A Preliminary Study on the Variation of Zooplankton Diversity, Abundance and Density in a Selected Branch of Diyawanna Oya Canal System

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Abstract

Zooplankton make the secondary level in aquatic ecosystems and provide a ready source of food for secondary consumers. Hence any fluctuation in their population will directly affect the food webs, and eventually the whole ecological system. This study was carried out along a main branch of Diyawanna Oya, during the period of February to July, 2003. The objectives of the study were to find out the variation in diversity, abundance and density of zooplankton present in a selected branch of Diyawanna Oya and their correlation with some environmental parameters. Zooplankton & water samples were collected monthly from six stations representing both edges and the middle of the canal. During the study, 39 species of rotifers, 9 species of cladocerans, 6 species of copepods, 5 species of ostracods, some larval stages of malacostracans, 2 species of large protozoans and one Tardigrade species were recorded. There was a significant monthly variation in the average density of zooplankton. It was positively correlated with the flow rate ($r = 0.81$), depth ($r = 0.47$) and temperature ($r = 0.58$) of water. And there was a significant variation in density and abundance among six sampling stations. Density values of stations were positively correlated with DO level ($r = 0.72$) while it was negatively correlated with total alkalinity ($r = -0.78$), total hardness ($r = -0.67$) and conductivity ($r = -0.6$). The highest average density of zooplankton was recorded from Kotte whereas the least was from Torrington. Additionally, the possibility of ousing Lacane sp., Philodina sp. and Moina micrura taxa as indicators was also noted.

Keywords: Zooplankton, Diyawanna Oya, environmental parameters, correlation, indicators

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Introduction

Diyawanna Oya canal system with its surrounding environment is one of the precious assets which exist in the Colombo metropolitan of Sri Lanka. The system has added economical, historical, environmental and recreational value to the capital of Sri Lanka. In order to maintain the good health of this water body, it is important to monitor the status of water quality by measuring any changes in abiotic or biotic factors regularly. Therefore several local authorities plus some government agencies such as Land Reclamation and Development Cooperation (SLLRC) and Urban Development Authority (UDA) are in-charge of its proper maintenance and development. Recent studies have proven that some Zooplankton species and their dimensions can be used as indicators in monitoring water quality (Haberman and Haldna, 2014). Thus, the current study can be considered as a preliminary study that mainly focusses on Zooplankton diversity and their distribution in Diyawanna Oya Canal system. It can also be used as a baseline survey on the status of the canal system particularly on zooplankton, prior to the initiation of development activities around the area.

Sampling process of this study was carried out in 2003. Soon after, due to the speedy development taken place in Sri Jayawardenapura, Kotte urban area, most of the natural aquatic habitats were disturbed, restored, restructured or altered. Though zooplankton have short life spans and can regenerate within a short period of time, it would be worth keeping track on pre and after records on environmental status of the canal system to monitor the extent to which development has affected the environment.

Zooplankton are microscopic organisms, which drift or float freely in any water column. They mostly live in the pelagic zone of oceans, seas, or in freshwater bodies. Freshwater zooplankton play a major role as primary consumers in lower trophic levels of most aquatic food chains and food webs. They are also involved in nutrient cycling and affect the density of phytoplankton in water bodies. Zooplankton are also one of the most important nutrient rich food sources for fish fry and for some adult fishes that live in aquatic systems (Battish,1992). The main taxonomic groups of zooplankton in fresh water bodies are Crustacea (Cladocera, Copepoda, Ostracoda), Rotifera, Gastrotrichs and Protozoa.

According to Fernando (1974), Sri Lanka has no natural lakes, yet over 10,000 'Lakes' have been constructed for irrigation of rice fields,

water storage, for drinking and for the generation of hydroelectric power. They have been colonized by zooplankton via the rivers and have a relatively rich fauna except for typical lake species. Zooplankton in these man-made lakes are poor in species diversity and they are also poor in littoral and benthic animals. According to Fernando (1974), zooplankton community in low country shallow lakes is diverse in species composition. However, in the up country reservoirs, the zooplankton species are few that results in a very low fish production in these lakes.

Most common taxa of zooplankton in Sri Lanka are Rotifera, Cladocera, Copepoda and Ostracoda. Around 140 Rotifera species belonging to 42 genera have been recorded from Sri Lanka (Rajapaksa & Fernando, 1984). Species of both limnetic and littoral forms were among them. The planktonic Rotifers of Sri Lanka are mainly represented by the members of 7 families   known as Brachionidae, Asplanchnidae, Synchaetidae, Hexarthridae, Conochilide, Filinidae and Collothecidae. Their species diversity is lower in the limnetic habitats than in the littoral (Rajapaksa and Fernando, 1984).

The composition of the Cladocera in Sri Lanka is typically tropical with few *Daphnia* and *Ceriodaphnia* species, which are the dominant species in the temperate zone (Fernando, 1980a). About 68 species of Cladocera belonging to 7 families (Sididae, Daphnidae, Bosminidae, Monidae, Macrothricidae, Chydoridae and Leptodoridae) have been recorded from Sri Lanka (Rajapaksa and Fernando, 1984).

Twenty-seven species of Copepods belonging to 3 groups are recorded from the freshwater habitats of Sri Lanka. They compose 13 species of Cyclopoids, 11 species of Calanoids and 3 species of Harpacticoids (Rajapaksa and Fernando, 1984). Two species of Gastrotricha were recorded by Fernando & Mendis in 1962.

A few species of Osrtracoda occur as zooplankton. Most of the recorded species in Sri Lanka are benthic, some occur among the aquatic vegetation (Rajapaksa and Fernando, 1984).

Description of the Study Area

Diyawanna Oya is a man-made canal system which is located in the left bank of the lower valley of Kelani River in the Colombo district, Western province of Sri Lanka, within the ranges of latitudes 6 52' 55" - 6 55' 45" N and longitudes 79 52' 35" - 79 55' 15" E.

