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Hydrography, nutrients and abundance and distribution of zooplankton in Negombo Lagoon, Sri Lanka.

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Abstract

Negombo Lagoon is a productive fishing ground and also a sink for many anthropogenic effluents draining from its surrounding urban area. The seasonal abundance and distribution of zooplankton were investigated in relation to some physico-chemical parameters of the lagoon from March 2008 to September 2009. Zooplankton and surface water samples were collected from five sampling sites where effluents are discharged to the lagoon and analyzed using standard methods.

Lagoon salinity ranged spatially from 0 - 25 ppt and mean monthly salinity varied from 1.08 ±1.75 to 15.23 ±5.33 ppt. Surface water temperature varied from 26.0 to 34.1^{0}C whereas mean pH ranged between 7.34 ± 0.32 and 8.02 ± 0.48. Variation of mean dissolved oxygen as between 5.73 ± 2.49 mg/l and 7.00 ± 1.87 mg/l. Micro-crustaceans represented the major component of zooplankton assemblage and ranged from 54.37 to 84.33% throughout the study period. A higher percentage of freshwater cladocerans was recorded during low salinity period (February-April, 2009) in Dundugam Oya and from April to June in Hamilton canal, the main freshwater inlets of the lagoon. Mean cladoceran density in Dandugam Oya was (1.96±3.50 individuals/l) higher compared to the cladoceran density in Hamilton canal (0.47±1.10 number/l). Nevertheless there was no significant relationship between salinity and the density of cladoceran. A positive significant correlation was found nitrate-N concentration and copepod density ($r = 0.804$; $p<0.01$) for the site in Dungalpitiya, where rotifer density did not show positive relationship but correlated positively with phosphate-P concentration although it was statistically insignificant ($r = 0.489$; $p>0.05$). Further, rotifer density in Madabokka area showed a positive and significant relationship with nitrite-N concentration ($r = 0.731$; $p<0.01$). The molluscan abundance showed a significantly positive correlation with salinity ($r = 0.713$; $p<0.01$) for the Dandugan Oya site.

High concentration of phosphate and occurrence of pollution indicator species reveal organic pollution in the lagoon. Abundance of plankton was strongly influenced by the water circulation pattern and direct or indirect human impacts that occur at each site of the lagoon.

Introduction

Coastal lagoons, estuaries and bays are characterized by rapid changes in environmental parameters both temporally and spatially due to the influences of tides, coastal currents, freshwater influx, atmospheric processes and anthropogenic activities (Hsu et al. 2008). These are highly dynamic and diverse coastal regions of high productivity depend on the amount of plankton present in a particular water body (Guy 1992; Islam et al. 2005). The seasonality of abundance, dynamics and productivity of phytoplankton and zooplankton plays a decisive role in determining the economic potential of lagoons. The evaluation of seasonality of plankton and elucidation of its causes are therefore of considerable ecological importance. The gross primary productivity of the Negombo lagoon was high ranging from 139.5 to 213.75 mg C m^{-3} h^{-1} compared to other coastal lagoons in Sri Lanka (Jayasiri 2004). Nevertheless, chlorophyll-a contents indicate non-eutrophic condition in Negombo lagoon throughout the year although there are localized sites of high chlorophyll-a contents. The abundance and diversity of zooplankton in inlet canals of the Negombo lagoon have also been examined (Arulananthan et al. 2000). Sanjeewa et al. (2007) found that total fish and shrimp catches in the lagoons were influenced by salinity and water temperature. One of the most interesting biotic and abiotic features of lagoon ecosystem is their seasonal variation. Thus, seasonal variations of the physico-chemical variables of the lagoon can be expected to cause variation in abundance and diversity of plankton (Davies et al. 2009).

Physicochemical characteristics of lagoons are regulated by several factors such as quality and quantity of freshwater fluxes, sediment transport, influx of sea water, tidal force and wind induced mixing of fresh water and sea water. In addition, the bottom topography and mean depth and human impacts are also of major importance.

There is no regular information on the seasonal abundance and distribution of zooplankton as well as the water quality of this lagoon. Therefore in the present study, physicochemical characteristics and their impact on diversity, density and seasonal variation of zooplankton in Negombo lagoon were examined.

