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The Spatial Variation of Macrobenthic Community in the Negombo Estuary in Relation to Physico-chemical Parameters

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Abstract

Analysis of physico-chemical parameters gives an insight to the the spatial distribution of benthic communities in estuaries. With this view the present study was carried out to see whether the spatial distribution of macrobenthic fauna is governed by the physico-chemical parameters in sediment and overlying water in Negombo estuary, Sri Lanka. This study also attempted to determine the key physico-chemical determinants that govern this spatial distribution.

During the study, the macrobenthic fauna at Moya, Virisiyanu Duwa, Kadol Kele, Dungalpitya, and Pamunugama within the estuary were collected and their species diversity and species richness were determined. Physico-chemical parameters such as the pore water salinity, temperature, pH, sand %, silt %, clay % and OM % in sediment as well as the salinity, pH, temperature, conductivity, DO, BOD_5 and NO_3^- concentration in the over lying water were measured and analyzed using appropriate standard techniques.

Results revealed that the species richness, species diversity, structure of the macrobenthic community and the physico-chemical parameters in sediment and the over lying water and the varied significantly between the five study sites. However, the species diversity and the species richness were positively correlated with the salinity and sand % while they were negatively correlated with the BOD_5, silt % and OM % in the sediment and overlying water. It is therefore evident that the spatial distribution of macrobenthic fauna in Negombo estuary is governed by a combination of some key physico-chemical parameters such as salinity, sand %, OM % and BOD_5 in the sediment and over lying water in this tropical estuary.

Key words: Negombo estuary, Physico-chemical parameters, Spatial variation of Macrobenthic communities.

Introduction

Estuaries are transitional environments between rivers and the sea, and are characterized by widely varying, localized and often unpredictable adverse hydrological and physico-chemical environmental conditions (Day *et al*. 1989). Of the macrobenthic invertebrates in estuaries the commonest forms are the polychaetes, crustaceans and the molluscs (Kumar, 2000). The adult forms of these macrobenthos have a limited mobility so that they are directly exposed to the adverse localized changes in the environment in that the non-resistant forms perish leaving only a subset of the original community (Probert, 1984). Therefore the

Estuarine macrobenthic community show a patchy distribution within the estuary where the benthic community structure often varies from place to place depending on the degree of the localized environmental change (Reish, 1955; Wass, 1967; Probert, 1984).

Ecological studies related to the dynamics of benthic communities in the tropical estuaries are scarce (Dahanayaka and Wijeyaratne, 2006) and the theories used to explain their dynamic nature are largely based on the studies from temperate regions (i.e. Alongi, 1990; Frid and James, 1988; Frid, 1989). These studies have shown that the structure of the temperate estuarine benthic communities are regulated by biological factors (Bonsdorff, 1992) or by physicochemical factors (Thistle, 1981) or by a combination of both (Olsgard & Gray, 1995).

The present study, therefore, was carried out with a view to investigate how the spatial distribution of macrobenthic community in a tropical estuary in Sri Lanka, is governed by localized physico-chemical variations within the estuary. In this study, the variation of the benthic community structure was determined in relation to some physico-chemical variables in the sediment and over lying water. This study also aimed at to identify the key physico-chemical determinant/s that govern the spatial variation of this macro benthic community in the estuary.

Materials and Methods

This study was carried out at the Negombo estuary (Figure 1) during the dry season (January–June) of the year 2010. Negombo estuary is situated on the west coast of Sri Lanka (7 ^{0} 12’ 0 N and 79 ^{0} 50’ 0 E to 7 ^{0} 6’ 0 N and 79 ^{0} 55’ 0 E). It is a shallow, well mixed basin type estuary, approximately 10 km in length, 3.5 km in width and has a mean depth of about 1.2 m (Samarakoon and Van Zon, 1991) and receives freshwater mainly from Dandugam Oya, a river that is discharged to its southern end. The estuary opens to the sea by a single narrow opening at Negombo at its North-western end. Five study sites namely Moya, Virisiyanu Duwa, Kadol Kele, Dungalpitiya and Pamunugama (Figure 1) representing of the mouth, island canals segment, southwest margin and head of the estuary were selected for the present study.

Ten sediment core samples, each with 6 cm diameter and 15 cm deep, were collected using a soil corer from ten random locations from the sub tidal zone at each site. These samples were wet sieved separately *in situ* through a 0.5 mm mesh and the macrobenthic fauna and the residues retained were preserved in Rose Bengal in 5% formaldehyde solution following Murugesan and Khan (2007). Later the faunas were sorted out and identified to the nearest possible taxonomic category using the standard identification keys provided by De Silva (1961, 1963), Fauchald (1977), Sabelli (1982), Pinto (1986), Khan (1992), Richmond (1997), Robertson et al. (1997), TMMP (2000) and enumerated under a binocular microscope.

Dissolved oxygen (DO) (WTW DO meter; Oxi 315i/SET), salinity (ATAGO refractometer; S-10), temperature (mercury glass bulb thermo meter), conductivity (WTW conductivity meter, Cond 340i/SET) and pH (WTW pH meter, pH 315i/SET) of the over lying water were measured *in situ* at five random locations in each site. Further, the temperature, pH and salinity of five sediment pore water samples were also measured. The pore water was collected by squeezing the sediment core samples.