The canal system functions as the main drainage system of Colombo city. Since its elevation is closer to the sea level and flow rate depends on the storm water, water body becomes stagnant or slow moving during the dry period. As a result, industrial and domestic waste disposed to the water body does not flush away easily. Eventually it generates many health hazards to the public who live in the surrounding area. The major catchment areas of this system are the low-lying marshlands known as Kolonnawa marsh, Heen-ela marsh and Kotte marsh. These are also important as major flood detention zones in the city of Colombo (Wetland Site Report, 1995). Total land area that covers those marshy areas was around 400 ha. Out of them Kolonnawa is the largest marsh (214.3 ha) while Heen-ela is the smallest (87.7 ha). Figure 1 illustrates the study area, which includes a main canal (Diyawanna-Wellawatta canal), 6 sampling stations, and two marshes namely Kotte (KM) and Heen marsh (HM).
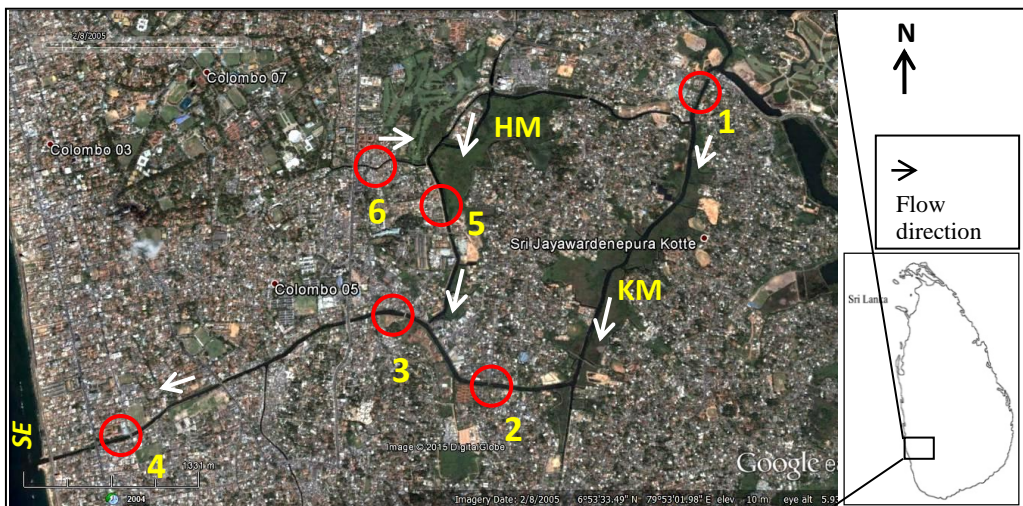

Figure 1. Site map of the study area : Diyawanna Oya Canal system and six sampling stations. *(1. Kotte , 2. Nawala , 3. OUSL, 4. Wellawatta, 5. Kirimandala Mw., 6. Torrington, KM - Kotte Marsh, HM – Heen Marsh)*

The depth of these canals reduces or fluctuates due to the heavy soil erosion and sedimentation of silt during the rainy season. Therefore to control bank erosion, most of the banks are covered with stone

barriers & wire meshes known as 'gabions'. The average depth of the canals is about 1.5 meters. Canal system often clogs with floating weeds & dumps (polythene, plastics & domestic wastes). It has been found that 43.5% of the families in the study area dump their household garbage into the marsh (Wetland Site Report, 1995).

The main objectives of the study were to find out the variation of zooplankton species diversity, density and abundance along a main branch of Diyawanna Oya. Another objective is to find out if there is any correlation between density variation and some environmental parameters recorded during the study.

Materials and Methods

Sampling Site:

Six sampling stations were selected, which were different from one another in respect of human influences and environmental factors. Selection procedure was mainly focused on the presence of marshes, industries and human settlements. Kotte and Nawala stations were the least populated areas, where as Torrington consisted of large numbers of settlements. OUSL station was heavily affected by industrial wastes while Right bank of Kirimandala Mawatha station was affected by Nitrogen rich discharges, released by some food factories. Wellawatta station was located in an urbanized area, which was also affected by seawater intrusion. The easy access to the sampling point was also considered when selecting these sampling stations.

Sampling Method:

Zooplankton were collected from all six stations once a month, during the period of February to July 2003 using a conical plankton tow net with 100μm mesh size and 0.30m mouth diameter. It was towed horizontally between surface and 0.5m depth for about 20 meters distance along the canal, both in two banks and from the middle of the canal using a non-mechanized boat. The volume of water filtered through the net was approximately 1.413 m^3 (1413 Litters). At the same time some environmental parameters such as temperature, flow rate and water level were measured on the spot. Additionally, water samples were collected for further analysis of DO, pH, Conductivity, Alkalinity and Cl$^-$ concentration. Preserved plankton samples were analyzed at the laboratory by using the light microscope. Identification of zooplankton was done using keys and some illustrated guides authored by Fernando & Mendis (1962),

Fernando (1963,1969 & 1974), Chengalath & Fernando (1974,1974), Fernando (1984), Neale (1984), Battish (1992), Edmondson (1959), Dole-Olivier et al., (2000), Ricci & Balsamo(2000) and Barnes (1998).

Results

Species Diversity of Zooplankton in Diyawanna Oya

Among zooplankton, thirty-nine (39) species of rotifers, nine (9) species of cladocerans, six (6) species of copepods, five (5) species of ostracods, some larval stages of malacostracans, one (1) species of Branchiopods, two (2) large protozoans and one (1) tardigrade species were recorded. Among rotifers *Brachionus falcatus, Lecane bulla* and *Philodina* sp. were the most abundant. *Ceriodaphnia cornuta, Diaphanasoma excisum* and *Moina micrura* were the most abundant cladoceran species.

The checklist of zooplankton recorded during the study has been given in Table 1.