Materials and Methods

Study area: Negombo lagoon is a shallow basin estuary of approximately 3,164 ha in extent, located between latitude 7' – 7°12' N and longitude 79° 79°53' E in west coast of Sri Lanka. It is connected to the sea by a single narrow opening, the Negombo channel segment at its northern end, which is open year round. The Negombo estuary extends 12 km in length, 3.75 km at its widest point (Jayakody 1994). It has a surface area of 35 km^2 and holds about 22.5 million m^3 of water (Hettiarachchi and Samarawickrama 2003). The exchange of water in the lagoon is influenced by the tides from the ocean and freshwater supply from the inland. The lagoon receives freshwater from the Attanagalu Oya which empties as Ja-Ela and Dandugam Oya at its southern end.

Sampling sites

Five sampling sites (Madabokka, Dandugan Oya, Hamilton canal, Dungalpitiya and Munnakkaraya; Figure 1) which represent various pollution inputs were selected for this study. Water samples for physico-chemical analyses and plankton analysis were conducted monthly intervals from March 2008 to September 2009. Surface water samples for physico-chemical parameters (pH, salinity, total suspended matter, Phosphate-phosphorus, nitrate-nitrogen and nitrite-nitrogen concentrations) were collected in one-litre for sterilized plastic containers and analyzed following standard methods as described below.

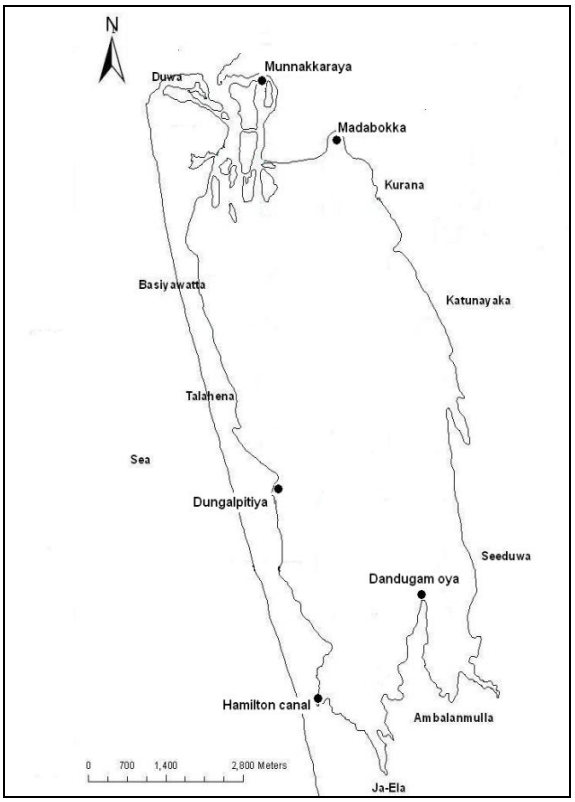

Figure1. Map of Negombo lagoon showing sampling sites.

***In-situ* measurements**

The surface water and air temperature were measured *in-situ* to the nearest 0.1°C accuracy using a mercury thermometer while water depth was measured to the nearest 1 cm using a calibrated pole. The surface water salinity was measured using a salinity refractometer, whereas pH was determined with a portable pH meter (Model: HANNA/HI-8314). Water samples collected in air-tight glass stoppered bottles, were processed in the field with Winkler reagents for laboratory analysis of dissolved oxygen content as described by Mackereth et al. (1978).

Biological oxygen demand (BOD) was measured using methods according to APHA (1998) for water analysis. Phosphate-phosphorus, nitrate-nitrogen and

nitrite-nitrogen concentrations were measured (APHA 1998) using Spectrophotometric methods (HACH-DR 4000U). Chlorophyll-a concentration was measured using spectrophotometric method as described by Parsons et al. (1984). Total suspended matter was measured using gravimetric method described by (Silva et al. 1996).

Zooplankton samples were collected using plankton net with a mesh size of 100µm. and a net mouth area of 0.07m^2. The volume of water passed through the net was measured using a calibrated flow meter that was attached to the middle of the net frame. The filtered samples were washed into the sterilized collecting bottles and immediately fixed in 5% formalin. In the laboratory, one ml of each sample were investigated at different magnifications (100X, 400X) using a binocular microscope with a sedgewick rafter counting chamber. Identification was done by using plankton keys by Todd et al. (1996) and Omori and Ikeda (1984). The zooplankton density was expressed as number of organisms per litre. Data on rainfall for the sampling period was obtained from the Meteorological Department, Colombo, Sri Lanka.

Pearson's correlation (r) analysis was performed to investigate whether physico-chemical variables are related to zooplankton diversity. MINITAB (ver. 14) software package was used for statistical analysis.

