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The Occurrence of Cyanobacteria in the Reservoirs of the Mahaweli River Basin in Sri Lanka

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Abstract

About forty species of cyanobacteria belonging to twenty-four genera have been reported so far from Sri Lanka's reservoirs. Of these, except for *Microcystis aeruginosa*, the other species are either rare or occur only in small numbers. The composition of the phytoplankton in 21 reservoirs in the Mahaweli river basin were examined during February-March, 1994 to determine whether the cyanobacteria exhibit a particular pattern of distribution and abundance. Of the cyanobacteria found in the Mahaweli reservoirs, the genus *Anabaena* occurred in two reservoirs. It was dominant in the Ambewela reservoir (relative importance - 70%) while in the Kande-Ela reservoir, which is located in the immediate downstream of the Ambewela reservoir, its relative importance in the phytoplankton community was only 1%. The relative importance of the genus *Microcystis* ranged from 46% to 2% and was found in twenty water bodies. The genus *Pseudanabaena* was found in four reservoirs with a relative importance ranging from 4% to 46%. *Coelosphaerium* sp. was found in two water bodies but its relative importance varied from 7% to 1%. The genus *Lyngbia* was found in one water body with a relative importance of 1%. In addition, several other genera of cyanobacteria reported by others were found in a few numbers. Of the five major genera of cyanobacteria, *Microcystis* had the highest distribution and relative abundance in the Mahaweli river basin. The lowest relative abundance and distribution were recorded for *Planktolyngbia*. The relative importance of cyanobacteria in the phytoplankton assemblage in most of the reservoirs were found to be high (>50%) or moderate (25-50%) when total phosphorus and NO_3-N contents are relatively low. Further when the NO_3-N content is very low, pH also appears to affect the relative importance of cyanobacteria.

Introduction

Phytoplankton communities in tropical lakes are generally similar to summer communities of temperate lakes (Vyverman 1996). In addition, there is a large number of tropical taxa including pantropical and regional endemic elements (Vyverman 1996). A majority of surface water bodies in the tropics are eutrophic although hypertrophic conditions or the occurrence of algal blooms are also not unusual (Hutchinson 1973). The generally accepted phenomenon is that the occurrence of cyanobacteria or blue-green blooms is triggered by nutrient enrichment (Hutchinson 1973). Eutrophication is an important issue in limnological research, and the global scenario is that most of the surface water bodies are being subjected to cultural eutrophication. Nevertheless, knowledge on hypertrophic phenomena is still scarce (Barica & Mur 1980). Further, ecophysiology of bloom forming planktonic algae is poorly understood (Alvarez-Cobelas & Jacobsen 1992).

In Sri Lanka, a dense dark green bloom of *Spirulina* sp and *Microcystis aeruginosa* co-exists in the Beira Lake (Colombo Lake) since the early eighties (Hirimburegama 1998). The Beira Lake has now become a nuisance water body with no aesthetic value because of this bloom. It was assumed that the deeper highland reservoirs constructed in the Mahaweli basin for the generation of hydropower are least susceptible for hyper-eutrophication, although a dense thick bloom of *Mycrocystis aeruginosa* covered the entire Kotmale reservoir during the dry spell of 1991. The "Kotmale Bloom" had serious impacts on operational activities but disappeared gradually with the onset of the northeast monsoonal rain. In contrast, a scum of *Anabaena aphanizomenoids* was scattered in the Parakrama Samudra with the onset of the second inter-monsoon in 1993 and it also disappeared with the release of water to the command area during the 'Maha' cultivation season. Further, a perennial bloom of *Microcystis aeruginosa* has been observed in a small irrigation tank called Kuda Sithulpahuwa in the Menik Ganga basin (Dr. L. P. Jayatissa pers. comm.). Patchy distribution of *Microcystis* scum in irrigation and hydropower reservoirs in the Mahaweli basin is not unusual. About 50% of all cyanobacterial blooms tested around the world were toxic and certain blue-green algal strains found in Sri Lanka also produce toxins (Jayatissa 1995). It was also hypothesized that the occurrence of mass mortality of *Amblypharyngodon melettinus* in the southern basin of the Parakrama Sumudra (Dumbutulu Wewa) in June 1998 was due to the toxin produced by a cyanobacteria, *Microcystis aeruginosa* (Anon. 1998)

