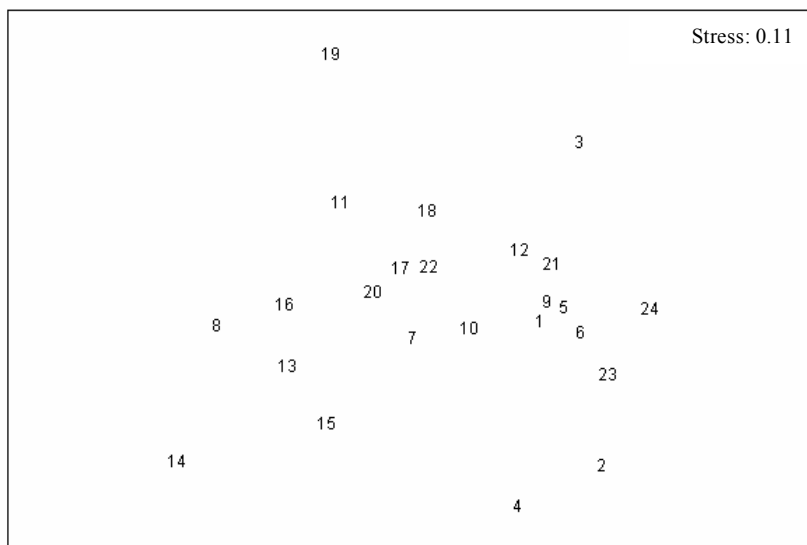

Fig. 3: Two-dimensional MDS ordination of sampling sites of Negombo estuary according to the abundance of macrobenthic invertebrates.

At about 28% level of similarity, sampling site 4, which was located at the canal segment of the estuary, was separated from other sampling sites in the Bray-Curtis analysis (Fig. 2). No polychaete species were recorded at this site except for *Eunice* sp. Further, there were no amphipod or isopod species recorded at this site. Only one species of Assimineid, one species of Hydrobiid, one species of Nassariid and two species of Thiarids were recorded as gastropods at this site. The latter two species were recorded only from this sample site.

Sampling site 3, which was located at the middle part of the canal segment of the estuary, was separated from other sampling sites at about the 38% level of similarity in the Bray-Curtis similarity analysis (Fig. 2) in the MDS ordination (Fig. 3). No amphipod or isopod species recorded at this sampling site. One species of errantid polychaete was only present at this site.

Spearman rank correlation coefficients for permutations of environmental variables of the BIO-ENV function, which are statistically significant, are given in Table 7. These results indicate that the combination of salinity, percentage of sand and presence of mangroves mostly affect the diversity and abundance of macrobenthos. The depth, % clay and % organic matter content also significantly affect the abundance and diversity of macrobenthos in the Negombo estuary.

Discussion

The composition and abundance of benthic organisms are closely related to the water quality of aquatic environments (Mackenthum, 1966; Costa et al. 1997; Weerasundara et al. 1999; 2000; Pathiratne & Weerasundara 2004) and therefore, benthic organisms are considered to be good indicators of the past and present conditions of water (Bruse et al. 1975, Gamlath & Wijeyaratne 1997). The presence of unusually large populations of benthic organisms as well as absence of some others can be used as indicators of pollution in water bodies (Hart & Fuller 1974; Lobe & Space 1993).

The lowest species diversity and species richness were recorded in the sampling site 14. The rapid flow rate at this site may have contributed to low species diversity and species richness. Most of the species recorded in other parts of the estuary were not found at the sampling site 19. The abundance of most of the macrobenthic species that were present was also lower than their abundance in other parts. These factors may have contributed for the separation of sampling site 19 at about 25% level of similarity in the Bray-Curtis similarity analysis and in the MDS ordination (Fig. 3). Use of fishing gear such as encircling nets and brush piles was noted in this area and the sewage from nearby human dwellings may have contaminated water at this site. These factors may have contributed to the low abundance of macrobenthos, at this sampling site. Low organic matter and high sand contents, together with high salinity may have contributed to the variation in

the macrobenthic community at sampling site 2 from that of other sampling sites. The substrates with high organic matter content are preferred by sedentarian polychaetes and amphipods. Therefore high sand content at the sampling site 2 may have significantly contributed for the absence of sedentarian polychaetes and amphipods at this site. Absence of polychaetes and amphipods at sampling site 4 also may be due to high sand and low organic matter contents. Perkins (1974) also reported similar trends. This sampling site was also located near human dwellings and this may have also contributed for the difference in the macrobenthic community structure at this site from that of other sites.

The low abundance and/ or absence of some common polychaetes, gastropods and some crustaceans may be the reason for this separation of sampling site 3 from other sampling sites at 38% level of similarity. This sampling site is located close to of an effluent discharge point of a shrimp farm. Effluents from shrimp farm may have contributed for this difference in the community structure of benthic macrofauna at this site from that of other sites.

The area of sampling site 25 is highly polluted due to sewage discharged from the households. Further, the circulation of water at this part of the estuary was also observed to be very poor. Benthic organisms are reported to be rare in heavily polluted waters (Pearson & Rosenberg 1978). Therefore, the water in this part may be highly polluted resulting in the absence of benthic macrofauna.

The results indicate 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. The Spearman rank correlation coefficients given in Table 7 also indicates that % sand content in the estuary is a significant factor that affect the diversity of benthic fauna.

Mollusks are found to be abundant in the areas with dense vegetation (Hart & Fuller 1974). However, in the present study, high abundance of mollusks was recorded at sample site 2, where there was no vegetation. Therefore, it appears that vegetation cover cannot be considered as a factor contributing to abundance of all species of mollusks in general.

Cerithidea cingulata was recorded to be abundant on the mud flats adjoining the mangroves (Pinto 1986). However, in the present study *Cerithidea cingulata* was not recorded in sampling sites that were close to mangroves (sample sites 4, 13, 14 and 24) but was found to be abundant in other sampling sites including those which are not close to mangrove areas. Nevertheless, the Spearman rank correlation coefficients given in Table 7

indicate that the mangroves are a significant factor, which contributes to community structure of benthic macrobenthos of this estuary as a whole.

Use of some types of fishing gear such as encircling nets has been reported to affect the macrobenthic community structure by destroying the seagrass beds (Anon. 1994). In the present study, seagrass beds were not found in some of the sampling sites, where the encircling nets are used. They include sampling site 9, 10, 11, 17, 18 and 22. However in some sampling sites where encircling nets are operated, such as sites 6, 19, 20 and 23 seagrass coverage is high or moderate. Therefore it appears that use of encircling nets is not the only factor that affects the abundance of seagrasses. However, when the abundance of seagrasses is low the species richness of macrobenthos was also found to be low.

Perkins (1974) has reported that benthic community structure depends on environmental factors such as salinity, temperature, dissolved oxygen content, depth, organic mater content, soil texture and size of sediment particles. During the present study the temperature and dissolved oxygen content were not measured because the temperature was reported as more or less constant and the dissolved oxygen content varies within the same range throughout the estuary (Silva 1981). The Spearman's rank correlation coefficients calculated for permutations of environmental variables indicate that in Negombo estuary, the environmental variables that significantly affect the community structure of macrobenthos are the depth, salinity, organic matter content, % sand and clay contents in the sediments and the abundance of mangroves.

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.

Acknowledgement

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