Results

Mean values of physico-chemical and biological parameters in Negombo lagoon during the study period are given in Table 1. The salinity of the lagoon varied from 0 ppt (in Dandugam Oya and Hamilton canal) to 25 ppt (in Munnakkaraya) at selected sites. The mean water depth varied from 46.38±9.91cm in Madabokka to 196.69±32.36 cm in Dandugam Oya. A wide pH range (7.34±0.32-8.02±0.48) was recorded throughout the study period at each sampling station. Dissolved oxygen ranged from 5.73±2.49 mg/l in Munnakkaraya to 7.00±1.87 mg/l in Dungalpitiya. Also BOD levels ranged between 2.06±1.15 mg/l in Madabokka to 3.00±0.71 mg/l in Dungalpitiya. The mean nitrate varied from 0.59±0.36 to 1.23±0.92 mg/l, while phosphate ranged from 0.68±0.98 (Dungalpitiya) to 1.18±1.02 mg/l (Munnakkaraya) during the study period. According to results mean chlorophyll *a* of all sampling locations ranged from 12.39±8.03 to 54.03±58.43 µg/l throughout the study period.

Monthly variation of physic-chemical parameters in the sampling sites selected and mean monthly rainfall in the area are graphically shown in Figure 2. Higher amount of total suspended matter was recorded in Hamilton canal (410 mg/l) and Dandugam oya (1300 mg/l) during September 2008 and July 2009 respectively. Mean Nitrate-N content varied between 0.59±0.36 to 1.23±0.93 mg/l except in June 2009 in Dungalpitiya when it increased above 4.4 mg/l. Not surprisingly, there is a marked influence of monthly precipitation on physico-chemical parameters of the lagoon (Figure 2).

Table 1. Mean values (± SD) of physico-chemical and biological parameters in Negombo lagoon (March 2008 – September 2009).

Parameter	Location				
	Madabokka	Dandugam Oya	Hamilton Canal	Dungalpitiya	Munnakkaraya
Water Temperature (^{0}C)	30.11±1.67	29.95±0.98	31.07±1.23	30.87±1.36	30.10±1.80
Water Depth (cm)	46.38±9.91	196.69±32.36	85.54±10.04	53.77±10.38	114.15±26.17
Secchi Depth (cm)	45.45±10.11	79.36±19.27	58.45±9.50	50.64±9.34	65.20±15.61
Salinity ($^0/_{00}$)	11.50±4.61	1.08±1.75	3.00±3.14	11.77±4.64	15.23±5.33
pH	8.02±0.48	7.34±0.32	7.36±0.28	7.80±0.36	7.64±0.36
Suspended matter (mg/l)	50.65±111.35	115.72±356.88	53.79±110.89	17.49±27.03	25.31±25.99
Dissolved Oxygen (mg/l)	6.24±2.91	6.69±2.11	6.40±1.90	7.00±1.87	5.73±2.49
Biological Oxygen Demand (mg/l)	2.06±1.15	2.33±0.56	2.53±1.25	3.00±0.71	2.30±0.71
Chlorophyll (mg/l)	38.18±60.59	25.57±31.55	54.03±58.43	21.50±24.76	12.39±8.03
Nitrite-N (mg/l)	0.0098±0.015	0.0038±0.0031	0.0104±0.009	0.0100±0.008	0.0093±0.0064
Nitrate-N(mg/l)	1.23±0.92	0.59±0.36	0.94±0.63	1.03±1.14	0.88±0.40
Phosphate-P(mg/l)	0.88±0.98	0.90±0.98	0.80±0.75	0.68±0.98	1.18±1.02