Several studies have been carried out on the systematics of phytoplankton algae in Sri Lankan surface waters (West & West 1904; Apstein 1907, 1910; Fritsch 1907; Lemmermann 1907; Crow 1923a, b; Holsinger 1955; Foged 1976; Abyewickrema 1979; Rott 1983; De Silva 1993; Rott & Lenzenverger 1994). There are three distinct forms of perennial water bodies in the Mahaweli river basin i.e., ancient irrigation tanks, recently built or restored irrigation tanks, and hydropower and storage reservoirs constructed under the Mahaweli Development Project. Today, these man-made water bodies with their inter-connected canals and channels have formed a somewhat sophisticated and complicated hydrological net work in the Mahaweli river basin. The present study examined the composition of phytoplankton in twenty-one surface water bodies in the Mahaweli river basin in Sri Lanka to determine whether the cyanobacteria exhibits a particular site-specific pattern of distribution and abundance.

Material and Methods

The water bodies in which the present study was carried out together with the altitude, catchment area, mean depth, maximum depth and surface area are given in Table 1. Sampling commenced in mid February 1994 and was completed in March 1994 within the first inter-monsoon. The pH and electrical conductivity were measured using Horiba pH meter (Model H-7LD) and Jenway Conductivity Meter (Model 4070) respectively. Phytoplankton samples were collected with a Wisconsin Plankton Net (55 µm mesh size) from the centre of each water body and immediately fixed in 5% formalin. Water samples were also collected from each water body and analyzed for total phosphorous, nitrate-nitrogen (APHA 1987) and chlorophyll-a contents (Marker *et al.* 1980) in the laboratory. Phytoplankton species were examined using an Olympus Stereo Microscope at 10x, 40x and 100x magnifications. Taxonomic descriptions given by Abeywickrama (1979), Rott (1983) and Rott & Lenzenverger (1994) were used during the identification of phytoplankton. Quantitative analysis of phytoplankton was done by counting the individual species under the optical microscope using a Sedgewicjk rafter cell. The relative importance of individual species was thus estimated. In each reservoir, the phytoplankton species were then ranked from 1, the species with the highest abundance being given the rank 1. The relative rank of a particular species in the phytoplankton community in the Mahaweli basin (RR) was then calculated using the following equation.

$$RR = ((\sum R_i n_i)/ N_i).(N/ N_i)$$

where, R_i = rank of the i^{th} genus;
n_i = number of reservoirs with the rank R_i;
N_i = total number of reservoirs with species i;
N = total number of reservoirs studied.

The species with the lowest RR was considered to be the most widely distributed and abundant species in the Mahaweli river basin.

