PHYTOPLANKTON SPECIES DIVERSITY AND ABUNDANCE IN SATELLITE LAKES OF LAKE VICTORIA BASIN (TANZANIAN SIDE)

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ABSTRACT

Studies on phytoplankton species diversity and abundance were carried out in 8 selected satellite lakes within the Lake Victoria basin during two wet seasons (March-April 2002 and January-February 2003) and one dry season (August-September 2002). Higher species richness (76 species) of phytoplankton species was recorded in rain season than in dry season (47 species). The observed species represents six classes, cyanophytes, chlorophytes, cryptophytes, basillariophytes, euglenophytes and dinophytes, of fresh water algal flora. Species diversity was generally low, with diversity indices (H') ranging from 0.21 for Lake Kyarano to 0.09 for Lake Ikimba. On the contrary, Lake Katwe was richer in terms of species (66) followed by Burigi (49) and Ikimba (47). Lake Kubigena represented a lowest number (17) of species. Lake Burigi showed the highest abundance (611624 cell/ml) in rain season, while Lake Kyarano showed the lowest abundance (1336 cells/ml) recorded in dry season. Cyanophytes dominated (75-98% of counted cells) the phytoplankton community throughout the study period followed by bacillariophytes (0.2 -14% of counted cells) in all lakes except Lake Kyarano, which was dominated by Dinophytes (71%), whereas euglenophyta and chrysophyta were rarely encountered. The results clearly show that the phytoplankton community of satellite lakes were largely dominated by cyanophytes. This may indicate high nutrient loading (pollution) in these lakes that are certainly resulting from the surroundings. These findings call for a special attention on cyanobacteria occurrence and their unforeseen effects such as toxin production and oxygen depletion during nights that may results into fish killings.

INTRODUCTION

Phytoplankton species are essential component of the trophic structure in aquatic ecosystems. They are responsible for approximately 40% of the planet's total annual primary production, although the magnitude of their contribution to global primary production is not appreciated due to their small fraction of total photosynthetic biomass (US National report to IUGG 1994). They are also an important source of food for zooplankton and some of the fishes in the aquatic food web. Some species of phytoplankton largely contribute to human affair in everyday life, and they are of economic importance. For example, some species of blue green algae such as *Spirulina* spp. are sources of many valuable products that may be used as food or fodder due to their high protein content and vitamins (US National report to IUGG 1994).

Several water bodies (satellite lakes, rivers and ponds) exist throughout the Lake Victoria basin, and support the livelihood of people surrounding them. They are sources of water for domestic use, and they also support small-scale fisheries. The unique habitat of these small water bodies may harbour a rich variety of organisms including endangered fish species, for instance some indigenous fish species which are said to have declined markedly from the main lake (Ogutu-Ohwayo 1990). The changes in the main Lake Victoria have been linked directly to the increase in human population growth and the associated subsistence agriculture, intense animal husbandry and unplanned occupancy of the riparian shorelines for access to fish and water that lead to, eutrophication and overfishing (Hecky 1993). Another consequence is the removal of phytophugous Haplochromine and native tilapines (Goldschmidt and Witte et al. 1992), which has greatly altered the biological trophic structure of the lake (Hecky &Bugenyi 1992), drastically reducing the grazing pressure and leaving an excess of phytobiomass. Low algal biomass composed mainly of diatoms was reported in earlier limnological surveys with offshore chlorophyll *a* ranging from 1.2 to 5.5. mg m^{-3} and 10-15 mg m^{-3} inshore (Talling 1966). The current chlorophyll *a* measures at 8.4 to 40 mg m^{-3} and 22.2 to 67.1 mg m^{-3} in the offshore and the inshore areas, respectively and the daily integral productivity per unit area increased form an average of 7.0 to 13.9 g O_2 $m^{-2}d^{-1}$ offshore (Muggide 1993). According to Verschuren et al. (2001), Lake Victoria was stable between 1820 and 1940, with *Cyclostephanos*, and *Aulacoseira* making a large proportion of diatoms (80% and 15%, respectively*)* and *Nitzschia acicularis* absent or too rare to be preserved. The abundance of these three taxa started to increase between about 1940 and the early 1960, with *Nitzschia acicularis* archiving 50% of the diatom community. Today, the thinly silicified *Nitzschia acicularis* comprises about 94% of the total diatom abundance. The species shift is interpreted as evidence for Si limitation due to the increased diatom growth. In addition, Kling et al. (2001) working on fossil data observed that elimination of *Aulacoseira spp*. occurred in the past 20 years. This reduction matched with the increased occurrence of massive cyanobacterial blooms. Ochumba and Kibaara (1989) and Lungaiya et al. (2000) also observed increased cyanobacterial abundance in the lake.