Variation of Zooplankton Diversity within Six Sampling Stations

It was revealed that Nawala station, which is nourished with water coming from Kotte marsh, had the highest zooplankton species richness while Torrington which was heavily influenced by human activities had shown the lowest. The graph below (Fig. 2) illustrates the pattern of variation of zooplankton diversity (species richness) among six sampling stations. Further to Shanon-Wiener Diversity Index, Kotte station has scored the highest value of 3.36 where as Nawala, OUSL, Wellawatta, Kirimandala Mw. and Torrington stations area 3.27, 2.98, 2.79, 2.85 and 0.82 respectively.

Table 1. Checklist of zooplankton taxa & their total number of occurrence during the study (N = Number of Occurrence)

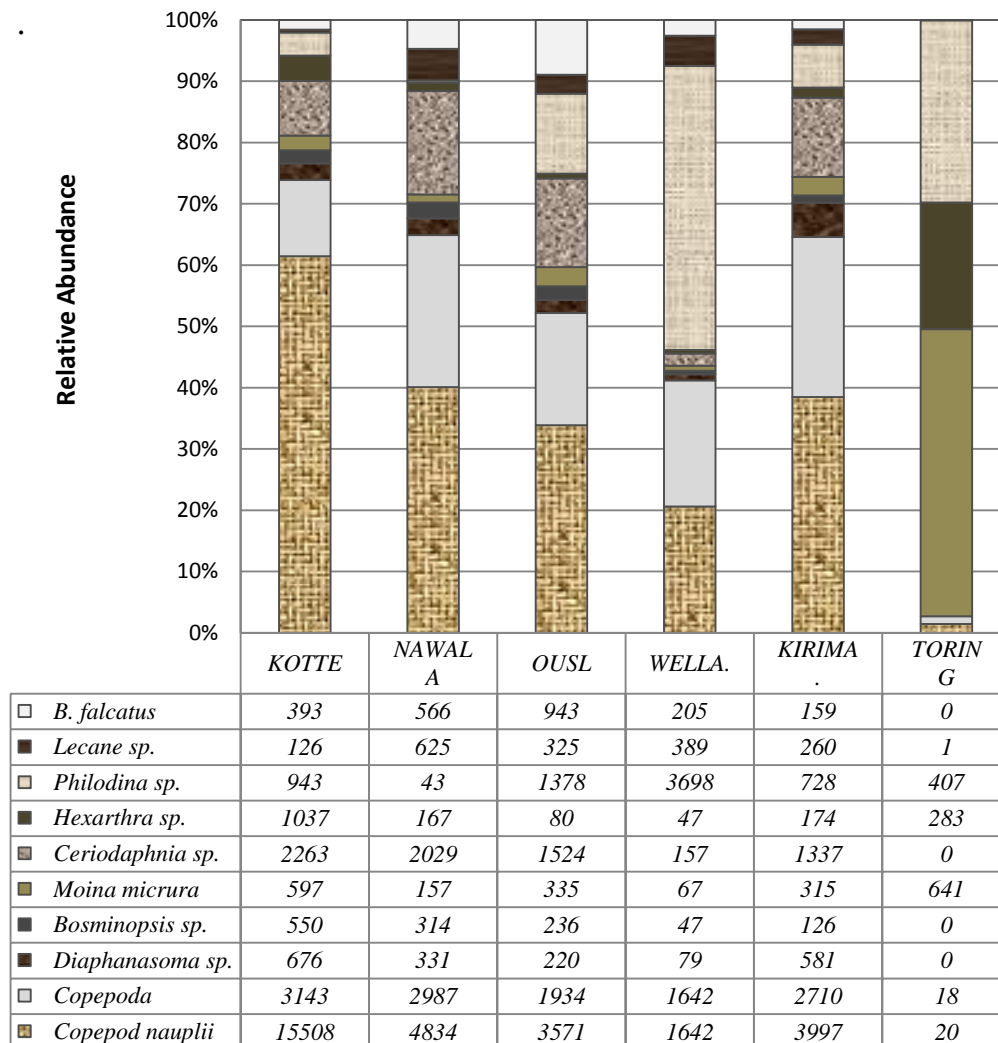| Taxonomy	N	Taxonomy	N
		Phylum Arthropoda	
Phylum Rotifera		**Class Crustacea**	
Order Ploimida		**Order Cladocera**	
Brachionus angularis	5	*Diaphanasoma excisum*	36
Brachionus calyciflorus	32	*Ceriodaphnia cornuta*	49
Brachionus caudatus	16	*Monia micrura*	43
Brachionus donneri	12	*Bosminopsis dietersi*	34
Brachionus falcatus	44	*Oxyurella sinhalensis*	3
Brachionus forficula	4	*Psedochydorus globosus*	1
Brachionus patulus	13	*Macrothrix triserialis*	18
B. quadridentatus	9	*Euryalona orientalis*	14
Platyias quadricornis	11	*Ladigia acanthocercoides*	4
Keratella tropica	14	**Sub class Copepoda**	
Lecane bulla	44	**Order Cyclopoida**	
Lecane quadridentata	4	*Mesocyclops sp.*	66
Lecane ungulata	3	*Thermocyclops crassus*	51
Lecane sp1	10	*nauplii stage 1*	86
Lecane sp2	1	*nauplii stage 2*	61
Lecane sp3	5	**Order Calanoida**	
Lecane sp4	5	*Phyllodiaptomus sp.*	50
Lecane sp5	2	*Eudiaptomus sp.*	41
Lecane sp6	32	*nauplii stage 1*	62
Philodina sp.	68	*nauplii stage 2*	37
Asplanchna brightwelli	18	**Order Herpactocoida**	
Euchlanis dilatata	28	*sp.1*	2
Trichocera cylindrica	2	**Class Ostracoda**	
Trichocera chattoni	14	**Order Podocopida**	
Lepadella patella	1	**Super Family :Cypridoidae**	
Scaridium longicaudum	1	*sp.1*	
Testudinella patina	19	*sp.2*	1
Filinia sp.1	3	*sp.3*	17
Filinia sp.2	3	**Class Malacostraca**	1
Macrochaetus collinsi	1	*crab nauplii 1*	
Macrochaetus sericus	2	*crab nauplii 2*	1
Trichotria tetractis	1	*crab nauplii 3*	4
Sinantherina spinosa	7	**Insecta**	4
Sinantherina semibullata	33	*Odonata nymphs*	
Cephalodella giba	14	**Protozoa**	9
Hexarthra mira	30	*Arcella sp.*	
Mytillina sp.	1	*Centropyxis sp.*	22
		phylum Tardigrada	10
		sp.1	8
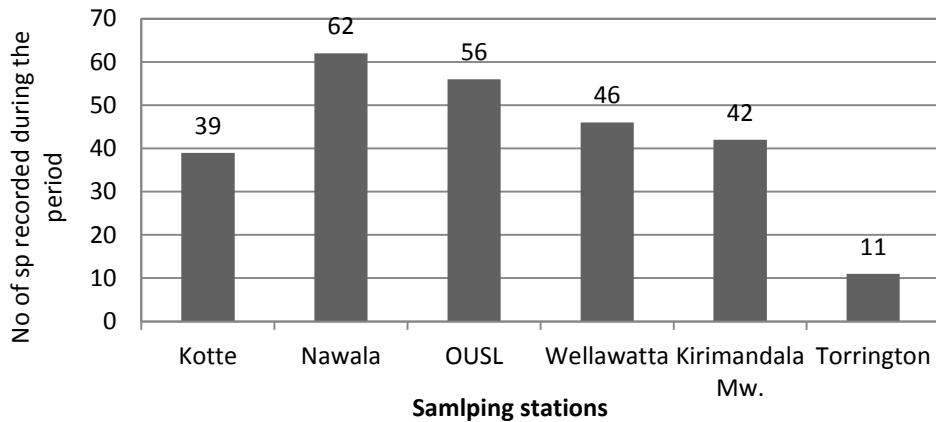
Figure 2. Variation of zooplankton diversity (species richness) among six sampling stations