In addition, water samples were collected from each site into ten 250 ml glass stopper bottles and immediately transported to the laboratory in ice boxes where five of them were used to determine the dissolved NO_3^- content while the remainder was used to determine the BOD_5. The dissolved NO_3^- was determined by a UV spectrophotometric method at 220 nm (UV spectrophotometer: CECIL/CE 1021) following Clesceri *et al.* (1998). Five sediment samples collected from each site were subjected to determine the approximate proportions of organic matter (OM), clay, silt and sand separately as described by Williams (2001) and Brady and Weil (1999).

The % abundance of the major taxa were calculated, and the species richness and the Shannon-Wiener diversity index (Magurran, 1991) were determined separately for the five sites. Benthic community structure between the five sites were analyzed using the Bray-Curtis similarity clustering method (Clarke and Warwick, 2001). Before the analysis, abundance data were (log x+1) transformed. Significant differences between the major clusters in the resulting dendrogram were analyzed using one-way ANOSIM. Physico-chemical parameters in overlying water as well as in the sediment between the five sites were analyzed separately using one-way ANOVA. When significant differences were noted, Tukey's pairwise comparison tests were carried out separately. Further, the physico-chemical parameters of water and sediment between the five sites were also analyzed separately using Principal Component Analysis (PCA) to find out the key physico-chemical parameter/parameters that is/are characteristic to each site. The relationship between species diversity and species richness and the PC1 scores for sediment and water parameters were also analyzed separately by regression analysis. All the data were analyzed at $\alpha = 0.05$ in MINITAB (Version 14) and PRIMER (Version 5) for windows as appropriate.

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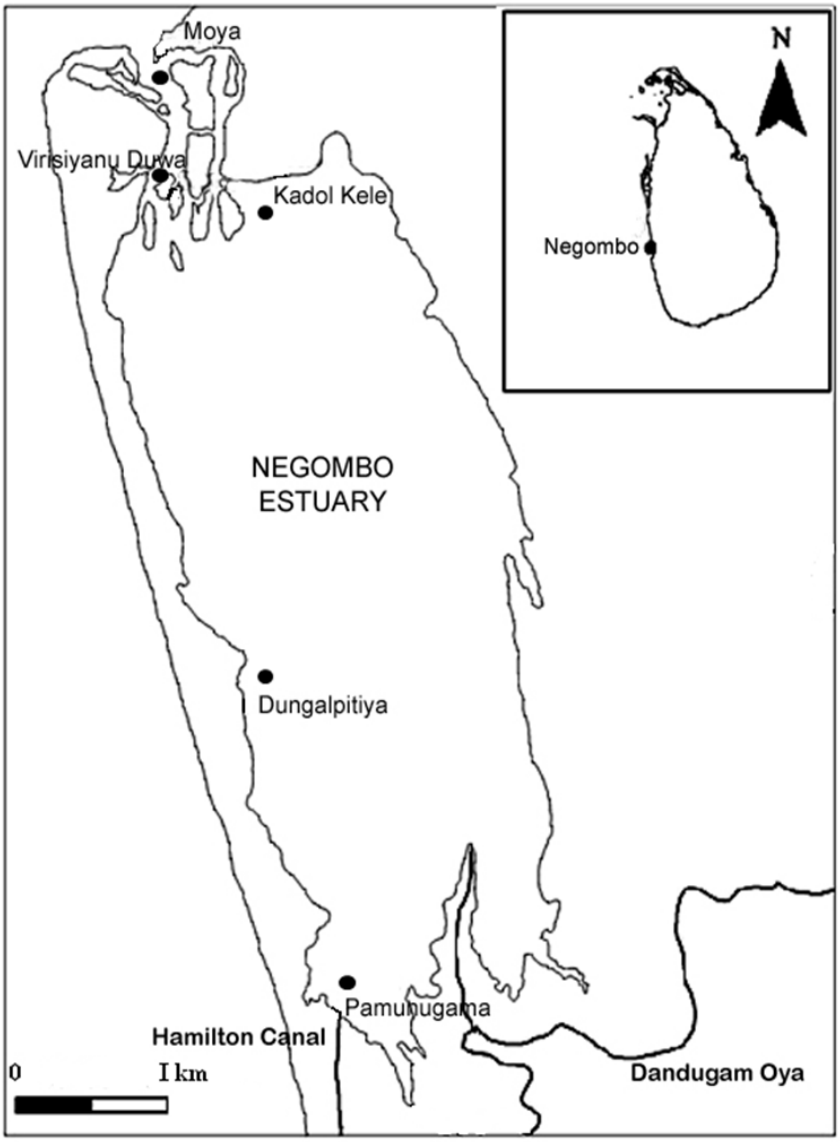

Figure 1. The five study sites in Negombo Estuary; Moya, Virisiyanu Duwa, Kadol Kele, Dungalpitiya, and Pamunugama. Moya is situated by the mouth, Virisiyanu Duwa and Kadol Kele occur within its channel segment, Dungalpitiya occurs in the southwest margin while Pamunugama occurs at the head of the estuary. Inset shows the location of Negombo estuary in Sri Lanka.

Results

Altogether 87 macrobenthic taxa belonging to ten major groups (i.e., polychaetes, amphipods, isopods, decapods, gastropods, bivalves, scaphopods, anapsids, crinoids, and sipunculoids) were found in the five study sites. Of these macro-benthos, the polychaetes, gastropods, amphipods and bivalves dominated in all samples with % contributions of 32.18%, 22.99%, 14.94% and 11.49% respectively (Table 1). However, their distribution was not uniform among the five study sites (Figure 2). Noticebly, the highest number of taxa was recorded at Kadol kele while the lowest was at Pamunugama (Table 2).

