Seasonal Abundance of Two Species of Rotifers (*Brachionus calyciflorus* and *Keratella tropica*) in Kandy Lake, a Tropical Urban Water Body in Sri Lanka

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Abstract

Monsoon-bound seasonal abundance of two species of rotifers (*Brachionus calyciflorus* and *Keratella tropica*) was examined in relation to the population densities of Cladoceran zooplankton and phytoplankton and some limnlogical characteristics in Kandy Lake, a tropical urban water body in Sri Lanka, using standard techniques. Kandy Lake did not show marked seasonal variation influenced by the monsoons with respect to limnological parameters except for bicarbonate alkalinity and chlorophyll-a content. The population densities of *Brachionus calyciflorus* declined and *Keratella tropica* became dominant during the first inter-monsoon (March-April) when the abundance of total cladocerans and *Microcystis aeruginosa*, a cyanobacterial species with toxigenic strains, were high under relatively turbid conditions. *Brachionus calyciflorus* was re-established progressively during the subsequent season with decreasing populations of *Microcystis aeruginosa* and increasing densities of *Aulacoseira granulata*, a filamentous centric diatom, and *Pediastrum simplex*, a colony forming green algae.

The likely explanation for the marked suppression of *Brachionus calyciflorus* during the first inter-monsoon could be the abundance of toxin forming cyanobacteria strains of *Microcystis aeruginosa* or else a combined effect of *Microcystis aeruginosa* and interference competition resulting from high densities of total cladocerans under unfavourable environmental factors such as high turbidity.

Introduction

Rotifers are of fundamental importance in aquatic ecosystems due to their high efficiency in transforming primary production of phytoplankton and energy stored in bacteria into energy accessible by other organisms. They also show quick responses to environmental changes and are therefore considered as good indicators of water quality and trophic states (Sládecek 1983; Matveeva 1991). Rotifers, which are mainly confined to freshwater habitats, also show a cosmopolitan distribution

perhaps due to different, highly adaptive life-history strategies (Gilbert 1985). The population densities of rotifers can be suppressed either by other pelagic zooplankton such as cladocerans when they compete for the same food resource or by direct interaction (Gilbert 1988). Filamentous and non-filamentous cyanobacteria adversely affect rotifers by mechanically interfering with feeding or by producing toxins, which reduce longevity and fecundity (Gilbert and MacIssac 1991; Rothhaupt 1991).

It has been hypothesized that densities of rotifer populations in hydrologically dynamic reservoir ecosystems are regulated either by rapid throughput or predator pressure of zooplanktivorous fish (Duncan and Gulati 1983; Duncan 1984; Jayatunge 1986). The environmental factors or life-history strategies that determine the population abundance of planktonic rotifers in tropical aquatic habitats are poorly understood although attempts have been made to address their taxonomy (Fernando 1980a, b; Rajapaksa and Fernando 1982).

In the present study, the monsoon-bound seasonal variation in population densities of two species of rotifers (i.e. *Brachionus calyciflorus* and *Keratella tropica*) was studied with an especial emphasis on cladoceran populations, phytoplankton densities and basic limnological characteristics of an urban water body, Kandy Lake in Sri Lanka. Kandy Lake, a non-harvesting water body, which receives a fair amount of wastewater, has peculiar characteristics such as long retention time, and poor species diversity and high population densities of fish. The primary objective of this study was to determine whether the seasonal abundance of two-rotifer species in Kandy Lake is influenced by cladocerans and toxic cyanobacteria (*Microcystis aeruginosa*).

Study site

Kandy Lake ($7°$ $18'$N; $80°$ $39'$E at 510 m MSL), a water body of scenic beauty, located in the heart of the hill capital of Sri Lanka, Kandy, was constructed between 1810 and 1812. It is 18 ha in area and 12.5 m in maximum depth and has a capacity of 0.348 MCM with a perimeter of 3.05 km. Two small brooks, which drain 2.85 km^2 of the catchment, feed the Lake and water spills over only following heavy rains during the main rainy season (Oct - Dec). Evaporation losses are high during the dry months (Feb - Mar). The Lake has two morphologically distinct basins (deep and shallow) but has no prominent littoral zone and the entire perimeter is surrounded either by public roads or cement or concrete walls (Fig. 1). Erosion and subsequent transport of sediment over several decades has resulted in substantial siltation of about 1.5 m sediment thickness in the deeper basin. In addition, wastewater drains into the lake through 28 inlets including small hotels, hospitals, schools and temples. Being located adjoining to a major religious centre, the Temple of Tooth, fishing and bathing are prohibited in the lake and also the lake water is not utilized either for irrigation or for other domestic purposes.