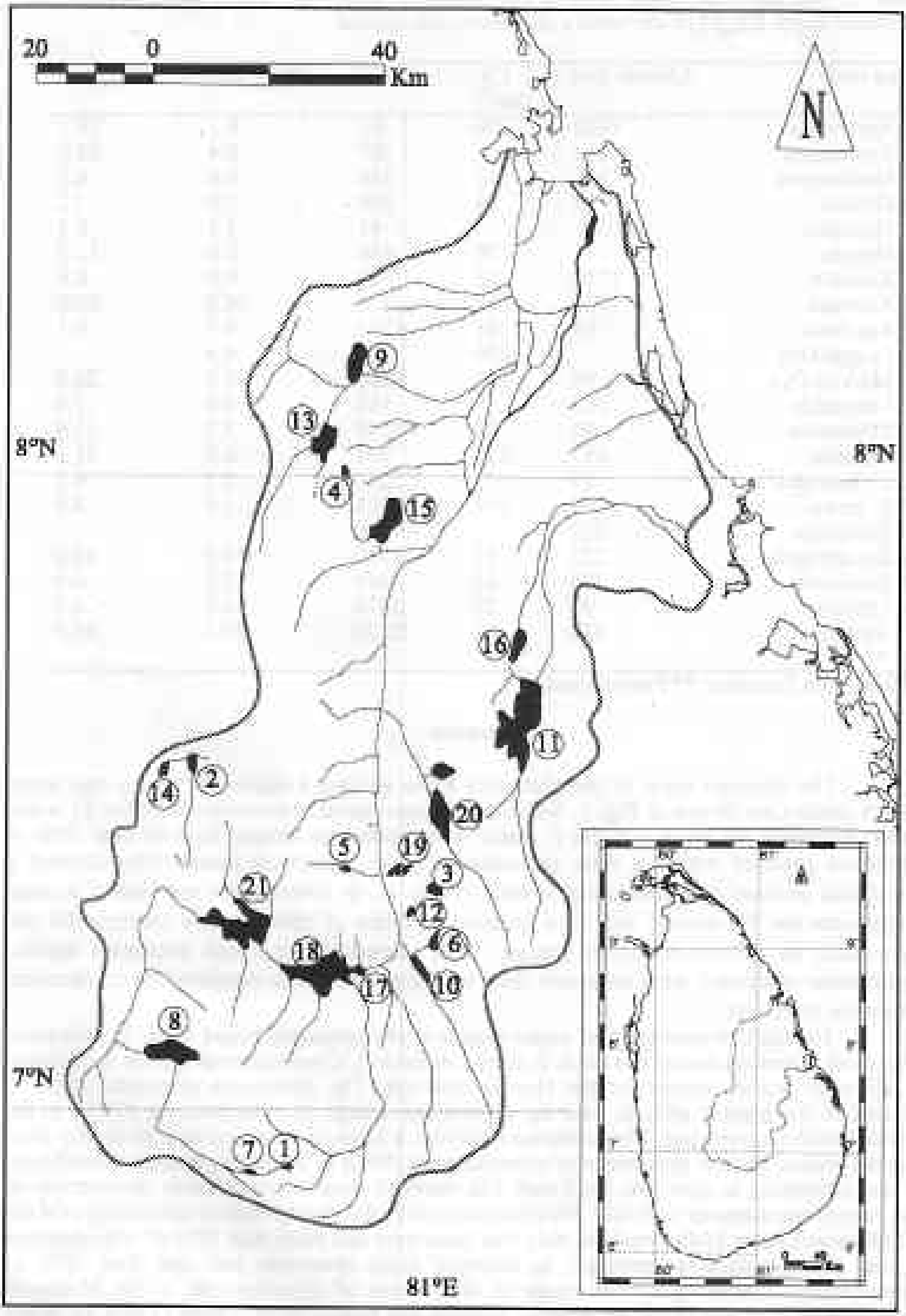

Fig. 1. Map of the Mahaweli river basin indicating the 21 reservoirs studied. Arabic numerals represent individual reservoirs indicated in Tables 1-4. Inset shows the Mahaweli river basin in Sri Lanka in relation to rest of the island.

Table 1. Altitude, catchment area (CA), reservoir area (A), mean depth (D_{mean}) and maximum depth (D_{max}) of the twenty one reservoirs studied.

Water body	Altitude (m)	CA (km^2)	A (ha)	D_{mean} (m)	D_{max} (m)
01. Ambewela	1830	08	61	8.1	19.1
02. Bowatenna	414		507	8.4	23.2
03. Dambarawa	102	07	344	4.6	6.1
04. Giritale	94	24	308	7.0	12
05. Hasalaka			41	3.1	6.1
06. Hepola		70	868	3.0	12.2
07. Kan-Ela	1710	02	45	4.9	8.4
08. Kotmale	703	29	1374	26.8	90.0
09. Kaudulla	65	81	1765	4.7	9.1
10. Loggal Oya		250		4.5	
11. Maduru Oya	96	453	6280	9.5	26.0
12. Mapakada	105	08	186	4.4	7.6
13. Minneriya	96	24	2550	5.3	11.6
14. Nalanda	457	124	304	4.9	21.3
15. P' Samudra*	59	72	2266	5.3	6.7
16. P' ttewa**	97	154	1213	1.9	5.9
17. Rantambe	205		400		
18. Randenigala	232	31	1350	36.6	80.0
19. Sorabora	240	62	445	3.3	6.6
20. Ulhitiya	97	28	2270	4.6	6.3
21. Victoria	438	31	2270	30.5	98.0