Table 1. Major benthic taxa recorded at the five study sites. Total number of taxa in each major taxon and their percentage contributions are indicated.

Major Taxon	No. of Taxa	% contribution
Polychaetes	28	32.18
Gastropods	20	22.99
Amphipods	13	14.94
Bivalves	10	11.49
Decapods	5	5.75
Isopodes	3	3.45
Scaphopods	1	1.15
Anapsids	1	1.15
Crinoids	1	1.15
Sipunculoides	1	1.15
Other unidentified crustaceans	4	4.60
Total	**87**	**100**

Table 2. Major benthic taxa recorded at the five study sites in Negombo estuary. Number of taxa belonging to each major taxon and the total number of taxa in each study site are indicated (n = 10 from each site).

	Study site				
Major taxon	Kadol-Kele	Virisiyanu-Duwa	Moya	Dungal-pitiya	Pamunu-gama
Polychaetes	17	9	13	3	4
Gastropods	15	13	10	10	7
Amphipods	12	5	0	8	4
Bivalves	6	7	7	1	2
Decapods	5	3	0	0	0
Isopods	3	3	0	0	0
Scaphopods	1	1	0	0	0
Anapsids	0	1	0	0	0
Crinoids	1	0	0	0	0
Sipunculids	1	0	0	0	0
Other unidentified crustaceans	4	4	1	1	0
Total	**65**	**46**	**31**	**23**	**17**

There was an increasing trend of the species richness and species diversity from the head end (i.e. Pamunugama) to the channel segment (i.e. Kadol Kele) of the estuary where the lowest species richness and species diversity were recorded at Pamunugama while they were the highest at Kadol Kele (Table 3).

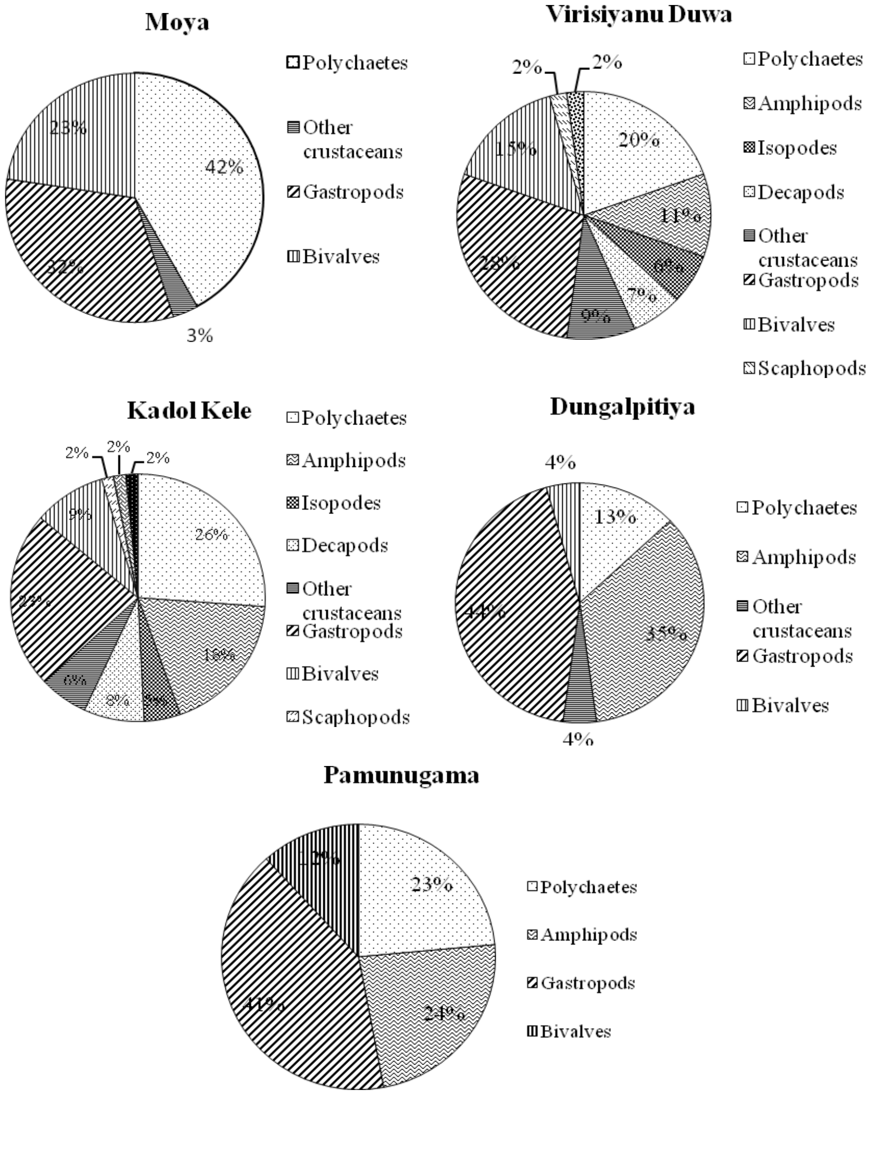

Figure 2. Composition and the % contribution of the major benthic taxa i.e. polychaets, gastropods, amphipods and the bivalves, among the five study sites in Negombo estuary (n = 10).

Table 3. Species richness and species diversity based on the Shannon Wiener Diversity Index (H') between the five study sites.