Except for the studies conducted on meso and macro aquatic fauna during 1979-1980 (De Silva and De Silva 1984) the Kandy Lake has not been subjected to a comprehensive limnological study. Dissanayake et al. (1982, 1986) reported that Kandy Lake has been enriched with P and N compounds and polluted with some heavy metals. A detailed limnological study commenced in 1997 revealed that the Lake was permanently stratified with a thick anoxic layer in the deeper basin (Silva 2003) and two species of phytoplankton, i,e., a diatom (*Aulacoseira granulata*) and a green algae (*Pediastrum simplex*), showed alternating monsoon-bound oscillations. A chronic cyanobacteria species (*M. aeruginosa*), which had some toxin producing strains (Jayatissa et al. pers. comm.) emerged as a bloom and formed into a thick scum in the shallow basin with the onset of the southwest monsoon in May 1999 (Silva 2003). The bloom disappeared within two months following the physical removal of scum and raising of the water level.

Materials and Methods

Zooplankton and phytoplankton were collected biweekly from January to December 2000 at four sampling sites of Kandy Lake (Fig. 1) using a Schindler Patalas sampler (15 l). Phytoplankton were collected using a 10 μm meshed net for taxonomic studies. Water temperature, dissolved oxygen content, electrical conductivity, bicarbonate content, pH and Secchi depth were determined at each site *in situ*. Dissolved Oxygen content was measured using WTW Oxi 330 oxygen probe while electrical conductivity was measured using Jenway conductivity meter Model 4070. The bicarbonate alkalinity and pH were measured by alkalinity acidimetric titration and using a Jenway 3030 pH meter respectively.

Water samples were collected from 1 m depths at each sampling site and transported immediately to the laboratory, which is located 1 km southwest of the Lake. In the laboratory, zooplankton samples were fixed in 5% formalin and phytoplankton samples were preserved in Lugol's solution. Sub samples of zooplankton were identified and counted using a Sedgwick rafter cell under a stereomicroscope. Water samples of 100 ml each, fixed in Lugol's were processed for counting under an inverted microscope using a Sedgwick rafter cell. A known volume of water sample was filtered through GFC filter papers and chlorophyll-a content was determined (Marker et al. 1980). The least squared technique of regression was used to compare the relationship between chlorophyll-a content and Secchi disk visibility. The significance of the regression line was tested by analysis of variance (F-statistics). Significance of the seasonal variability of environmental parameters was examined using analysis of variance (one-way ANOVA) and the inter-relationship between populations was tested using a multiple range test (SNK procedure).
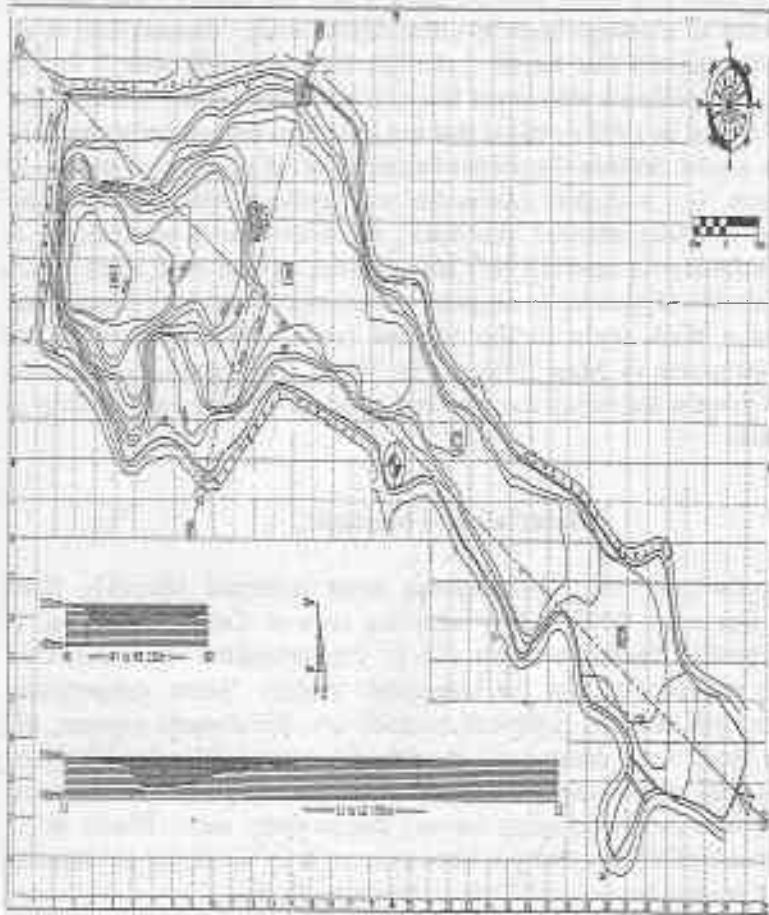
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Figure 1. Map of the Kandy Lake showing sampling sites (A-D: Sampling sites).