These changes and human related activities are also believed to cause noticeable effects in satellite lakes, ponds and other small water bodies surrounding Lake Victoria. From the available literature, very little is known about algae flora in these water bodies. Ecological studies in these satellite lakes may contribute greatly to both the scientific and conservation interests. This study provides fundamental information on the phytoplankton species diversity and abundance in some selected satellite lakes of Lake Victoria basin, the Tanzanian side.

MATERIALS AND METHODS

Sampling stations were selected in all three regions (Mara, Kagera and Mwanza) surrounding Lake Victoria in the Tanzanian side. The water bodies in Mara region were Mara river, Lake Kirumi, Kyarano and Kubigena, in Kagera region were Lake Burigi, Katwe and Ikimba while Mwanza region was Lake Malimbe only. Mara River and most of satellite lakes were surrounded by papyrus swamps and macrophytes. Most of satellite lakes were relatively shallow with a maximum depth of 1-5 m, the deepest depth was recorded at Kyarano dam with maximum depth of 8 m.

Samplings were carried out during two wet season (March-April 2002 and January - February 2003) and one dry season (August-September 2002). Samples for species diversity were collected by towing a plankton net (30 µm) on the surface at a minimum speed of a boat. Part of the collected samples were kept un-preserved for live sample observation while the remaining samples were preserved by 0.7% lugol's solution and 2.5% formaline. Identification was done with the help of identification keys such as that of Mosille (1984) and

John et al. (2002) up to generic level, and species level whenever it was possible.

Water samples for phytoplankton abundance were taken at different depths using a Van Dorn water sampler (1 litre). The samples were immediately fixed as explained above and kept in cool dark place before laboratory analysis. Upon return to the laboratory, 5 ml of the water sample was placed in a sedimentation chamber and left to sediment for at least 24 h. After sedimentation, counting of number of phytoplankton cells (filaments or cell are presented as cells/ml) was done using an inverted microscope (Leitz - Labovert FS, made in Germany) according to standard procedures (Utermohl 1958).

RESULTS

Phytoplankton Species Diversity

A total of 76 species of phytoplankton which represents five classes (cyanophyta, chlorophyta, bacillariophyta, dinophyta, and Euglenophyta) were identified from the surveyed satellite lakes during wet season (Table 1). During the dry season however, 47 phytoplankton species were encountered. In both dry and wet seasons, Lake Katwe showed the highest number of species (67) followed by Lake Burigi(49 species) and Ikimba (47 species). Lakes Malimbe, Kubigena and River Mara recorded the least number (30, 31 and 32 species respectively). Among the classes, chlorophyta showed the greatest number of species (45) followed by cyanophyta (39 species), during both wet and dry season. Euglenophytes and dinophytes were rarely encountered.

Table 1: Species of phytoplankton recorded during the wet season (X), dry season (+), both seasons (X+) or not found (blank) in various satellite lakes