Relative Abundance of Some Major Taxonomic Groups of Zooplankton

Figure 3 shows the variation of relative abundance (%) of 10 frequently recorded zooplankton taxa in six sampling stations during the study period. The abundance values (no of individuals per cubic meter) of those taxa for each and every station have been given in the graph. According to the graph, except for Torrington, Copepod adult and nauplii have been the most abundant taxa (over 40%) in almost all stations. For Torrington it was *Moina micrura,* which is a cladoceran species and showed the relative abundance around 50%. Though Wellawata showed relative abundance more than 40% as a total figure for copepod adults and nauplii, the most dominant taxa for the station was *philodina* sp which is a Rotifer species.

Variation of Zooplankton Density

There was a significant monthly and spatial (station wise) variation of zooplankton density in Diyawanna Oya. According to Figure 4 the highest zooplankton density was recorded in March, 2003 whereas the lowest was in July, 2003. When considering the average density variation of the six stations, Kotte station has recorded the highest zooplankton density while Torrington has shown the lowest (see Figure 5).

		KOTTE	NAWALA	OUSL	WELLA.	KIRIMA.	TORING
☐	B. falcatus	393	566	943	205	159	0
■	Lecane sp.	126	625	325	389	260	1
☐	Philodina sp.	943	43	1378	3698	728	407
■	Hexarthra sp.	1037	167	80	47	174	283
▨	Ceriodaphnia sp.	2263	2029	1524	157	1337	0
▨	Moina micrura	597	157	335	67	315	641
■	Bosminopsis sp.	550	314	236	47	126	0
■	Diaphanasoma sp.	676	331	220	79	581	0
☐	Copepoda	3143	2987	1934	1642	2710	18
▨	Copepod nauplii	15508	4834	3571	1642	3997	20

Sampling stations and abundance values (no. of ind/m³)

Figure 3. Variation of relative abundance of ten frequently occurred zooplankton taxa in six sampling stations and their abundance values (individuals per cubic meter).
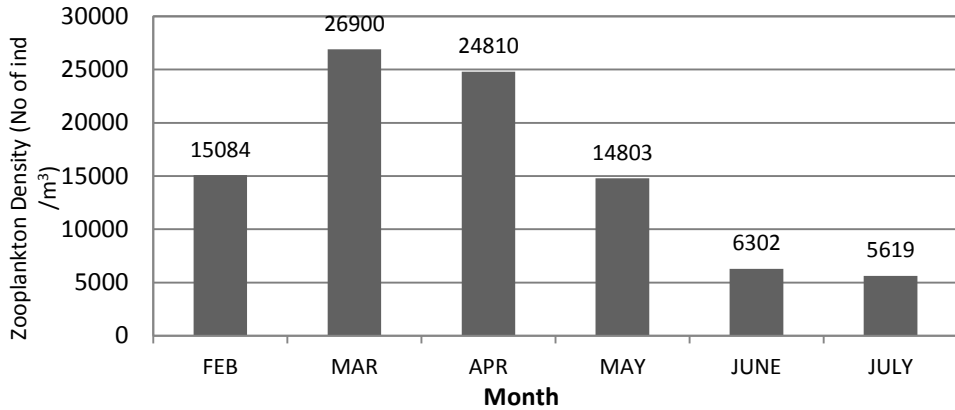
Figure 4. Monthly variation of zooplankton density in Diyawanna Oya (Feb-July 2003)
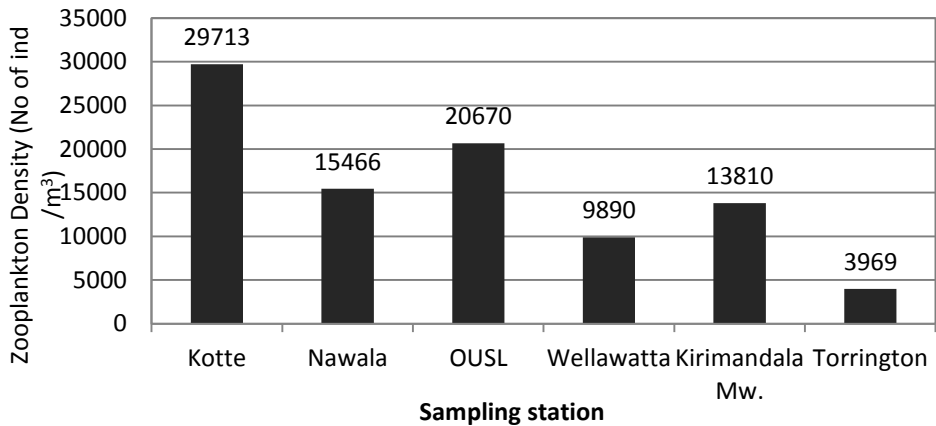