Results

The magnitude and distribution of rainfall in the watershed of the Lake was more or less similar during four monsoon-defined seasons i.e., Dec-Feb, northeast monsoon (NEM); Mar-Apr, first inter-monsoon (FIM); May-Sep, southwest monsoon (SWM) and Oct-Nov, second inter-monsoon (SIM) in 2000 (Table 1). Daytime surface water temperature ranged between 26.0°C and 28.0°C and electrical conductivity varied between 212 μS cm^{-1} and 239 μS cm^{-1} during the study period with no significant seasonal variation (p>0.05) (Table 1). The seasonal change in pH also showed a similar pattern but it varied between 6.96 and 8.61 and the widest range was recorded during the southwest monsoon (Table 1). The mean

value of bicarbonate alkalinity showed a significant seasonal variation ($p<0.05$) with the lowest (111 mg l⁻¹) and the highest (119 mg l⁻¹) being during the first inter-monsoon and southwest monsoon respectively (Table 1). The mean seasonal value of Secchi depth was lowest (81 cm) during the first inter-monsoon and it was highest (121 cm) during the southwest monsoon. One-way ANOVA showed no significant seasonal variation in Secchi disk visibility ($p>0.05$) (Table 1). However, chlorophyll-a content showed a significant seasonal variation ($p<0.05$) and the seasonal mean was highest (31.0 μgl⁻¹) during the first inter-monsoon, which is more or less similar to that of the value computed for (29 μgl⁻¹) second inter-monsoon (Table 1). The mean seasonal chlorophyll-a content was lowest (20 μgl⁻¹) during the southwest monsoon and it was not significantly different from the value computed for the northeast monsoon (23 μgl⁻¹) according to one-way ANOVA (SNK test).

Table 1. Monsoon defined mean seasonal values (± SD) of some environmental characteristics of Kandy Lake during the study period (Jan-Dec 2000). NEM – North-east monsoon; FIM – First intermonsoon; SWM – South-west monsoon; SIM – Second intermonsoon; Prob – Probability level.

Parameter	NEM	FIM	SWM	SIM	F-ratio	Prob
Rainfall Mm	371	349	358	442		
No. of rainy days	08	08	06	06		
Temperature °C	26.9 ± 0.75	27.5 ± 1.73	27.4±1.99	26.9±1.31	0.262	0.852
EC μS cm⁻¹	231 ± 3.47	225 ± 9.52	231 ± 4.82	230 ± 4.02	0.880	0.474
PH	7.68 ± 0.22	8.15 ± 0.31	7.73 ± 0.53	7.82 ± 0.24	1.348	0.296
Alkalinity mg l⁻¹	114 ±4.21	111± 5.49	119±2.86	117±1.64	5.603	0.009
Secchi Depth Cm	119 ± 29	81 ± 30.4	121 ± 14.4	113 ± 13.6	3.164	0.055
Chl-a μg l⁻¹	23 ± 12.1	31.0 ± 7.9	20 ± 3.1	29 ± 0.97	8.173	0.001

Zooplankton were dominated by rotifers with only few species of cyclopoid copepods and cladocerans present (Table 2). Five species of copepods belonging to four genera were identified from Kandy Lake during the study period. *Phyllodiaptomus annae* was the most widely distributed and abundant copepod found during the study period. However, it was not

present in the samples in one occasion during the first inter-monsoon. The density of *P. annae* was relatively low during the second inter-monsoon. *Mesocyclops thermocyclopidus* also occurred in relatively large numbers except during the second inter-monsoon. Of the five common copepods found in Kandy Lake (Table 2), densities of *Cyclops pracinus, Thermocyclops decipans and Thermocyclops crassus* were relatively low.