SPECIES/TAXA	BURIGI	IKIMBA	KATWE	MALIMBE	KUBIGENA	KIRUMI	MARA	KYARANO
CYANOPHYTA								
Anabaena sp.	x		x			x		
A. flos-aquae Breb.ex Born.& Fl. var.*flos-aquae*	x	x	x	+x		+	+x	+
Anabaena spiroides Klebahn	x	x	x	x			x	
Anabaenopsis sp.	x	x	x			x	x	
Aphanizomenon flos aquae (Linnaeus) Ralfs	+	+		+	+	+		
Aphanocapsa sp.	x	x	x					
A. delicatissima West & West		x				x		x
A. elachista West & West		x						x
Aphanothece sp.	x		x	x			x	
Chroococcus sp.	x		x					
C. disperus (Keissler) Lemm.	x	x	x	x		x	x	
Cylindospermum sp.						x		
Cylindrospermopsis sp.	x		x			x		
Dactylococcopsis sp.	x		x			x	x	x
Lyngbya sp.	+x	x	x	+x				
L. circumcreta (G.S West) Anagn & Komarek	x		x				x	
L. contorta Lemm	x	x	x	x	+	x	x	x
Merismopedia sp.	x		x				x	
M. punctata Meyen	x		x			x		
M. tenuissima Lemn	x		x	x		x		
Microcystis sp.	x	x	x	x		x	x	
M. aeruginosa Kutz		+	+		+		+	
M. flos-aquae (Wittr.) Kirchin	+x	+x	x	+ x	+	+x	+x	x
M. pulverea Wood ex Honsg			+					

Table 1: (Continued)

SPECIES/TAXA	BURIGI	IKIMBA	KATWE	MALIMBE	KUBIGENA	KIRUMI	MARA	KYARANO
CYANOPHYTA								
M. viridiris (A.Br) Lemn	x	x	x				x	x
Nodularia sp.	x	x	x	x			x	
Nostoc sp.	x	x				x		x
N. linkia (Roth) Bornet		x						
Oscillatoria sp.	x	x	+x	+		x		x
O. Agardhii Gomont					+			
O. splendida Greville			x					x
O. tenuis (C. Agardh), Gomont	+	+			+			
Planktolyngbya undulata Kom. & Kling	x	x	x			x		x
P. tallingii Kom. & Kling		x	x			x		
**P. circumcreta* Kom & Kling	x	x				x		
Schizothrix sp.	x	x	x	x		x	x	
Spirullina sp.	x		x					
Spirullina platensis		x				x		x
Tolypothrix sp.								x
BACILLARIOPHYTA								
Asterionella sp.								
Aulacoseira sp.			x	x		x		
A. nyassensis var. *victoriae* O. Mull			+					
Cyclotella sp.	x	x	x+			x		
Eunotia lunaris	+		+		+			+
Flagillaria sp.			x			x		
Frustrulia sp.				x				
Navicula sp.	+x	x+	+	x		x	x	
Navicula gastrum	+	+	+	+		+	+	+
Navicula radiosa					+			
Nitzschia sp.	+x		x	x			x	x
N. acicularis (Kurz.) W. Smith Var. acicularis			x				x	
Pinnularia sp.					+			+
Rhizosolenia sp.								
Rhizosolenia victoriae schroder					+			
Rhopalodia sp.			+					
Surirella sp.			x		+	x	x	
Synedra sp.		x				x		x
S. acus Kutz							x	
S. cunningtonii G.S West					+			
S. ulna (Nitz.) Ehr.var.ulna	+				+		+	+
CHLOROPHYTA								
Ankistrodesmus sp.			x	x				x
A. falcatus var. *Spirulis*		x	x	+x		+	x	x
A. setigera								
Botrococcus sp.	+	+		+				+
B. braunii Kutz		+						
Closterium sp.	x	x	x+				x	
C. aciculare T. West			+					
C. leibleinii Kutz ex Ralfs					+		+	
C. ralfsii breb.Ex. Ralfs					+			
Closteridium sp.		x					x	
Closteriopsis sp.			x					

Table 1: (Continued)