Site	Species Richness	H'
Kadol Kele	65	3.476
Virisiyanu Duwa	46	3.244
Moya	31	2.831
Dungalpitiya	23	2.644
Pamunugama	17	2.273

Cluster analysis based on the Bray-Curtis similarity matrix showed three significantly different clusters in the dendogram (Figure 3) ($p < 0.05$, One-way ANOSIM). In the first cluster benthic communities at the channel segment of the estuary (i.e. Kadol Kele and Virisiyanu Duwa) clustered together at 45% similarity level. Further, the community structure between these two sites were more or less similar to each other ($p > 0.05$, One-way ANOSIM). In the second cluster benthic community within the body (i.e. Dungalpitiya) and head (i.e. Pamunugama) of the estuary clustered together at 50% similarity level where again the community structure between these two sites were more or less similar to each other ($p > 0.05$, One-way ANOSIM). However, the benthic community at the mouth (i.e. Moya) was significantly different from those of the other study sites ($p < 0.05$, one-way ANOSIM) (Figure 3).

The summary of the analysis of physico-chemical parameters in over lying water and sediment between the five study sites are shown in Table 4 and Table 5 separately. The physicochemical parameters in the overlying water (i.e. salinity, temperature, pH, conductivity, DO, BOD_5, and NO_3^- concentration) varied significantly among most of the five study sites ($p < 0.05$, Tukey's pair wise tests after One-way ANOVA) (Table 4). Similarly the physicochemical parameters in sediment (i.e., salinity, temperature, pH, sand%, silt%, clay% and OM%) too, varied significantly between the five study sites ($p < 0.05$, Tukey's pair wise tests after One-way ANOVA) (Table 5

Figure 3. Dendrogram showing the macrobenthic communities between the five study sites in Negombo estuary. Benthic community of Dungalpitiya and Pamunugama clustered together at 50% similarity level, while those of Virisiyanu Duwa and Kadol Kele clustered together at 45% similarity level. These two clusters are significantly different from each other ($P < 0.05$; One-way ANOSIM). The benthic community structure at Moya was significantly different from the above two communities and separated from them at 20% similarity level.

Table 4. Variation of the physico-chemical factors of over lying water between the five study sites of Negombo estuary (n = 5). Values are mean ± SE, range in parenthesis. “A” indicates whether the factor is significant in the one-way ANOVA ($p < 0.05$). Different subscript letters in a row show significant differences ($p < 0.05$) indicated by Turkey’s pair wise tests.

Physico-chemical parameter	Moya	Virisiyanu Duwa	Kadol Kele	Dungalpitiya	Pamunugama
Salinity (ppt) ^{A}	34±0^{a} (34 -34)	29.6±0.4^{b} (28-30)	32±0^{c} (32-32)	22±0^{d} (22-22)	8.8±0.49^{e} (8-10)
Temperature ^{0}C ^{A}	27.2±0.2^{a} (27-28)	30.2±0.2^{b} (30-31)	28±0 ^{a} (28-28)	28.2±0.2^{c} (28-29)	29.6±0.24^{b} (29-30)
Conductivity µS cm^{-1} ^{A}	923.4±3.49 ^{a} (911-931)	825.8±1.46^{b} (822-829)	1009.4±0.6^{c} (1011-1008)	758.4±1.5^{d} (762-753)	508±2.79^{e} (519-504)
pH ^{A}	8.2±0.023^{a} (8.25-8.14)	8.41±0.01^{b} (8.39-8.43)	8.37±0.04^{c} (8.51-8.28)	8.38±0.02^{c} (8.42-8.29)	8.06±0.070^{d} (8.22-7.89)
DO mgL^{-1} ^{A}	3.64±0.02^{a} (3.7-3.6)	3.34±0.02^{b} (3.3-3.4)	3.64±0.10^{a} (3.3-3.8)	3.8±0.14^{a} (3.5-4.2)	3.72±0.05^{a} (3.6-3.9)
BOD_5 mgL^{-1} ^{A}	1.8±0.15^{a} (1.4-2.1)	2.32±0.02^{b} (2.3-2.4)	1.64±0.05^{a} (1.5-1.8)	2.24±0.18^{a} (1.7-2.8)	2.5±0.05^{c} (2.3-2.6)

Table 5. Variation of the physicochemical factors of sediment between the five study sites of Negombo estuary (n = 5). Values are mean ± SE, range in parenthesis. A indicates whether the factor is significant in the one-way ANOVA ($p < 0.05$). Different subscript letters in a row show significant differences ($p < 0.05$) indicated by Turkey's pair wise tests.