Table 2. The relative abundance (number per litre) of zooplankton species found in the Kandy Lake during four monsoon bound seasons in 2000. Abbreviations are as given in Table 1.

Species Name	NEM	FIM	SWM	SIM
Cladocera				
Ceriodaphnia cornuta	8	8	4	4
Diaphanosoma exisum	2	5	4	3
Diaphanosoma sarsi	7	6	3	1
Diaphanosoma modiglini	12	14	20	9
Moina micrura	11	12	6	5
Copepoda				
Cyclops pracinus	18	9	6	1
Mesocyclops thermocylopidus	24	13	12	3
Phyllodiaptomus annae	37	19	12	6
Thermocyclops crassus	6	4	2	1
Thermocyclops decipans	5	6	8	9
Nauplii				
Nauplius Larvae	52	43	27	9
Rotifers				
Asplachna brightwelli	12	7	2	1
Brachionus calyciflorus	32	1	23	17
Brachionus donneri	0	1	2	0
Brachionus falcatus	40	50	17	21
Brachionus forficula	0	33	6	10
Filina terminalis	2	2	1	1
Horella brehmi	10	6	1	1
Keratella tropica	10	43	10	6
Testudinella elliptica	0	0	0	0
Tricocerca chattoni	2	9	2	1

Kandy Lake had five species of cladocerans that belong to three genera namely *Ceriodaphnia, Diaphanosoma* and *Moina* (Table 2). Of the genus *Diaphanosoma, D. modiglini* occurred in relatively large numbers during the study period. The two other species of the genus *Diaphanosoma* (*D. sarsi* and *D. exisum*) along with *Moina micrura* and *Ceriodaphnia cornuta* were found in relatively low numbers. With respect to rotifers there were ten species belonging to seven genera (i.e. *Asplachna, Brachionus, Filina, Horella, Keratella, Testudinella* and *Tricocerca* (Table 2). Of the genus *Brachionus, B. falcatus* was the dominant species found throughout the study period v·hereas *B. calyciflorus* was found in relatively large numbers except during the first inter-monsoon. The relative density of *Brachionus forficula* and *K. tropica* were high during the first inter monsoon. *B. donneri* and *Testudinella elliptica* were found only occasionally. The densities of other species of rotifers (*Filina terminalis, Horella brehmi, K. tropica,* and *Tricocerca chattoni*) were relatively low during the four seasons.

Thirty-seven species of phytoplankton were identified from the Kandy Lake during the study period (Table 3). Cyanophyceae was the dominant phytoplankton group and included mainly non-nitrogen fixing forms such as *Microcystis aeruginosa* and *Merismopedia punctata*. Of the diatoms, *Aulacoseira granulata* was dominant and the most widely distributed species. Among the green algae, 14 species were identified. Desmids were represented only by three genera (*Closterium, Cosmerium* and *Staurastrum*). Three species namely, *A. granulata* (a centric diatom), *Pediastrum simplex* (a green algae) and *M. aeruginosa* (a cyanobacteria) were seasonally dominant. *M. punctata* (cyanobacteria) was also found in moderately high numbers throughout the year.

Figure 2 compares the relative abundance of *B. calyciflorus, K. tropica* and total rotifers with the relative abundance of the dominant phytoplankton species. The relative abundance of *B. calyciflorus* was lowest during the first inter-monsoon when *M. aeruginosa* population was highest. *B. calyciflorus* became progressively abundant from the southwest monsoon to the northeast monsoon in conjunction with the alternating oscillation of *A. granulata* and *P. simplex* in the phytoplankton assemblage (Fig. 2). When *B. calyciflorus* declined, *K. tropica* became the dominant species. Figure 3 shows the relative abundance of *B. calyciflorus* and *K. tropica* in relation to the abundance of total cladocerans and *M. aeruginosa*. There was a marked decline in *B. calyciflorus* during the first inter-monsoon when the relative abundance of both total cladocerans and *M. aeruginosa* were high and *K. tropica* became the dominant rotifer. *B. calyciflorus* became dominant over *K. tropica* again when the abundance of *M. aeruginosa* and total cladocerans population were relatively low during the southwest monsoon and second inter-monsoon. Figure 4 depicts the distribution pattern of *B. calyciflorus* and *K. tropica* in relation to chlorophyll-a concentration in Kandy Lake. There is a clear relationship

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Table 3. List of phytoplankton species found in Kandy Lake during the study period (d-dominant; m-moderate; r-rare; NEM - Northeast monsoon; FIM - First Intermonsooon; SWM- Southwest Monsoon; SIM- Second Intermonsoon).