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Results

The drainage basin of the Mahaweli River and the locations of twenty-one water bodies studied are shown in Fig. 1. Some basic limnological characteristics of the 21 water bodies examined are given in Table 2. These water bodies are located from 60 m to 1800 m altitudinal gradient within a wide geo-climatic range. Electrical conductivity showed a significant increase with decreasing altitude (Table 2). In contrast, the nutrients (i.e. total phosphorus and N- nitrate) and algal biomass in terms of chlorophyll-a contents did not show such an altitude-associated change. With respect to mean and maximum depths, hydropower reservoirs were relatively deep with high drawdown compared to downstream irrigation reservoirs.

The relative abundance of major groups of phytoplankton found in the 21 Mahaweli reservoirs examined during this study is shown in Table 3. Cyanobacteria species were found in all water bodies except for the Hepola reservoir. The Ambewela reservoir, which is located in the highest altitude, had the highest percentage of cyanobacteria (74%) in the phytoplankton assemblage. Pimburettewa reservoir, a lowland irrigation tank in the dry zone had the second highest percentage of cyanobacteria (59%) in the phytoplankton assemblage. It was interesting to note that the Kande Ela reservoir located immediately downstream of the Ambewela reservoir had only 3% cyanobacteria in the phytoplankton assemblage. Of the 21 Mahaweli water bodies studied, only four reservoirs had more than 50% of cyanobacteria in the phytoplankton assemblage. In contrast, eight reservoirs had less than 10% of cyanobacteria indicating a wide range of distribution of cyanobacteria in the Mahaweli reservoirs irrespective of the geographic location and hydrological regime (Table 3). When the abundance of cyanobacteria was low green algae, desmids or diatoms dominated the phytoplankton assemblage. In addition, *Peridinium* sp., which belongs to the Family Dinophyceae was found to contribute for 53% of the phytoplankton community of the Nalanda reservoir which is located in an isolated sub-watershed of theMahaweli River basin.

Table 2. pH, Electrical Conductivity in μS (EC), total phosphorous (tP in $\mu g\ l^{-1}$), nitrate-nitrogen (NO_3^- -N in $\mu g\ l^{-1}$) and Chlorophyll-a (Chl-a in $\mu g\ l^{-1}$) of the 21 reservoirs.

Water body	pH	EC	tP	NO_3^--N	Chl-a
01. Ambewela	8.38	25	24	35	20
02. Bowatenna	7.19	85	41	72	03
03. Dambarawa	8.61	132	26	03	20
04. Giritale	8.37	180	75	50	28
05. Hasalaka	7.70	71	41	143	05
06. Hepola	7.80	90	26	94	10
07. Kan-Ela	6.98	13	07	222	05
08. Kotmale	6.70	43	05	366	07
09. Kaudulla	8.13	210	52	02	12
10. Loggal Oya	7.06	84	14	93	11
11. Maduru Oya	8.10	117	28	06	35
12. Mapakada	8.53	106	86	05	12
13. Minneriya	7.71	98	26	83	12
14. Nalanda	7.82	132	34	21	06
15. P' Samudra*	7.93	135	19	28	06
16. P' ttewa**	8.81	224	48	03	60
17. Rantambe	6.63	75	20	130	09
18. Randenigala	7.26	84	22	130	12
19. Sorabora	7.91	142	106	13	12
20. Ulhitiya	8.69	99	29	20	10
21. Victoria	7.03	57	24	30	11