Figure 5. Variation of zooplankton density among six sampling stations during the study period

Correlation Between Monthly Variations of Zooplankton Density and Some Environmental Parameters

Environmental parameter readings obtained from six stations were averaged and tabulated (Table 2) on monthly basis. Highest values recorded for each parameter are highlighted in the table. The highest rainfall was recorded in the month of May. Highest air and water temperature values were recorded in April. Chloride ion concentration was significantly high in both February and July. Dissolved Oxygen content of water has shown a peak value in March and secondly in June.

Monthly variation of overall zooplankton density of Diyawanna Oya was positively correlated with flow rate (r = 0.81), water temperature (r = 0.58), depth (r = 0.47) and dissolved oxygen content (0.26). Graphs in figure 6 have illustrated the pattern of monthly variation of zooplankton density and above mentioned environmental parameters together with their correlation values (r).

Table 2. Monthly variation of some environmental parameters of the study area, Diyawanna Oya (overall view) during the period of Feb – July, 2003.

	Parameter	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
1.	Rain fall (mm)	89.3	164	95.9	284.8	181.6	185.7
2.	Air temp (C°)	31.4	32.33	33.2	33	32.5	31.8
3.	Water temp (C°)	30.75	31.75	31.88	31.6	31.25	31
4.	Flow rate (ms^{-1})	0.1116	0.1496	0.1573	0.1046	0.0530	0.0762
5.	Water level (m)	0.23	0.35	0.32	0.29	0.37	0.37
6.	Average depth (m)	0.773	0.779	0.733	0.755	0.742	0.700
7.	pH value	6.57	7.35	6.41	6.18	6.65	6.58
8.	Tot. Hardness (m.mol.l^{-1})	0.00031	0.00026	0.00027	0.00028	0.00028	0.00029
9.	Tot. Alkalinity (m.mol.l^{-1})	0.00036	0.00028	0.00022	0.00024	0.00019	0.00023
10.	Cl$^-$ concentration (mgl^{-1})	112.65	45.26	72.42	50.04	64.12	111.90
11.	DO level (mgdm^{-3})	3.12	3.55	2.38	1.45	3.03	2.05

Table 3. Average values of some environmental parameters recorded from six sampling stations of Diyawanna Oya (Feb – July, 2003).