Species Name	NEM	FIM	SWM	SIM
Cyanophyceae				
Anabaenopsis raciborskii	R	M	r	r
Anabaenopsis sp. 2	R	M	r	r
Anabaenopsis sp. 3	R	R	r	r
Chroococcus limneticus	R	M	r	r
Chroococcus sp. 2	R	R	r	r
Cylindrospermopsis sp.	R	M	r	r
Merismopedia punctata	M	M	m	m
Microcystis aeruginosa	D	D	d	d
Microcystis flosaquae	R	M	r	r
Microcystis wesenbergii	M	M	m	m
Oscillatoria sp.	R	M	r	r
Rhaphidiopsis sp.	R	R	r	r
Spirulina sp.	-	R	-	-
Diatomophyceae				
Aulacoseira granulata	D	D	d	d
Coelastrum sp.	R	M	r	r
Cyclotella sp.	R	M	r	r
Cymbella sp.	R	M	r	r
Navicula sp.	R	R	r	r
Pinnularia sp.	R	R	r	r
Rhizosolenia sp.	R	R	r	r
Chlorophyceae				
Ankistrodesmus sp.	R	R	r	r
Centritractus sp.	R	R	r	r
Dictyosphaerium sp.	R	R	r	r
Golenkinia radita	R	R	r	r
Kirchneriella sp.	R	R	r	r
Mallomonas sp.	R	R	r	r
Monorophidium sp.	R	R	r	r
Oocystis sp.	R	R	r	r
Pediastrum simplex	D	D	d	D
Scenedesmus sp.	R	R	r	R
Spyrogyra sp.	R	R	r	R
Tetraedron limneticum	R	R	r	R

Table 3 (Continued)

Species Name	NEM	FIM	SWM	SIM
Zygnemaphyceae				
Closterium sp.	R	R	r	r
Cosmarium sp.	R	R	r	r
Staurastrum rotula	R	R	r	r
Staurastrum sp. 2	R	R	r	r
Stauastrum sp. 3	R	R	r	r
Euglenophyceae				
Euglena sp.	R	M	r	r
Phacus sp.	R	M	r	r