SPECIES/TAXA	BURIGI	IKIMBA	KATWE	MALIMBE	KUBIGENA	KIRUMI	MARA	KYARANO
CHLOROPHYTA								
Coelastrum microporum Nag.	+		+					
Coelastrum sp.			+					+
Cosmarium sp.		x	x				x	x
Crucigenia sp.						x		
Gonatozygon monotaenium de Bary			+					
Hormidium sp.		x						
Kirchneriella sp.			x				x	
Monorophidium sp.			x					
Neritium sp.				x				
Netrium digitus (Ehr. Ex.Ralfs)Itzgsohn et Rhothe					+			
Nephrocytium sp.	x							
Pediastrum sp.			x	x		x		x
P. duplex Meyen						+x		
P. simplex Meyen	+		x					
P. tetras Ehr (Ralfs)	x		x			x		
Scenedesmus sp.			x	x			x	
S. acuminatus (Lagerheim) chodat		x	x	x		x	x	
S. armatus (Chodat) Chodat		+				+		
S. dimorphus (Turpin) Kutz			x	x				
S. quadricauda Chod	x	x+	x	x		x		
Selenastrum sp.	x					x		
Selenastrum gracile Reinsch	+							
Sphaerocystis sp.	x	x	x	x			x	
Sphinctosiphon polymorphus		+						
Staurastrum sp.		+	x			x		
S. brevispinum breb			x					
S. cuspidatum Breb ex Ralfs	+	+	+					
Stauroneis anceps Krammer &Lange-Berlot					+			
Staurodesmus sp.		x						
Tetraedron sp. Kutz	x		x	x		x	x	x
T. limneticum Borge			+					
T. planctonicum		+						
Tetraedron trigonum Nagel	x+	x		x		x		x
Ulothrix sp. Kutz 1833		x	x					
U. variabilis	x							x
Volvox aureus Ehr	+	+						+
CRYTOPHYTA								
Cryptomonas sp.			x			x		x
DINOPHYTA								
Gymnodinium sp.						x		x
CHRYSOPHYTA								
Tribonema sp.								x
Dinobryon sp.			x					
EUGLENOPHYTA								
Euglena sp.						x	x	x
Trachelomonas sp.						x		x
Total Number of species = 112	**49**	**47**	**66**	**30**	**17**	**44**	**33**	**34**

However, species diversity was generally low for both seasons, as the Shannon Wienner diversity index (Zar 1999) showed very low values. According to this test, Lake Kyarano showed the highest diversity (H'=0.21) followed by Lake Kirumi and Malimbe (H'=0.20). The rest of the H' values for other lakes were below 0.2. Lake Ikimba showed the lowest species diversity (H'= 0.09). Despite their higher species richness, Lake Burigi and Katwe did not show high species diversity. Species that were common in all lakes and in both seasons were *Microcystis sp., Anabaena sp., Oscillatoria* spp. and *Planktolyngbya* spp. for Cyanophyta; *Scenedesmus* sp, *Ankistrodesmus* sp *and Tetraedon* sp for chlorophyta; and *Nitzschia sp, Aulacoseira* sp.*Navicula* sp and *Surirella* sp. represented the dominant diatoms.

Phytoplankton abundance

During the wet season, high numerical abundances were recorded at Lake Burigi (611624 cells /ml), followed by Lake Katwe (246034 cells/ml) and Kirumi (226946 cells /ml), (Table 2a) while Lake Ikimba had the lowest abundance (9208 cells /ml). Statistical test (One Way ANOVA) showed that variation among the lakes was not greater than expected by chance, (F = 0.86, P = 0.53). During the dry season, Lake Kirumi was the most abundant (28833 cells /ml), followed by Mara River (12489 cells/ml) Malimbe (11707 cells/ml). Kyarano was the least abundant (1336 cells/ml) (Table 2b). However, there was no statistical significance difference between different lakes (One Way ANOVA, F = 0.922, P = 0.52).

Table 2a: Phytoplankton abundance (individuals/ml) in the surveyed Satellite lakes during wet season

Taxa	Kirumi	Katwe	Kyarano	Burigi	Ikimba	R.Mara	Malimbe
Cyanophytes	179754	233757	239	581102	8249	9496	38368
Chlorophytes	12661	3645	0	9061	863	96	9112
Cryptophytes	384	192	2638	477	0	0	0
Bacillariophytes	31654	8345	240	20745	96	1343	3837
Euglenophytes	959	0	2638	0	0	96	0
Dinophytes	1535	96	13908	238	0	0	0
Total	**226946**	**246034**	**19663**	**611624**	**9208**	**11030**	**51317**

Table 2b: Phytoplankton species abundance (individuals/ml) in the surveyed Satellite lakes during dry season