|	Location	Mean flow rate (ms^{-1})	Mean water level (m)	mean Depth (m)	pH value	Conductivity (Ms)	DO level (mgdm^{-3})	Cl$^-$ cocentration (mgl^{-1})	Alkalinity (m.mol.l^{-1})	Hardness (m.mol.l^{-1})
1.	Kotte	0.0241	0.41	0.645	6.40	65.45	5.47	43.50	0.00019	0.00019
2.	Nawala	0.0957	0.37	0.830	6.64	70.25	2.93	62.11	0.00022	0.00024
3.	OUSL	0.1284	0.34	0.837	6.81	86.40	1.83	88.01	0.00022	0.00031
4.	Wellawatta	0.3059	0.18	0.611	6.61	115.33	2.20	130.76	0.00030	0.00033
5.	Kirimand.Mw.	0.0822	0.32	0.631	6.54	90.33	2.87	65.38	0.00026	0.00028
6.	Torrington	0.0161	0.31	0.928	6.74	96.25	0.29	66.64	0.00035	0.00034
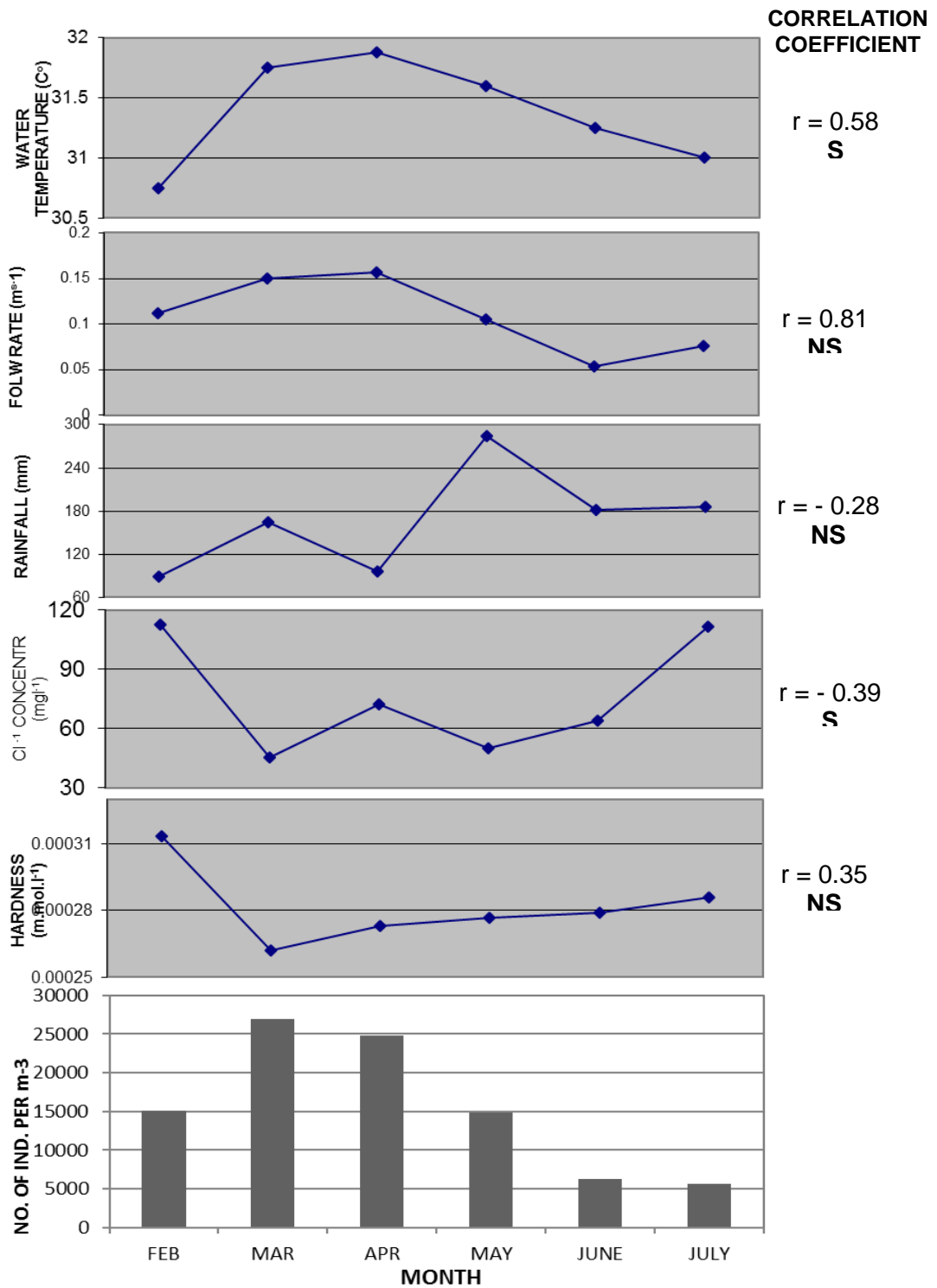
Figure 6. Monthly variation of zooplankton density (No. of ind. /m³) and its correlation with some environmental parameters recorded from the study area, Diyawanna Oya
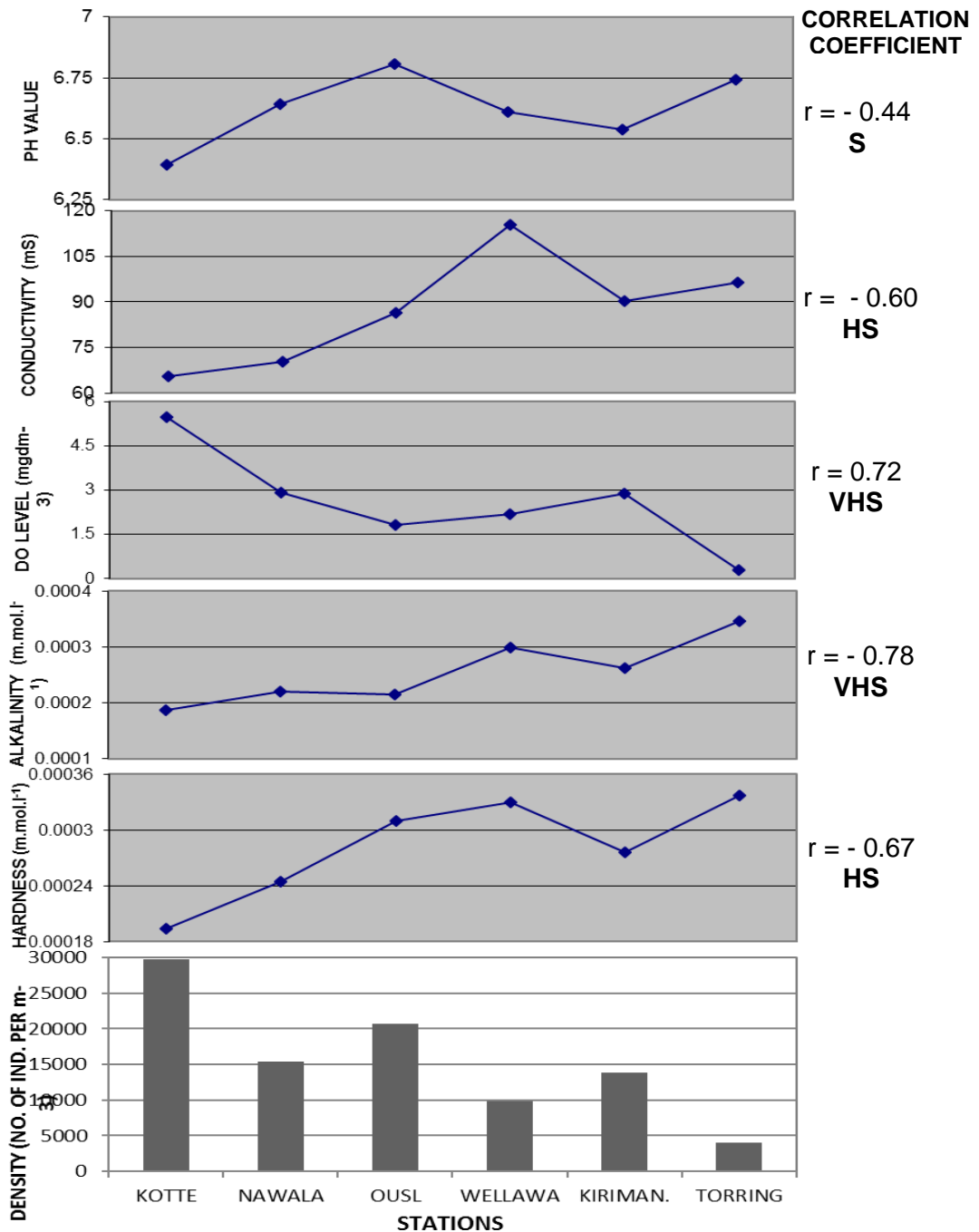
Figure 7. Variation of average zooplankton density (No. of ind. /m³) in six sampling stations and its correlation (r value) with some environmental parameters recorded from the study area.