* Parakrama Samudra; ** Pimburettewa

Table 4 depicts the relative importance of main genera of phytoplankton in the 21 Mahaweli reservoirs studied. The cyanobacteria genus *Pseudanabaena* was found in 4 reservoirs with percentage abundance ranging from 4% to 46%. The phytoplankton community in the Ambewela reservoir was dominated by a *Pseudanabaena* sp (70%) while it was 44% of the total phytoplankton assemblage in the Pimburettewa reservoir. The population of *Pseudanabaena* in the Kande-Ela reservoir, which is located at the immediate downstream of the Ambewela reservoir was 1%. The Dambarawa reservoir had the highest *Microcystis* population (46%) compared to the other water bodies. The relative abundance of genus *Microcystis* ranged from 2% to 46% but it was found in 20 water bodies except in the Hepola Oya reservoir. *Coelosphaerium* sp. was found in two water bodies (i.e., Minneriya and Ulhitiya) and its relative abundance was 1% in Ulhitiya and 7% in Minneriya. *Planktolyngbia* sp. was found only in the Giritale reservoir with a relative abundance of 1%. In addition, several other genera of cyanobacteria reported by others (Rott 1983; Rott & Lenzenverger 1994) were also found in some reservoirs, but in few numbers which could be ranked as rare species. The values for relative ranks for major genera of phytoplankton in the reservoirs studied are given in Table 5. Of the five major genera of cyanobacteria found in the reservoirs *Microcystis* was the most widely distributed and abundant genus.

The relationship of NO_3-N content and total P content in the reservoirs studied are shown in Fig. 2. The reservoirs where the relative importance of cyanobacteria is high (>50%), or moderate (25-50%), are concentrated in the lower left region in the Fig. 2. Nalanda reservoir in which the relative importance of cyanobacteria is low (<25%) also lies in this region of the Figure.

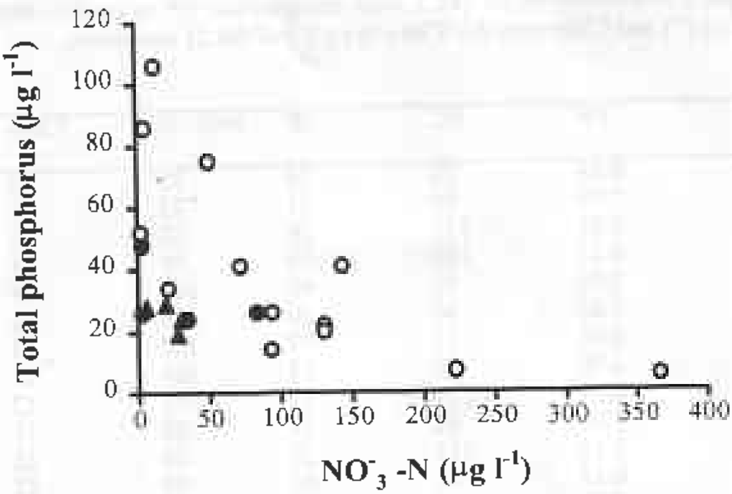

Figure 2. Percentage occurrence of cyanobacteria in relation to NO^-_3-N and total phosphorus contents in the reservoirs studied (% occurrence of cyanobacteria: <25% low- o; 25-50 % moderate - ▲ and >50% high - •).

Table 3. The relative importance of major phytoplankton groups in the Mahaweli reservoirs studied.

Water body	Relative importance of major phytoplankton groups					
	Cyanophyceae	Chlorophyceae	Zygnemaphyceae	Diatomophyceae	Dinophyceae	Others
01. Ambewela	74	03	04	16	00	03
02. Bowetenna	05	18	10	61	00	09
03. Dambarawa	50	04	34	05	00	07
04. Giritale	19	52	01	25	00	05
05. Hasalaka	04	02	77	14	00	04
06. Hepola	00	04	90	02	00	04
07. Kan-Ela	03	00	84	12	00	01
08. Kaudulla	07	13	00	78	00	03
09. Kotmale	22	00	69	06	00	03
10. Loggal Oya	05	04	79	08	00	04
11. Maduru Oya	47	01	48	01	00	03
12. Mapakada	21	00	72	02	00	05
13. Minneriya	50	03	00	81	00	03
14. Nalanda	13	25	00	04	53	02
15. P' Samudra*	27	46	00	09	00	09
16. P'ttewa**	59	03	0.2	37	00	04
17. Randenigala	06	02	92	00	00	01
18. Rantambe	04	01	85	08	00	05
19. Sorabora	08	04	01	85	00	02
20. Ulhitiya	27	00	65	01	00	03
21. Victoria	26	00	63	08	00	03