Physico-chemical parameter	Moya	Virisiyanu Duwa	Kadol Kele	Dungalpitiya	Pamunugama
Salinity ppt ^{A}	33±0^{a} (33 -33)	29.2±0.49^{b} (28-30)	31.2±0.49^{c} (30-32)	20±0^{d} (20-20)	8±0^{e} (8-8)
Temperature ^{0}C ^{A}	27.2±0.2^{a} (27-28)	30.2±0.2^{b} (30-31)	30.2±0.2^{b} (30-31)	27±0^{c} (27-27)	29.6±0.24^{d} (29-30)
pH^{A}	8.12± 0.02^{a} (8.1-8.2)	8.34± 0.04^{b} (8.2-8.4)	8± 0.06^{c} (7.8-8.1)	8.18± 0.09^{d} (7.9-8.4)	8.02± 0.07^{e} (7.8-8.2)
Sand %^{A}	98.55± 0.36^{a} (83.61 - 99.1)	89.76± 1.91^{a} (70.6 - 94.8)	77.45± 2.01^{b} (70.6 - 81.9)	66.6± 3.9^{c} (52.5 - 75.5)	1.43± 0.61^{d} (0 - 3.65)
Silt %^{A}	1.45± 0.365^{a} (0.89 - 2.86)	9.75± 1.6^{b} (5.3 - 14.8)	21.67± 2.0^{c} (17.4 - 28.7)	30.86± 3.82^{d} (21.1 - 44.2)	97.3 ± 0.58^{e} (95.6 - 98.7)
Clay %^{A}	0± 0^{a} (0 - 0)	0.492± 0.33^{a} (0.0 - 1.6)	0.88± 0.19^{a} (0.58 - 1.63)	2.54±0.36^{b} (1.71 - 3.40)	1.28±0.44^{c} (0.65 - 2.3)
O M %	0.90±0.09 ^{a} (0.72 - 1.21)	3.14±0.23^{b} (2.42 - 3.82)	3.95±0.54^{c} (2.3 - 5.5)	3.54±0.57^{d} (2.60 - 5.71)	7.80±0.78^{e} (5.04 - 9.3)

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The highest water salinity was recorded at Moya, while it was the lowest at Pamunugama. Pamunugama water also recorded the highest BOD_5 and the lowest conductivity values. The highest pore water salinity, sand % and the lowest silt % and organic matter % were recorded at Moya, while the vice versa were recorded at Pamunugama. Dungalpitiya recorded the highest DO and NO_{3-} in water with the lowest clay % in sediment. However, the remaining physico-chemical parameters in the sediment as well as in the over lying water varied between the five sites, but with no any obvious pattern.

Table 6. Summary of the PCA between the physicochemical parameters of water among the five study sites. Cumulative % variation of only the PC1 and PC2 are shown. A high cumulative percentage as high as 81.1% of the total variation among physico-chemical parameters are explained by PC_1 and PC_2 axis.

Eigen Values					
PC	Eigen values	% Variation	Cum.% Variation		
PC1	3.69	52.8	52.8		
PC2	1.98	28.3	81.1		
Eigen Vectors					
Variable	PC1	PC2	PC3	PC4	PC4
Salinity	0.476	0.241	0.076	-0.310	-0.779
Temperature	-0.307	0.532	-0.078	-0.437	0.125
Conductivity	0.504	0.127	0.186	0.001	0.433
pH	0.359	0.213	-0.555	0.607	-0.036
DO	-0.058	-0.705	0.029	0.007	-0.247
BOD	-0.450	0.092	-0.516	0.064	-0.253
NO-3 Conc.	0.301	-0.303	-0.615	-0.584	0.253
Principal Component Scores					
Sample	SCORE1	SCORE2	SCORE3	SCORE4	SCORE5
Moya	1.098	-0.178	0.476	-1.075	0.000
Virisianuduwa	-0.144	2.332	-0.619	0.088	0.000
Kadol Kele	1.833	-0.203	0.911	0.768	0.000
Dungalpitiya	0.382	-1.486	-1.328	0.136	0.000
Pamunugama	-3.169	-0.464	0.560	0.084	0.000

Principal component analysis revealed that Pamunugama is characterized by having the highest BOD_5 and the lowest salinity in overlying water (Table 6, Figure 4) and the highest silt % and OM % and the lowest salinity in the sediment (Table 7, Figure 5). At the other extreme, Moya is characterized by the highest salinity and conductivity in water (Table 6, Figure 4) and the highest sand %, silt % and pore water salinity in the sediment (Table 7, Figure 5). Of the three remaining sites, Dungalpitya is characterized by having the highest levels of DO and NO_{3-} in the overlying water (Table 6, Figure 4), while the sediment of this site contained a high clay % (Table 7, Figure 5). However, it appeared that both Kadol Kele and Virisiyanu Duwa shared more or less similar sediment and water characteristics that are between Moya and Pamunugama.

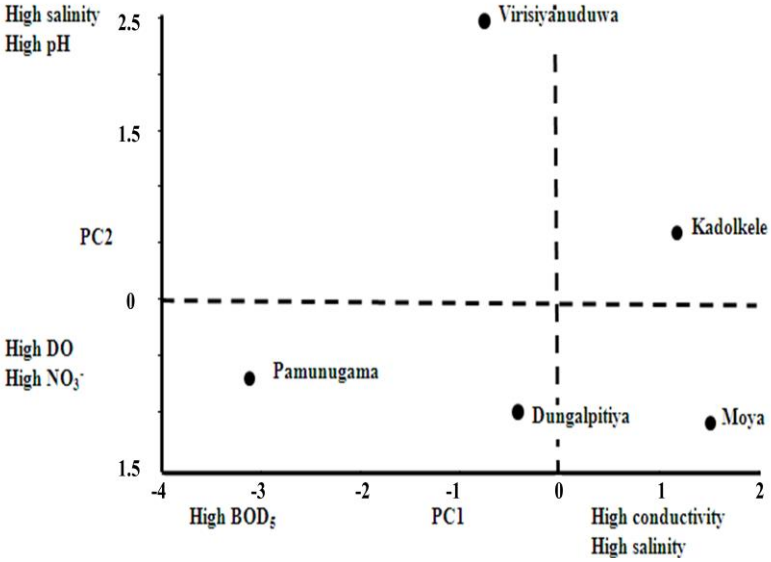

Figure 4. Ordination of the five study sites based on PC_1 and PC_2 scores of PCA of the physico-chemical parameters of over lying water.