Table 4 has given the statistically analysed correlation coefficient values (r) and their level of significance for each and every relationship. Flow rate has shown a Very High Significant Positive Correlation (VHS) with the density variation while water temperature and depth have shown a Significant Correlation (S). Though Dissolved Oxygen Content has showed a positive correlation, it was not a significant relationship.

Table 4. Correlation coefficient (r) between density and some environmental parameters. [VHS – Very High Significant Correlation (r>0.70), HS – High Significant Correlation (r>0.6/<0.74), S – Significant Correlation (r>0.35/<0.59), NS – No Significant Correlation (r<0.35)]

	Relationship	Monthly variation	Significance	Spatial Variation	Significance
1	Density- Depth	0.47	S	-0.29	NS
2	Density - Flow rate	**0.81**	**VHS**	-0.19	NS
3	Density - rainfall	-0.28	NS	_	_
4	Density - Air Temp.	0.32	NS	_	_
5	Density –Water Temp.	0.58	S	_	_
6	Density – Conduct.	0.03	NS	**-0.6**	**HS**
7	Density - pH	0.32	NS	-0.44	S
8	Density - Hardness	0.35	S	**-0.67**	**HS**
9	Density - Alkalinity	0.23	NS	**-0.78**	**VHS**
10	Density - Cl-	-0.39	S	-0.36	S
11	Density - DO	0.26	NS	**0.72**	**VHS**

Correlation Between Zooplankton Density Variation in Six Sampling Stations and Environmental Parameters

Environmental parameter values obtained from six sampling stations during the study were averaged and given in Table 3. As per values given in the table flow rate, conductivity and Chloride ion concentration values recorded in Wellawatta station were considerably higher than all other stations. A remarkable average Dissolved Oxygen value (5.47 mgdm^{-3}) was reported from Kotte station.

When considering their correlation with zooplankton density variation in six stations, it has shown a Very High Significant (VHS) positive correlation with dissolved oxygen (r = 0.72), Very High Significant (VHS) negative correlation with total alkalinity (r= - 0.78), and High Significant (HS) negative correlation with both total

hardness (r = - 0.67) and conductivity (r = - 0.6). Graphs in fig. 7 illustrate clearly the pattern of zooplankton density variation in six sampling stations with some environmental parameter values.

Discussion

Overall zooplankton community in Diyawanna Oya study area was composed of Rotifers (39 species) that represented the highest diversity, Cladocerans (9), Copepods (6), Ostracods (5), Protozoans (2) and some larval forms and minor groups (Tardigrata). Similar results were obtained in Prakrama Samudra by Fernando & Rajapaksa in 1983. They have recorded 32 species of Rotifers, 7 species of Cladocerans, 6 species of Copepods and 4 species of Protozoans etc. Correspondingly in Bolgoda Lake, Wignarajah & Amarasiriwardana (1983) have found that the highest number of species belonged to Phylum Rotifera, and others (Copepoda, Cladocera and Ostracoda) were with lower numbers. From a study conducted in Vortsjarv Lake, Central Estonia in the growing season, has identified 54 metazooplankton species that include with 29 Rotifers, 17 Cladocerans, and 8 copepods have been identified (Haberman & Haldna, 2014) . Another investigation on limnological features and zooplankton assemblage study performed in Funil Reservoir, Rio de Jeneiro, Brazil by Branco e*t al.* (2002) recorded parallel results for zooplankton composition as in 21 Rotifer species, 6 Cladocerans, 3 Copepods and some testate amoeba varieties.

From a recent study carried out by Wickramasinghe, et al. (2012) in Kotte and Kolonnawa wetland, has revealed a total of 12 taxa of zooplankton that composed of 8 Rotifers, 3 Copepods and 1 Cladoceran species. Though their abundance is aligned with this study, their species richness is poor than what we have recorded in 2003. Causes behind above contrast would be due to the drastic changes which happened in wetland land use pattern and the canal system with the development activities commenced in the area by 2005 or may be due the method used for zooplankton sampling. As in this study approximately 1413 Litters of freshwater were filtered through the plankton net to collect zooplankton while it was only 10 Litters by Wickramasinghe, et al. (2012). This hypothesis is further assisted by the study carried out in Lakes of the Northern Coast of Rio Grande do Sul state, Brazil on zooplankton and water quality by Pedrozo & Rocha (2005), where they have filtered 300 litters of water using a suction pump and plankton nets. From that study, 62 taxa were identified, which consisted of by 40 Rotifera taxa, 15 Cladocera

taxa and 7 Copepoda taxa, showing comparatively a high species richness of zooplankton.

Additionally, some studies were carried out in Beira Lake, which were also a part of the Colombo canal system but not directly connected with Diyawanna Oya by several other researchers. It is noteworthy that zooplankton diversity in Beira Lake was relatively lesser than common inland freshwater habitats. During the study conducted by Kamaladasa & Jayatunga (2007) only a total of 10 zooplankton species were found from both South and East Beira Lakes. Among them there were 6 Rotifers, 3 Cladocerans and 1 Copepod species. According to the records of hydro biological investigations done by Costa & De Silva (1969) *Brachionus* sp., *Keratella* sp., *Diaphanosoma* sp., *Diaptomus* sp., Cyclops sp., and crustacean nauplii were the most notable of the Zooplankton, with copepod cyclopoidea.

In the present study, there was a remarkable variation of species diversity within the sampling stations. Higher diversity index values were recorded from Kotte and Nawala, which were influenced by Kotte and Heen marshes. Some species like *Hexartha* sp., *Diaphanasoma* sp. and *Ceriodaphnia* sp. were also commonly found from these stations. However, the most common taxa in Kotte were Copepod adults and nauplii throughout the study period. On the other hand, Torrington which was the least diverse station and heavily affected by domestic pollutants, was the station where *Moina micrura* and *Philodina* sp were the most abundant species recorded. *Moina micrura* is considered which is of the "tolerant" or "benefited" by the organic contamination in the system (Pedrozo & Rocha, 2005). Therefore, high abundance of *Moina micrura* can be an indicator of high level of organic pollution.