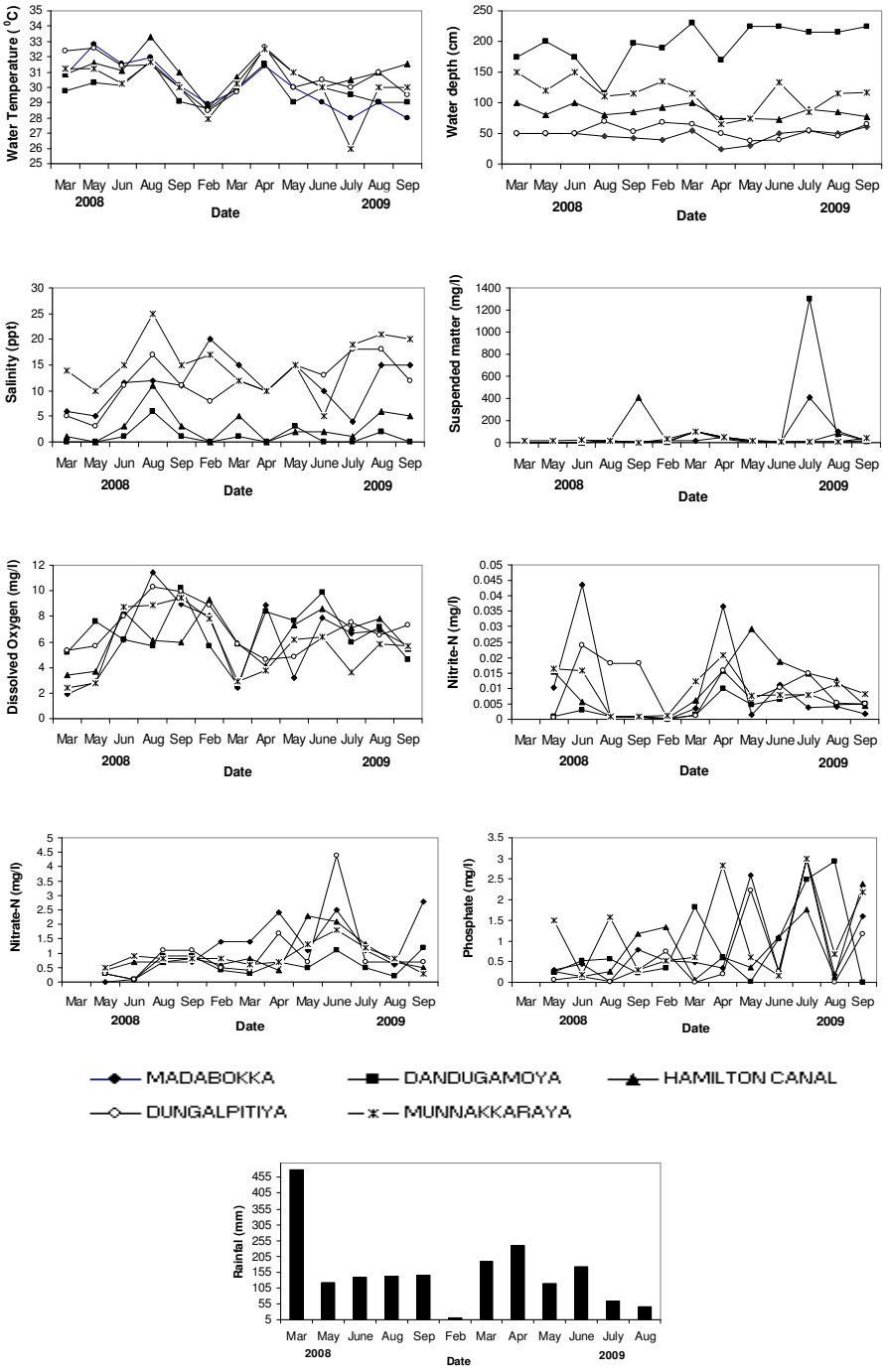

Figure 2. Monthly variation of water temperature (°C), water depth (cm), salinity (‰), suspended matter (mg/l), dissolved oxygen (mg/l), nitrite-N (mg/l), nitrate-N (mg/l), phosphate concentration (mg/l) of the five sampling sites of Negombo lagoon and rain fall (mm) during the sampling period.