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Discussion

Typically phytoplankton communities in tropical lakes are dominated by cosmopolitan taxa along with pantropical taxa in lowland lakes and northern montane species in highland lakes while species with more restricted distribution usually occur in low densities (Vyverman 1996). Of about 4700 taxa recorded from Indo-Malaysian and North Australian regions, majority is comprised of chlorophytes (67%), especially desmids (57%), diatoms (19%) and blue green algae (6%) and there is only a small number of phytoflagellates(Vyverman 1996). The results of this study clearly show that the relative importance of cyanobacteria in the phytoplankton community varies from reservoir to reservoir irrespective of their geographical location and hydrological regime. Even adjoining reservoirs receiving outflow of the upstream reservoirs had a completely different spectrum of phytoplankton. The occurrence of cyanobacteria has been attributed mainly to nutrient enrichment (Hutchsinson 1973). Similarly attempts have been made to correlate the occurrence of cyanobacteria to catchment characteristics and land use changes (Martin 1993). The generally accepted phenomenon is that nitrogen limited aquatic environments promote the growth of cyanobacteria when phosphorus is not limited. However, the results of this study show that nitrogen limitation is not the only factor that promotes the growth of cyanobacteria in eutrophic tropical lentic ecosystems. It is interesting to note that the highest relative importance of of cyanobacteia in the phytoplankton community occurs in Ambewela reservoir which is located at the highest altitude and the next highest value was recorded in Pimburettewa reservoir which is a lowland irrigation tank in the dry zone. However in Pimburettewa reservoir, the most abundant species was different from that of Ambewela reservoir.

Table 4. Relative importance of major phytoplankton genera found in the Mahaweli reservoirs studied. Cyanobacteria species are highlighted. Ank – *Ankistrodesmus*; Aulc - *Aulacoseria*; Clos – *Closterium*; Clsp - *Coelosphaerium*; Clst - *Closterium*; Cosm – *Cosmarium*; Dict – *Dictyosphaerium*; Goln - *Golenkinia*; Melo – *Melosira*; Micr – *Microcystis*; Pedi – *Pediastrum*; Peri – *Peridinium*; Plyn - *Planktolyngbia*; Pdab - *Pseudanabaena*; Stra – *Staurastrum*; Synd – *Synedra*.