Although not statistically significant, it was found that both the species diversity and species richness increased with the increasing salinity, conductivity and pH, and decreased with increasing BOD_5 in the overlying water ($P > 0.05$, Regression analysis) (Figure 6).

Further, the species diversity and species richness increased with the increasing salinity and sand %, and decreased with the increasing silt % and OM % of sediment (Figure 7). However, as earlier, this relationship was also not statistically significant ($P > 0.05$, Regression analysis). From the regression analysis, however, it is evident that both the species diversity and species richness increased from the head end (i.e. Pamunugama) to the mouth end (i.e. Moya) of the estuary

Table 7. Summary of the PCA between the physico-chemical parameters of sediment between the five study sites. Cumulative % variation of only the PC1 and PC2 are shown. A high cumulative percentage as high as 82 % of the total variation among physico-chemical parameters are explained by PC_1 and PC_2 axis.

Eigen Values					
PC	Eigen values	% Variation	Cum.%Variation		
PC 1	4.37	62.4	62.4		
PC 2	1.37	19.5	82.0		
Eigen Vectors					
Variable	PC1	PC2	PC3	PC4	PC5
Salinity	0.453	-0.183	0.155	0.300	0.639
Temperature	-0.117	-0.744	-0.351	0.439	-0.122
pH	0.241	0.144	-0.887	-0.316	0.148
Sand%	0.474	0.023	-0.014	0.211	-0.733
Silt%	-0.473	-0.038	0.019	-0.232	-0.103
Clay%	-0.245	0.601	-0.213	0.714	0.047
OMC	-0.463	-0.172	-0.142	0.093	0.064
Principal Component Scores					
Sample	SCORE1	SCORE2	SCORE3	SCORE4	SCORE5
Moya	2.068	0.198	0.936	-0.686	0.000
Virisianu Duwa	1.315	-0.752	-1.423	-0.134	0.000
Kadol Kele	0.259	-0.977	0.679	0.883	0.000
Dungalpitiya	-0.276	1.936	-0.286	0.372	0.000
Pamunugama	-3.366	-0.406	0.095	-0.436	0.000

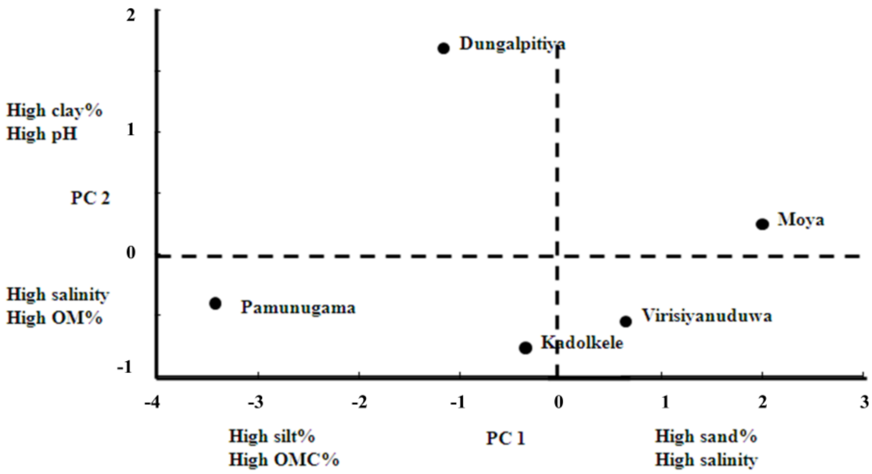

Figure 5. Ordination of the five study sites based on PC_1 and PC_2 scores of Principal Component Analysis of physico-chemical parameters of the sediment.

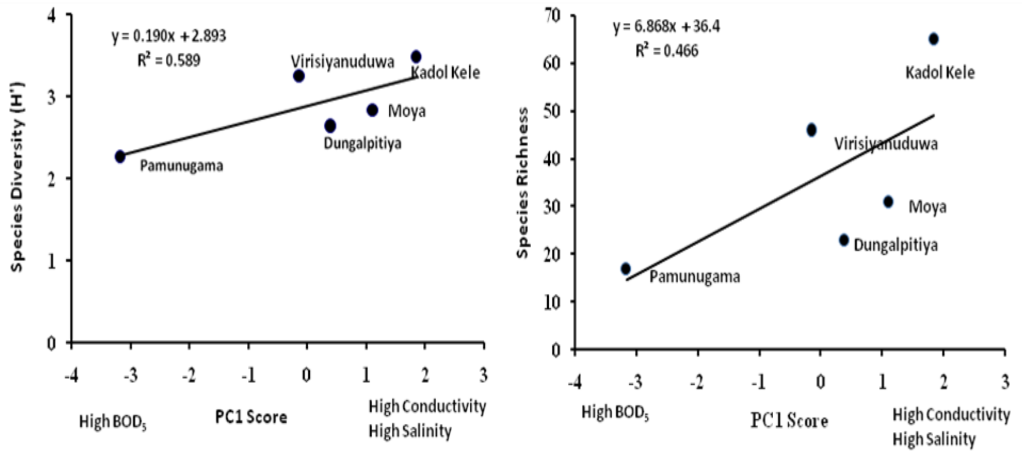

Figure 6. Linear regression of Shannon Wiener diversity index (H’) and the species richness of the five study sites against the PC1 score for physico-chemical parameters of the overlying water.