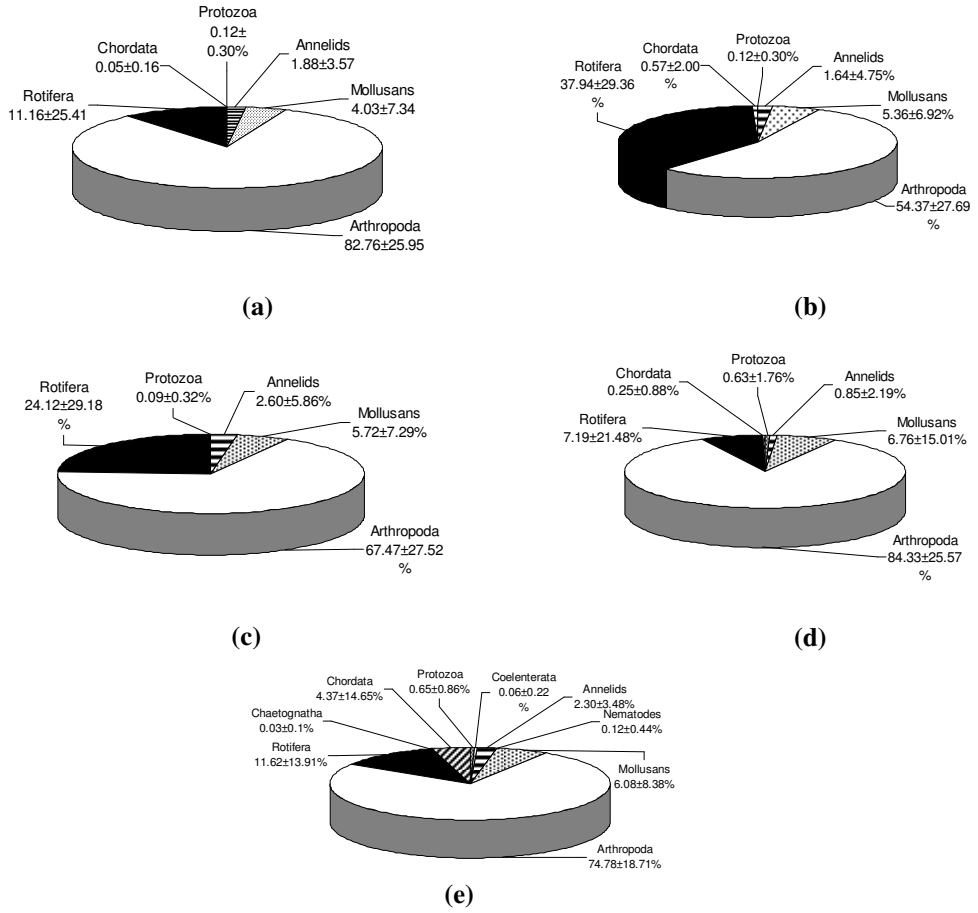

Figure 3. Mean percentages of zooplankton in the five sampling sites (a) Madabokka, (b) Dungalpitiya, (c) Hamilton canal, (d) Dandugam Oya, (e) Munnakkaraya during the sampling period.

Mean percentages of zooplankton in the five sampling sites are shown in Figure 3. Crustaceans were the most diverse and abundant group of zooplankton in the Negombo lagoon during investigation period and contributed 54.37 to 84.33% of the zooplankton community. Of the class Crustacea, the order Cladocera, Copepoda (Calanoid, Cyclopoid, Harpacticoid and crustacean larvae), Euphausiaceae, Decapoda, Mysidacea were recorded. Results of the present study showed that copepods represented the 95.8 to 99.5% of the crustacean density. Out of the copepods majority were represented by nauplius larvae ranging from mean monthly proportions of 44.98% to 67.34%. Monthly variation of zooplankton in the five sampling sites (Figure 4) indicated that higher density of freshwater cladocerans was recorded during low salinity period (February-April 2009) in Dundugam Oya and April to June in Hamilton canal, the sites where main freshwater outfalls are located. However, mean cladoceran density (1.96±3.50 number/l) in Dandugam Oya was higher than that of Hamilton canal.