Overall density of zooplankton had fluctuated outstandingly throughout the study period. Higher values were obtained just before the commencement of the rainy season. Similar results have been obtained for Rotifer species by Costa & De Silva (1978) in Beira Lake. The maximum number of Rotifers was recorded in the drier months (June and July) or before the monsoon period. According to the observation of Wignarajah & Amarasiriwardena (1983) in Bolgoda Lake, only the populations of nauplii showed peaks with the monsoonal periods, while the rest of the zooplankton population showed higher fluctuations with peaks during the inter-monsoonal periods. The reason behind this is perhaps the ability of Copepods for movement against water flow with their body size and biomass which is comparatively higher and much favoured to withstand

heavy storm water movements which take place in monsoon than other zooplankton groups.

Variation of zooplankton density has shown a significant negative correlation with Chloride ion concentration (Cl⁻) level during the study period. This may be due to the inflow of saline water through canals upwardly during the high tidal season probably by June onwards. Wallawatta, OUSL and Nawala were the stations that are directly subjected to this situation. In the months of June and July, density and abundance of zooplankton in these stations had fluctuated. Interestingly the abundance of *Lacane* sp. has increased during these months. Hence, there is opportunity of considering *Lacane* sp. as an indicator of high Cl ion concentration or saline water intrusion.

Monthly variation of zooplankton density had positively correlated with the Flow rate, DO level and water temperature during the six months study period. Mean flow rate, DO values and water temperature were higher in March and April while they were lower in later months. As noted by Schöll & Kiss (2008) the ability of some zooplankton taxa (rotifers) to reproduce in waters with high flow velocities (above 0.4 m/s) is very low, or indeed nil. Lower flow rates in later months may be a result of stagnation of water by obstructing freshwater runoff to the sea and rising of sea water level in the high tidal season. This could have also caused low DO content in water due to lessening of water movements. Temperature was declined due to the variation of weather in the monsoon period, which also has shown some significant positive correlation with density variation in six month. Branco (2002) revealed that some Rotifer taxa such as *Brachionus calyciflorus* and *Euchlanis dilatata* were associated with increasing of water temperature. As per Matsumura-Tundisi et al.(1990) cited by Pedrozo & Rocha (2005) Rotifers are opportunistic organisms whose densities change with temperature in a short time, some of them can adapt to a fast population growth during favourable seasons. Similarly, in the month of February and April, there was a higher density of *Brachionus calyciflorus* and *B. falcatus* mostly with eggs in OUSL and Nawala stations. These were the months, which also recorded high temperatures, and lower rain falls during the study period.

Average density values of zooplankton within six sampling stations also have shown a dramatic variation within the study. It reported a high significant positive correlation with DO level (r = 0.72). The highest density of zooplankton as well as the highest DO value were recorded from Kotte station, which is associated with Kotte and

Kolonawa marshes plus the main Diyawanna Oya Lake. In contrast, the lowest density of zooplankton was recorded from Torrington, which also showed lowest average DO value. In some occasions it was noted that there was no fluctuation in that water body. The major reason is that the water column had to be flowed through low elevated area to higher. In such months DO levels were recorded as zero (February, April and May). However, DO values were increased in later months caused by heavy rains, indicating that there is a significant positive correlation between DO level and rain fall. Wickramasinghe, et al. (2012) has observed a similar kind of situation in the study conducted in Kotte and Kolonnawa wetlands. Wickramasinghe has reported a clear differentiation of the density of taxa in flowing and stagnated habitats.

Total alkalinity and hardness of water showed highly significant negative correlation with zooplankton density variation among stations. Torrington, which contained the highest total hardness and total alkalinity values recorded the lowest density of zooplankton. Wallawatta, Kirimandala Mawatha and OUSL stations also obtained highervalues for these environmental characteristics. When considering the species abundance, in stations like Wallawatta and Kirimandala Mawatha, the most commonly occurred species during the period were *Philodina* sp. and Copepod adult stages. From this study, these species can be considered as tolerant species, which are able to withstand such unfavourable conditions.

The study revealed that conductivity, pH and Cl⁻ concentrations were negatively correlated with density variation along stations. Wallawatta, which is located close to the outfall to the sea, had the highest value of Cl⁻ concentration and conductivity. This condition is more preferable for planktonic crustaceans like Copepods. As per the results, Wellawatta station was mostly abundant with higher densities of Copepod and some Rotifer sp. such as *Philodina* sp., *Lecane bulla* and *Lecane ungulata.*

Conclusion

From this study, it was revealed that there was a significant variation of zooplankton species composition, diversity, their abundance and density in the period of February to July 2003 and also among six sampling stations of Diyawanna Oya. Some Rotiferan and Cladoceran taxa like *Lacane* sp., *Philodina* sp. and *Moina micrura,* have shown some indicator properties that can be used to monitor some environmental changes of the canal system. Further studies should be carried out based on this hypothesis for better

results. Flow rate had shown a very highly significant (VHS) positive correlation with the monthly variation of zooplankton density. There was a highly significant (VHS) positive correlation between DO content and average density variation of zooplankton in six sampling stations. Simultaneously, there was a high significant (HS) negative correlation with alkalinity, hardness and conductivity. The situation may have been changed by now as the canal system had gone through a rapid development process within the last few years by improving the condition of the canals as well as changes in land use in the surrounding. Also a boat service for visitors and daily passengers was established by the government. There after the canal system was occupied with plenty of mechanical boats. As a result, it may have affected by the effluents released out to the water by the boats. The canal system provides livelihoods and food sources for the community which lives around. Also it plays a major role in balancing the environmental health of Colombo metropolitan, which is the capital city of Sri Lanka. Thus, it is vital to pay more attention on proper maintenance of the canal system considering its ecological value as well as the historical and socio-economical values.

Acknowledgements

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