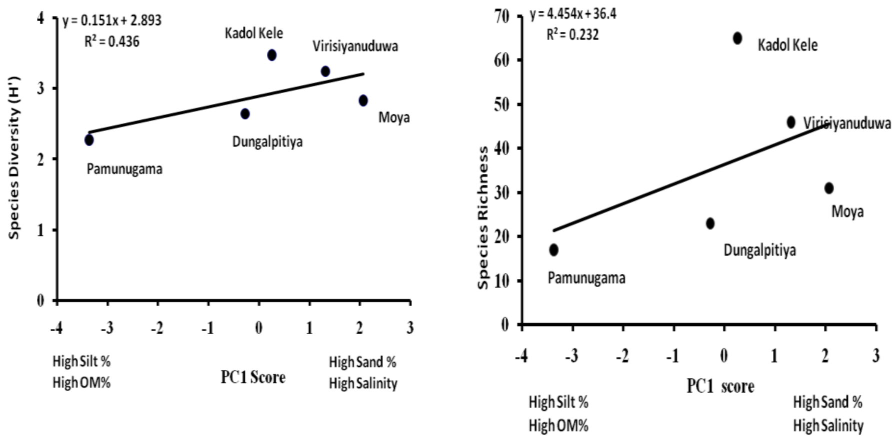

Figure 7. Linear regression of Shannon Wiener diversity index (H’) and the species richness of the five study sites against the PC1 score for physicochemical parameters of sediment.

Discussion

The present study was carried out to determine whether the spatial distribution of macrobenthic community in Negombo estuary is governed by the physicochemical parameters in sediment and the over lying water in pre-selected sites. Results revealed that the species richness, species diversity and the structure of the macrobenthic community varied significantly between the study sites in relation to the variations of sediment and water characteristics among these sites.

Of the five study sites selected, Pamunugama is located at the head end of the estuary where freshwater is drained from the river, Dandugam Oya. As it is always the case in world rivers, Dandugam Oya too, carries a large amount of silt and organic debris from the associated lands along its way to the estuary. Further, the influence of the sea is minimum at this site hence chances are high for the silt and organic matter to settle on the bottom with time. Similar observations have made by Tagliapietra *et al*. (2004) where the suspended materials sink and accumulate on the bottom forming sediments characterized by fine particles and high organic matter content. Due to the high amount of organic matter microbial population should also be very high in this site. Therefore the site recorded the highest BOD_5 and silt % together with the lowest salinity.

On the other extreme, Moya is situated by the mouth of the estuary and is continuously influenced by the strong water currents from the sea and from the estuary. These water currents shear the bottom and suspend the less heavy silt, clay and organic matter particles to be carried away leaving the heavier sand particles on the bottom. Therefore the clay %, silt % and organic matter % are very low at this site. The salinity at this site is almost the same as that in the sea i.e, 35 ppt. It is interesting to note that the dissolved NO_3^- concentration of this site was relatively high probably due to the effluents from the raw fish processing factories established nearby as Moya is the main fish landing site in Negombo estuary. In spite of this, this site also recorded the highest dissolved oxygen level may be due to the swift mixing of water in this area.

Of the three remaining sites, Virisiyanu Duwa and Kadol Kele occur within the channel segment of the estuary and are about 1 km south to the Moya. The coastlines of these sites are partially margined by a dense cover of mangroves while the bottom is matted with a thick growth of sea grasses. These sites are relatively less disturbed by anthropogenic activities and are not directly influenced by the sea nor the fresh water drainage so that the physico-chemical parameters remained at moderate levels between Moya and Pamunugama.

The remaining site Dungalpitiya is situated about 3 km north to Pamunugama. It is a heavily polluted site where the untreated effluents from nearby piggeries, shrimp farms, and poultry farms are discharged. Owing to the fact this site is also occurring in a pocketed out stretch in the inner region of the estuary, the water is not circulating properly. The highest NO_3^- concentration and clay % recorded at this site may be due to the above reasons. During the field sampling it was also observed that the water colour at this site is greenish may be due to eutrophication.

Owing to the inherent features, it is therefore not surprising to find significant variations of the physico-chemical parameters in sediment and over lying water of these five study sites. Nevertheless, the salinity of water and sediment, sand % and conductivity showed an increasing trend together with a decreasing trend of silt %, clay %, OM % and BOD_5 from the head end (i.e. Pamunugama) to mouth end (i.e. Moya) of the estuary. This is usually the case with many estuaries in the world, particularly in the temperate region (McLusky, 1982). This is case for lagoons not for estauaries, hydraudynamics of estuaries are quite different from lagoons (see Bird 1983, 1994, 2000)

Many studies *viz.* Thorhaug (1974) and Anbuchezhian *et al*. (2009) have shown that the distribution of benthic organisms, species diversity, species richness and species evenness are closely related to the changes in the physico-chemical characteristics of water and sediment and also to anthropogenic effects on the environment. Therefore the less mobile macrobenthic communities in estuaries should be contrastingly different from locale to locale. Similar observations were noted between the five study sites in the present study too, where the benthic community structure between the mouth, body and the head of the estuary appeared to be less similar to each other. The % contributions of major macrobenthic taxa to the composition of the community structure at each site were also different.

Of the five sites, both Moya and Pamunugama are no true estuarine habitats as Moya is significantly influenced by the sea while Pamunugama is influenced by the freshwater drainage. Nevertheless, the three remaining sites share true estuarine features.