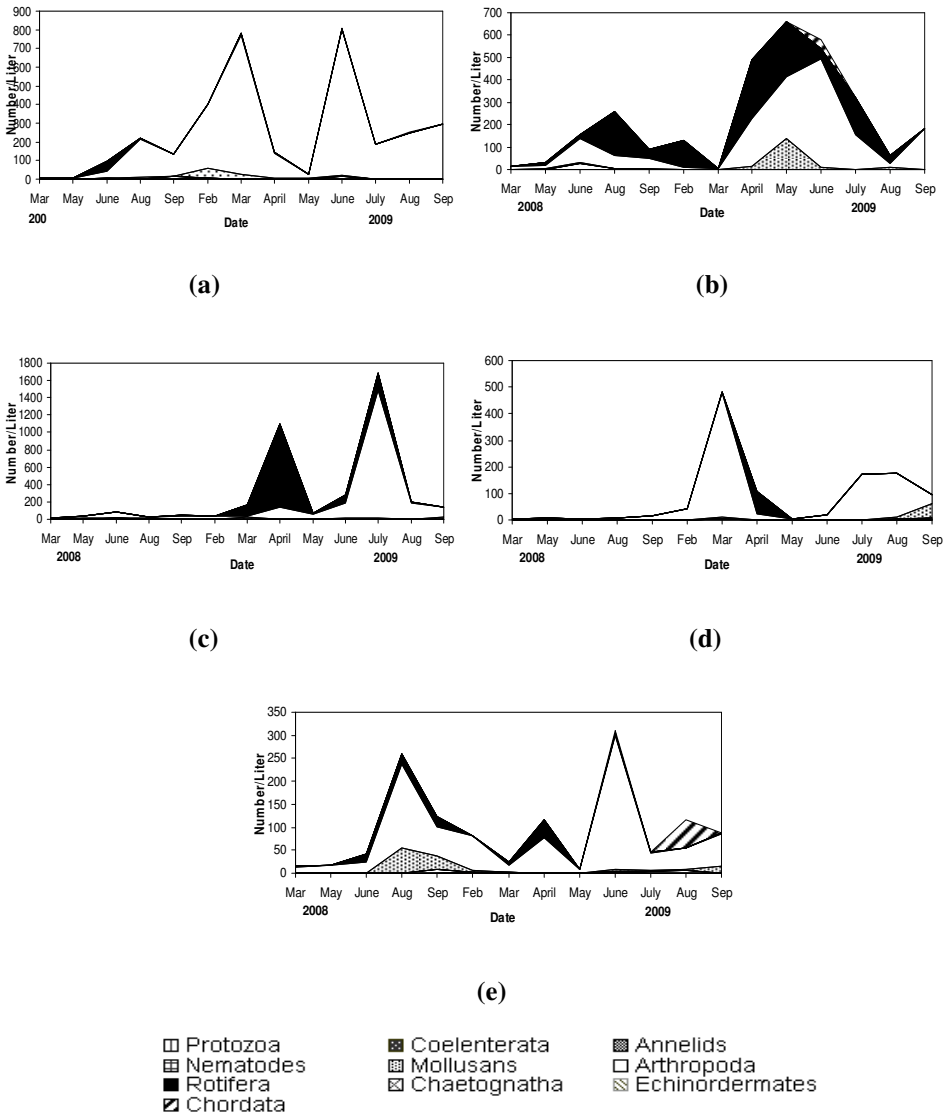

Figure 4. Monthly variation of zooplankton in the five sampling sites (a) Madabokka, (b) Dungalpitiya, (c) Hamilton canal, (d) Dandugam Oya, (e) Munnakkaraya during the sampling period.

Nevertheless, there was no significant relationship between salinity and density of cladocera. A significantly positive correlation observed between nitrate-N and copepods density ($r = 0.804$; $p<0.01$) in Dungalpitiya, whereas rotifer density also had positive but statistically non-significant correlation with phosphate content ($r = 0.489$; $p>0.05$). Further, rotifer density in Madabokka area also showed a positive and significant relationship with nitrite-N content of the area ($r = 0.731$; $p<0.01$). Molluscan abundance showed a significant positive correlation with salinity ($r = 0.717$; $p<0.01$) in Dandugam Oya.

Discussion

The mean surface water temperature varied between 29.8 and 31.0° C and all stations showed a similar trend during sampling period. Govindasamy et al. (2000) stated that surface water temperature is influenced by the intensity of solar radiation, insolation, evaporation, freshwater influx and cooling and mix up adjoining waters.

The highest suspended sediment content was recorded during the rainy season (1300 mg/l) in Dandugam Oya site, the main freshwater input to the lagoon. This observation might probably be due to increased sediment load from surface run-off. The estuary receives freshwater from the Attanagalu Oya which empties as Ja-Ela and Dandugam oya at its southern end. In addition, the Hamiltan canal is the connecting water course of the Kelaniya estuary and the Negombo estuary, running parallel to the west coast from the south to the north along the Muthurajawela marsh. According to Wickremaratne et al. (1991), freshwater enters the estuary from the Attanagalu Oya (Dandugam Oya and Ja-Ela) 1.5 km^3/y and from precipitation (0.2 km^3/y). As a result low salinity in Dandugam Oya has been recorded and higher salinity in Munnakkaraya due to increased tidal sea water incursion. Salinity is known to act as a limiting factor in the distribution of living organisms (Gibson 1982) and changes in salinity in the brackish water habitats such as estuaries, are due to the influx of freshwater from land run off caused by rainfall, evaporation loss and tidal volume (Saravanakumar et al. (2007). Seasonal salinity changes in Negombo lagoon is positively correlated with seasonal rainfall of the catchment area of the Attanagalu Oya (Silva and De Silva 1981; Rajapaksha 1997).