between the relative abundance of two rotifers and chlorophyll-a (chl-a) concentration. *B. calyciflorus* shows a marked decrease in abundance with increasing chl-a concentration whereas the abundance of *K. tropica* is inversely related with chl-a concentration.
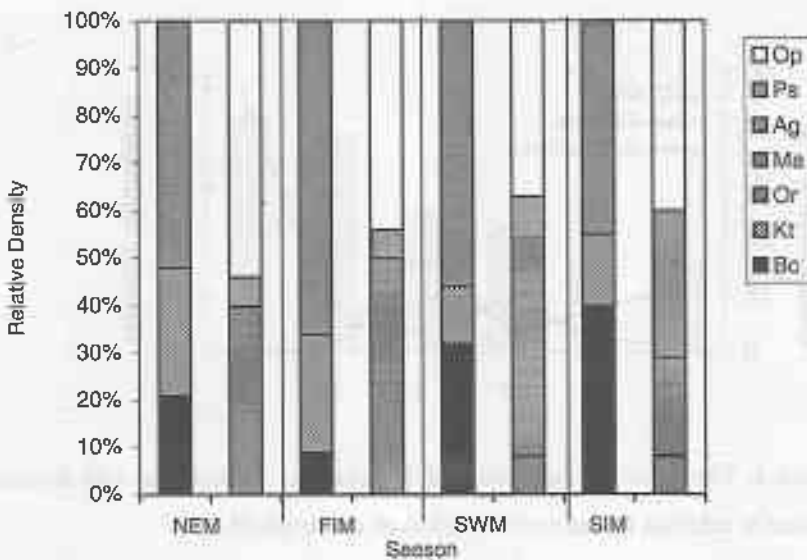
Figure 2. The relative abundance of *Brachionus calyciflorus* (Bc), *Keratella tropica* (Kt) and total rotifers (Or) with the relative abundance of *Microcystis aeruginosa* (Ma), *Pediastrum simplex* (Ps), *Aulacoseira granulata* (Ag) and other plankton (Op).
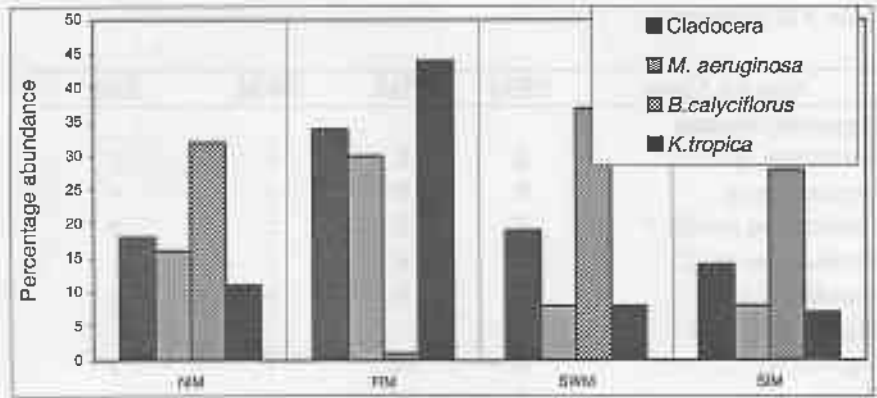
Figure 3. The relative abundance of *Brachionus calyciflorus* and *Keratella tropica* in relation to the abundance of total cladocerans and *Microcystis aeruginosa*.
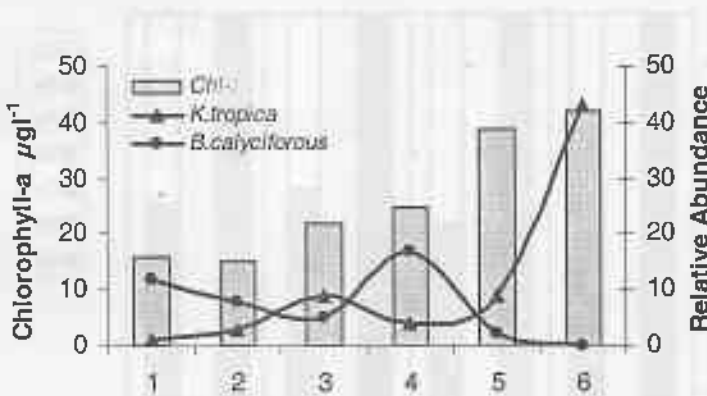

Figure 4. The relative abundance of *Brachionus calyciflorus* and *Keratella tropica* in relation to the concentration of chlorophyll-a

Discussion

Although it experiences weather and climate typical to the wet zone of Sri Lanka, Kandy Lake did not show a marked monsoon-bound seasonal variation in environmental parameters (i.e. Temperature, pH, EC and transparency) except for bicarbonate alkalinity and chlorophyll-a content during the study period, perhaps due to the uniform distribution of rainfall throughout the year 2000. Silva and Davies (1987) showed a significant monsoon bound seasonal variation in phytoplankton primary productivity

and related parameters in irrigation reservoirs in Sri Lanka. However bicarbonate alkalinity was significantly low during the first inter-monsoon. Low bicarbonate alkalinity, high pH, low transparency, coupled with optimum nutrient conditions (low N and high P) promotes the growth of toxic cyanobacteria such as *M. aeruginasa* (Jacoby et al. 2000). There is evidence that *M. aeruginasa* with toxigenic strains emerged in Kandy Lake in May 1999 under low light attenuation when N:P ratio was extremely low (Silva 2003). Although chlorophyll-a and Secchi disk transparency were negatively correlated, the outliers resulting from inorganic turbidity may weaken the significance of the relationship. Sudden and intermittent changes in turbidity may have significant effects on both zooplankton communities and phytoplankton assemblages. Rotifers belonging to family *Brachionidae* are strongly associated with environmental factors such as temperature, water flow, pH, salinity, alkalinity, mineralization, transperency etc. (De Manuel 1991). The species diversity of zooplankton, especially, planktonic crustaceans in Sri Lankan reservoirs is smaller than that found in temperate regions. Rotifers dominated by the genus *Brachionus*, are common in pelagic zooplankton communities in Sri Lankan reservoirs (Fernando 1980a; Rajapaksa and Fernando 1982; Jayatunge 1986). Further, it has been emphasized that rotifer population densities in hydrologically dynamic reservoir ecosystems are regulated either by rapid throughput or predator pressure of zooplanktivorous fish (Duncan 1984; Duncan and Gulati 1983; Jayatunge 1986). The changes in rotifer population in Parakrama Samudraya in Sri Lanka, a hydrologically dynamic irrigation reservoir were attributed to the flushing rate and predator pressure of two zooplanktivorous fish species namely *Hemirhamphus limbatus* and *Ehirava fluviatilis* (Duncan 1984). Jayatunge (1986) found that zooplankton population densities and composition were regulated by a hydraulic regime of the Kalawewa reservoir in Sri Lanka. The situation in Kandy Lake is quite different compared to irrigation reservoirs. Kandy Lake has a long retention time, free from zooplanktivorous fish and the fish fauna is dominated by cichlids (mainly *Oreochromis mossambicus* and *O. niloticus*) due to its stagnant nature and non-fishing practices. In shallow ponds where high densities of fish occur, the zooplankton may be almost exclusively Rotifera. This situation has been observed in ponds with high density of tilapia in Costa Rica (Hurbet and Mulla 1981). A similar result was reported by Moitra and Mukhejee (1972) in Calcutta fishponds. Duncan (1983) showed high population densities of rotifers during low water level in Parakrama Samudra. In Parakrama Samudra, high density of rotifers was observed in February 1978 (dry season) during high water level and also during a later period in 1980 during the October-November rainy season (Duncan 1983).