The highest species richness and species diversity (H') were recorded both at Kadol Kele and Virisiyanu Duwa. This endorsed the finding of Bosire *et al*. (2004) where the species diversity is higher in sediments that are associated with mangroves and sea grasses. As described earlier, these sites are undisturbed by man and possess a thick growth of sea grasses, and directly influenced by the associated mangrove cover. These dynamic mangrove and sea grass bed habitats support a diversified micro, and macro-organisms where the microbial flora, in particular, play an active role in decomposing mangrove foliage at the bottom. The benthic organisms are provided with a good supply of food in the detritus food chain (Kumar, 2000) and increase the diversity and abundance of macro benthic faunas.

Although Dungalpitiya too harbours mangroves and sea grasses it recorded a relatively low species richness and species diversity. This may be due to the high concentration of dissolved NO_{3-}, eutrophication, less rapid water circulation and many other human disturbances that are predominant features of this site.

In the present study, the species richness and species diversity (H') showed an increasing trend from Pamunugama to the Moya of the Negombo estuary. Further, both species diversity and the species richness appeared to be positively correlated with the salinity and negatively correlated with the BOD_5 in water and positively correlated with the salinity and sand % and negatively correlated with the silt % and OM % of the sediment. Nevertheless these relationships are statistically not significant. Inability to obtain significant relationships is mainly due to the morphology of the estuary where the Negombo estuary is a shallow basin type one in which the water is well mixed so that there are no gradient with respect to some physico-chemical factors such as salinity etc. Further, the results of the present study could have been improved had the number of sampling sites were increased and selected along a line transect that run from the head to the mouth of the estuary. This suggestion is made for future work related to the theme of this study. By improving this area, it could be possible to obtain a clearer picture of the relationship of macrobenthic community to the prevailing physico-chemical parameters of the estuary.

Prior to the present study, Dahanayaka and Wijeyaratne (2006) studied the spatial distribution of marobenthic fauna in Negombo estuary. They have sampled 25 different sites representing different regions of the estuary but have recorded only 76 macrobenthic taxa. Further they did not record any polycheate species from their sampling sites located near the mouth of the estuary i.e. Moya. However, the present study recorded 87 macrobenthic taxa merely by sampling only 5 different sites. In addition 13 polychaete species were also recorded from the Moya. The discrepancy of the findings of these two studies could be attributed to the apparatus used for sampling and the number of samples obtained from each site. For their study, Dahanayaka and Wijeyaratne (2006) used a Peterson grab to collect sediment samples and only 3 sediment samples were made from each site, while in the present study the sampling strategy was improved by choosing a soil corer to take sediment samples to a depth of 15 cm within the sediment and 10 such soil samples were made from each site. While the Peterson grab bites only the surface of the mud layer, the soil corer collects both the surface as well as the below sediment layers to a considerable depth so that chances are high to collect the macrobenthos such as polycheates that live within the deeper mud layers. Peterson grab is a good apparatus for less consistent muddy surfaces but unsuccessful at the bottoms dominated with sea grasses and pebbles as only the surface is scraped out leaving the deep burrowing forms intact and uncollected.

The present study found polychetes dominating in all the sediment samples collected from Moya. It is a known fact that polycheates are marine forms so that they should be expected more, as shown in this study, in a more marine site such as Moya. It is also true that sedentary polychaetes prefer to inhabit in places that are improvised with high levels of organic matter. Contrary to these facts, Dahanayaka and Wijeyaratne (2006) recorded a lesser number of polycheates at Moya, but many in the Southern part of the estuary. The present study found only a fewer number of polychaetes at organically rich Pamunugama and Dungalpitiya. Thus the low species richness of polycheates may be due to one or a combination of the above factors or the high level of pollution and eutrophication at these two sites. It could also be related to sediment properties and other environmental conditions prevailing in the area (Jayaraj *et al*., 2007).

Salinity is usually the major factor responsible for diversity patterns in estuaries (Remane and Schlieper, 1971). The importance of salinity on estuarine organisms is well documented, and this is likely the single most important factor affecting the distribution of the benthos (Gunter, 1961; Kinne, 1966). Sediment composition (Sanders, 1958, 1960) and sediment grain size (Dahanayaka and Wijeyaratne, 2006) have also been identified to be influencing the distribution of benthic fauna in an estuary. Particle size is a good measure of current energy and food variety, and it has long been recognized that benthic assemblages vary with particle size. For example, Pinnet (2000) suggested that organisms of the same feeding guild would dominate a particular type of substrate. Nevertheless, a single most important factor that is responsible for the spatial distribution of fauna in the Negombo estuary could not be identified as was seen in the present study where their distribution appeared to be governed by an interplay of salinity, BOD_5, soil texture etc. Similar observations have made by Dauer *et al* (2000) too, in temperate estuaries.

In conclusion, results of the present study revealed that the species richness and species diversity as well as the prevailing physico-chemical parameters varied significantly among the study sites within the Negombo estuary. The species diversity and the species richness were positively correlated with the salinity and negatively correlated with the BOD_5 in water and positively correlated with the salinity and sand

% and negatively correlated with the silt % and OM % of the sediment in the five study sites. It is therefore evident that the spatial distribution of macrobenthic fauna in this tropical Negombo estuary is governed by the interplay of some salient physico-chemical parameters such as salinity, sand % and BOD_5 in sediment and the over lying water.

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