The highest phosphate level (1.18±1.02 mg/l) indicates pollution since it is above the standard limit of 0.025mg/l in natural aquatic bodies as specified by USEPA (*United States Environmental Protection Agency*). This could be due to dumping of household wastes/detergents by the surrounding houses. Also it might be attributed to the raw human sewage and animal fecal matter being discharged into the canal water. The high biological oxygen demand values in Dungalpitiya site are also evident where shrimp farm effluents are received.

The total population density of zooplankton varied between 30,000 to 210,000 organisms/m^3 in Gulf of Kachchh, Gujarat reported by Saravanakumar et al. (2007). This density is rather similar to present study where the population density varied from 87 – 298 organisms per litre. The abundance of zooplankton in Negombo lagoon varied from 48-198 individuals l^{-1}. The average wet biomass of zooplankton in the lagoon was 0.5 g m^{-3} Arulananthan et al. (2000).

Of the zooplankton, cladocerans and cyclopoid copepods were most dominant forms fresh to low brackish water situations whereas the calanoid copepods were most dominant forms in higher brackish water situation (Emmanuell and Onyemal 2007). Similar results have been reported by Tackx et al. (2004), in an investigation on zooplankton of Schelde estuary (Belgium), where brackish water zone was dominated by calanoid copepods and cyclopoid copepods together with several cladocerans species dominated the freshwater and low brackish water transect of the estuaries.

The spatiotemporal structure of zooplankton assemblages and its correlation with environmental variables showed that salinity and nutrients were the main factors influencing the distribution of zooplankton. The micro zooplankton with short generation times, such as ciliates, rotifers and cladocerans which would probably be the first to respond to hydrological and nutrient perturbations (Romo et al. 2004). High amount of phosphate discharge from the adjacent shrimp farm in Dungalpitiya site is highly correlated with density of copepods in the area. It is evident that distribution pattern of copepods are often influenced by environmental factors, especially in estuaries, bays and lagoons (Hsu et al. 2008) and their distributions at some times and places, are obviously influenced by anthropogenic activities and hydrodynamic processes (Chang et al. 2004). The increased phosphate and nitrate levels in the lagoon could be attributed to oxidation of organic matter, human and animal waste, laundry, cleaning, fertilizer runoff and industrial discharges from urban areas. It seems that some locations of the lagoon are under stress due to the high phosphate concentration. Davies et al. (2009) stated that abundance, diversity and distribution of plankton are affected by seasonal variation of some physico-chemical parameters and biological regime of the aquatic environments. The results of the present study also showed that abundance of plankton was strongly influenced by the water circulation pattern and direct or indirect human impacts that occur in each study site of the estuary. It is pertinent to note that only treated effluents must be discharged into the lagoon. Proper waste water and solid waste management facilities should be provided to the surrounding dwellers of Negombo lagoon.

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References

APHA 1998.
Standard method for the examination of water and waste water. 20th Edition. Washington D.C.

Arulananthan, K.,C. Amarasiri, N. Sureshkumar and K. Haputantri 2000.
Negombo Lagoon, A report on status of environment, resources, exploitation and management options. National Aquatic Resources Research and Development Agency, Colombo (unpublished Report). 25 pp.

Chang W.B. and L.S. Fang 2004.
Temporal and spatial variation in the species composition, distribution and abundance of copepods in Kaohsiung harbor, Taiwan. Zoological Studies 43: 454-463.

Davies, O.A., J.F.N. Abowei and B.B. Otene 2009.
Seasonal Abundance and Distribution of Plankton of Minichinda Stream, Niger Delta, Nigeria. American Journal of Scientific Research 2: 20-30.

Emmanuel1, B.E. and I.C. Onyema1 2007.
The Plankton and Fishes of a Tropical Creek in South-Western Nigeria. Turkish Journal of Fisheries and Aquatic Sciences 7: 105-113.

Ezra, A. G. and D.I. Nwankwo 2001.
Composition of phytoplankton algae in Gubi Reservoir, Bauchi, Nigeria. Journal of Aquatic Sciences. 16(2): 115-118.

Gibson, R. N. 1982.
Recent studies on the biology of intertidal fishes. Oceanography and Marine Biology: an Annual Review 20:363-414.

Govindasamy, C., L. Kannan and J. Azariah 2000.
Seasonal variation in physico-chemical properties and primary production in the coastal water biotopes of Coromandel coast. Indian Journal of Environmental Biology 21:1-7.

Guy, D. 1992.
The ecology of the fish pond ecosystem with special reference to Africa. Pergamon Press, New York. pp. 220-230.