It has been shown that rotifer populations can be negatively affected by toxic or filamentous cyanobacteria (Seal et al. 1993). The *M. aeruginosa* found in Kandy Lake contained toxigenic strains (Dr. L.P. Jayatissa and Prof. Rudi Hofer, pers. comm.) and it has been observed that

B. calyciflorus ingested *M. aeruginosa* cells in fresh phytoplankton samples. High concentration of chl-a in Kandy lake is mainly due to the occurrence of high densities of *M. aeruginosa* colonies in the phytopklankton assemblage (Silva 2003). Attempts have been made to correlate rotifer densities and their species compositions to trophic status of the water body in many instances (Radwan 1976; Sládecek 1983; Karabin 1985). The toxigenic *Microcystis* that stopped the food intake in *Daphnia magna* did not inhibit feeding in *Brachionus rubens* and was ingested by the rotifers at a rate comparable to *Monoraphidium,* (Rothhaupt 1991). *B. rubens* cultured with *M. aeruginosa* died faster than non-fed controls. The rigid filaments of *Cylindrospermopsis* were not ingested by *B. rubens.* Therefore *B. calyciflorus* in Kandy Lake may be negatively affected by bio-chemical (toxin) properties of *M. aeruginosa* as shown by Matveeva (1991). Relationship between trophic status and rotifer composition may be attributed to relative abundance of toxin forming cyanobacteria as seen during this study. Annual range of chlorophyll-a and its seasonal variation in Kandy Lake showed an inter-monsoonal trophic shift associated with other environmental parameters. However, Kandy Lake is eutrophic but the magnitude of trophy varies over the seasons as a result of rainfall.

Large Cladocerans can compete out or suppress rotifer species, indirectly by exploiting shared food resources or by direct interaction (Gillbert 1988; Dawidowicz and Pijanowska 1991; Modenuitti et al. 1993). When the population density of *B. calyciflorus* declined in Kandy Lake during the first inter-monsoon the total Cladoceran density was high, in addition to the occurrence of dense colonies of *M. aeruginosa*. It seems that *K. tropica* is neither ingesting toxigenic cyanobacteria cells nor competing for the same food resource with Cladocerans. When conditions of lakes are constant rotifer communities may remain invariable for decades and a considerable increase in trophy has been observed to result in the extinction of some species and emergence of others (Dawidowicz and Pijanowska 1991, Modenutti et al. 1993) However, likely interpretation of changes in seasonal distribution of planktonic rotifer populations are complex and generalization is difficult to make. The seasonal changes in rotifer densities and composition have been correlated to temperature in warm temperate regions where variations are very common. Species develop maxima in summer, specially in late summer, with the development of certain blue green algal population. However, very little is known about seasonal succession among rotifers and their inter- and intra-specific competition in the tropics.

The most likely reason for the apparent suppression of *B. calyciflorus* during the first inter-monsoon could be the abundance of toxigenic strains of *M. aeruginosa* or else a combined effect of *M. aeruginosa* and interference competition resulting from high densities of total Cladocerans under unfavourable environmental conditions such as high turbidity.

Acknowledgements

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