Water body	% frequency of phytoplankton genera					Others
01. Ambewela	**Pdab 70**	Aulc 16	**Micr 04**	Cosm 04	Pedi 03	03
02. Bowetenna	Aulc 61	Pedi 18	Clos 05	Stra 05	**Micr 02**	09
03. Dambarawa	**Micr 46**	Cosm 34	Aulc 05	Pedi 04	**Pdab 04**	07
04. Giritale	Pedi 52	Aulc 25	**Micr 18**	Clos 01	**Plyn 01**	05
05. Hasalaka	Cosm 65	Aulc 14	Stra 12	**Micr 04**	Pedi 02	04
06. Hepola	Cosm 77	Stra 13	Pedi 02	Aulc 02	Dict 02	04
07. Kan-Ela	Cosm 83	Aulc 12	**Micr 02**	**Sdab 01**	Stra 01	01
08. Kadulla	Aulc 78	Pedi 10	**Micr 06**	Anks 03	Synd 01	03
09. Kotmale	Clos 54	**Micr 22**	Stra 13	Aulc 06	Cosm 02	03
10. Loggal Oya	Cosm 67	Stra 12	Aulc 08	**Micr 05**	Pedi 04	04
11. Maduru Oya	Cosm 48	**Pdab 24**	**Micr 23**	Pedi 01	Aulc 01	03
12. Mapakada	Cosm 65	**Micr 02**	Stra 05	Aulc 02	Clos 02	05
13. Minneriya	Aulc 81	Clsp 07	**Micr 06**	Pedi 03	Synd 01	03
14. Nalanda	Peri 53	Pedi 21	**Micr 13**	Goln 04	Aulc 04	02
15. P'ttewa*	**Pdab 44**	Aulc 37	**Micr 15**	Pedi 03	Cosm 01	04
16. P' Samudra	Pedi 46	**Pdab 16**	**Micr 11**	Goln 09	Aulc 09	09
17. Randenigala	Cosm 81	Stra 11	**Micr 06**	Pedi 01	Dict 01	01
18. Rantambe	Cosm 75	Stra 10	Aulc 08	**Micr 04**	Pedi 01	05
19. Sorabora	Aulc 85	**Micr 08**	Pedi 02	Anks 02	Clos 01	02
20. Victoria	Stra 49	Cosm 14	**Micr 13**	Clst 13	Aulc 08	03
21. Ulhitiya	Cosm 60	**Micr 26**	Stra 05	Aulc 05	Clsp 01	03

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Table 5. The relative ranks (RR) of major phytoplankton genera in the Mahaweli river basin.

Rank	1	2	3	4	5	RR
Family: Chlorophyceae						
Genus: *Ankistrodesmus*	00	00	00	02	00	39.3
Dictyosphaerium	00	00	00	00	02	44.6
Golenkinia	00	00	00	02	00	44.6
Pediastrum	02	03	02	04	05	4.6
Family: Cyanophyceae						
Genus: *Anabaena*	01	00	00	01	00	26.3
Coelosphaerium	00	01	00	01	01	36.8
Planktolyngbya	00	00	00	00	01	94.5
Microcystis	01	04	11	03	01	3.2
Pseudanabaena	01	02	00	00	01	8.2
Family : Dinophyceae						
Genus: *Peridinium*	01	00	00	00	00	21.0
Family: Diatomophyceae						
Genus: *Aulacoseira*	04	05	03	04	04	3.1
Synedra	00	00	00	00	02	52.5
Family: Zygnemaphyceae						
Genus: *Closterium*	01	00	01	01	02	18.4
Cosmarium	08	02	00	01	03	1.8
Staurastrum	01	04	04	01	01	5.1

Alvarez-Cobelas *et al.* (1994) attempted to explain the abundance and distribution of phytoplankton species in deep and shallow water bodies in relation to different limnological characteristics using multivariate techniques. Multivariate statistical techniques have proved to be a viable tool in the study of ecological variable influence on phytoplankton community dynamics (Varis *et al.* 1989; Van Tongerent *et al.* 1992; Alvarez-Cobelas *et al.* 1994; Romo & Tongerent 1995).

According to the present study, the altitude, mean depth, maximum depth, extent of the catchment area and electrical conductivity appear to have no significant effect on the relative importance of cyanobacteria in the phytoplankton community. However NO_3^--N content, total phosphorus content and pH acting together appear to affect the relative importance of cyanobacteria in the phytoplankton assemblage in these reservoirs.

Concentration of reservoirs with moderate or high relative importance (>25%) of cyanobacteria in the lower left region of Fig. 2 indicates that when NO_3^--N and total phosphorous contents are higher than 83 μg l^{-1} and 48 μg l^{-1} respectively, the relative importance of cyanobacteria is low. However in Nalanda reservoir, although the NO_3^--N content and total phosphorous content are less than the above values, the relative abundance of cyanobacteria is low. It should be noted that the NO_3^--N content is very low (21μg l^{-1}) in this reservoir and when all reservoirs with similar or lower NO_3^--N content are considered, this reservoir has the lowest pH. Therefore it appears that in addition to NO_3^--N and total phosphorous contents, pH also have some effect on the relative importance of cyanobacteria in the phytoplankton community when NO_3^--N is very low.

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