Hettiarachchi, S.S.L. and S.P. Samarawickrama 2003.
Towards Improved Environmental Management of the Negombo Lagoon. COPEDEC VI, Colombo, Sri Lanka.

Hsu, P.K., W.T. Lo and C.T. Shih 2008.
The coupling of copepod assemblages and hydrography in a eutrophic lagoon in Taiwan: Seasonal and spatial variations. Zoological Studies 47(2):172-184.

Islam, M.S., H. Hiroshi and M. Tanaka 2005.
Spatial distribution and tropic ecology of dominant copepods associated with turbidity maximum along the salinity gradient in a highly embayed estuarine system in Ariake Sea, Japan. Journal of Experimental Marine Biology and Ecology 316: 101-115.

Jayakody, D. S. 1994.
Traditional lagoon fisheries in Negombo. In: Development of Community-based Fishery Management (M.J. Morris, M. Hotta, and A.R. Atapattu, eds), Bay of Bengal Programme for Fisheries Management: BOBP/REP/72: pp.98.

Jayasiri, H.B. 2004.
Chlorophyll-a tool to determine the status of coastal lagoons. Proceeding of Tenth Annual Scientific Sessions of Sri Lanka Association for Fisheries and Aquatic Resources (Abstract). 9 p.

Mackereth, F. J. H., J. Heron & J. F. Talling 1978.
Water analysis some revised methods for limnologists. Freshwater Biological Association Scientific Publication, Ambleside, Cumbria No.36, 120 p.

Omori, M. & T. Ikeda 1984.
Methods in Marine Zooplankton Ecology. A Wiley–Interscience Publication, John Wiley & Sons, New York. 332 p.

Osore, M.K.W., J.M. Mwaluma, F. Fiers and M.H. Daro 2004.
Zooplankton composition and abundance in Mida Creek, Kenya. Zoological Studies 43(2): 415-424.

Parson, T.R., Y. Maita and C.M. Lalli 1984.
A Manual of Chemical and Biological Methods for Sea Water Analysis. Pergamon Press, Oxford. 173 pp.

Rajapaksa, J.K. 1997.
Low Frequency Tidal Response and Water Exchange in a Restricted Lagoon: The Negombo Lagoon, Sri Lanka. M.Sc. thesis, University of Gothenburg, Sweden.

Romo, S., M.R. Miracle, M.J. Villena, J. Rucda, C. Ferriol and E. Vicente 2004.
Mesocosm experiment on nutrient and fish effects on shallow lake food webs in a Mediterranean climate. Freshwater Biology 49: 1593-1607.

Sanjeewa, J.K.G.P., H.B. Jayasiri and P.A.T. Jayawardena 2007.
Fish abundance in relation to some environmental parameters and gear type in the Negombo Lagoon with special reference to shrimp. International Conference on Tropical Aquatic Research towards Sustainable Management, 15-16 February 2007, National Aquatic Resources Research and Development Agency, Colombo.

Saravanakumar, A., M. Rajkumar, J. Sesh Serebiah and G.A. Thivakaran 2007.
Abundance and seasonal variations of zooplankton in the arid zone mangrove of Gulf Kachchh-Gujarat, west coast of India. Pakistan Journal of Biological Sciences 10 (20): 3525-3532.

Silva, E.I.L. and S.S. De Silva 1981.
Aspects of the biology of grey mullet, *Mugil cephalus* L., and adult populations of a coastal lagoon in Sri Lanka. Bulletin of the Fisheries Research Station, Sri Lanka. 19:1-10.

Silva, E.I.L., S.Y. Namaratne, S.V.R. Weerasooriya and L. Manuweera 1996.
Water analysis (User–friendly Field/Laboratory Manual), Institute of Fundamental Studies, Kandy. 193 pp.

Tackx, M.L.M., N.D. Pauw, R.V. Mieghem, F. Azemar, A. Hannouti, S.V. Damme, N. Fiers and P. Meire 2004.
Zooplankton in the Schelde estuary, Belgium and the Netherland. Spatial and temporal patterns. Journal of Plankton Research, 26(2): 133-141.

Todd, C.D., M.S. Laverack and G.A. Boxshall 1996.
Coastal Marine Zooplankton. A Practical Manual for Students. Second edition. Cambridge University Press, Cambridge.

Wickremaratne W.S., J.M. Niwas, E.M.S. Wijeratne and K.S. Guruge 1991.
Ecological Survey of Muthurajawela: Hydrological Aspects (Unpublished Report). National Aquatic Resources Research and Development Agency, Colombo.