Taxa	Kirumi	Katwe	Kyarano	Burigi	Ikimba	R.Mara	Malimbe	Kubigena
Cyanophytes	26247	1670	0	334	1336	4708	11354	2337
Chlorophytes	916	1670	668	1837	204	6244	354	341
Cryptophytes								
Bacillariophytes	1670	0	668	0	334	1536	0	1670
Euglenophytes								
Dinophytes	0	0	0	334	334	0	0	334
Total	**28833**	**3339**	**1336**	**2504**	**2207**	**12489**	**11707**	**4682**

Cyanophytes dominated (in terms of numerical abundance and species number) all studied satellite lakes except for Lake Kyarano. For example this group contributed up to 98%, 95%, 95%, 86%, to the phytoplankton abundance in Lake Ikimba, Burigi, Katwe and Mara River respectively (Table 3). Kyarano dam was dominated by Dinophytes (71% of counted cells).

Table 3: The relative abundance of algal classes expressed as overall mean percentages of total number counted from the satellite lakes in both seasons

Taxa	Kirumi	Katwe	Kyarano	Burigi	Ikimba	R.Mara	Malimbe
Cyanophytes	79.21	95.01	1.22	95.01	98.73	86.09	74.77
Chlorophytes	5.58	1.48	0.00	1.48	1.14	0.87	17.76
Cryptophytes	0.17	0.08	13.41	0.08	0.00	0.00	0.00
Bacillariophytes	13.95	3.39	1.22	3.39	0.13	12.17	7.48
Euglenophytes	0.42	0.00	13.41	0.00	0.00	0.87	0.00
Dinophytes	0.68	0.04	70.73	0.04	0.00	0.00	0.00
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

DISCUSSION

Our results clearly indicated that species diversity varied with seasons and stations (sampled satellite lakes). In contrary to many findings in the main Lake Victoria, which indicates lower species diversity during rain season, this survey shows that high diversity in satellite lakes occurred during rain season. This may be explained by the fact that these lakes are shallow and are always thoroughly mixed to the bottom and therefore occurrence of various species are not limited by mixing rather may be limited by other environmental factors such as nutrients. It is clear that during rain season the satellite lakes receive drainage water from terrestrial environment that will add nutrients and in turn enable growth of many phytoplankter. During dry season, limiting nutrients such as nitrates and ammonia may reduce growth of many phytoplanktons. However, cyanobacteria has capacity to grow in lower nitrogenous nutrients by fixing atmospheric nitrogen. This give them advantage over others and therefore domination. Phytoplankton abundance increased slightly from wet to dry seasons. Theoretically, algal species composition and diversity is known to change seasonally in response to changes in physical, chemical and biological conditions of the lake (Reynolds, 1984), the most important parameters being light and nutrients. Increase in nutrients especially nitrate concentration is largely linked to terrestrial run-off (also see Talling & Talling (1965). Rainfall may be one of the reasons that caused the increase of nutrients, leading to increase in the numerical abundance of phytoplankton.

Likewise, cyanophytes were abundant in all the sampled lakes except Lake Kyarano, during both wet and dry seasons. Lake Ikimba showed the highest percentage of cyanophytes. This could have been attributed to the high concentration of nutrients (nitrate and phosphorous) that were recorded by Kulekana (pers comm) during the same period of time. Besides these reasons, a number of other factors accounts for the dominance of cyanobacteria in any water body. These include minimization of mortality through immunity to grazing by zooplankton. It is believed that cyanobacteria are not grazed to the same extent as other phytoplankton probably due to the large size of their colonies, or due to production of toxins of some cyanobacteria strains. Cyanobacteria has also the tendency of suppressing other algae through excretion of organic compounds that hinder the growth of other algae, (Dokulil and Teubner 2000). Lake Kubigena, which showed the lowest number of species diversity and abundance, the entire water surface was covered by floating macrophytes resulting into about 0 m transparency readings. Studies by Kulekana (pers comm) showed very low levels of dissolved oxygen (1.2 mg/l) and low nutrient concentrations in this lake as compared to other lakes. So light and nutrients could probably explain this phenomena, since they are the main factors that influence the phytoplankton growth.

This study has shown that phytoplankton community of satellite lakes largely consists of Cyanophytes mostly *Microcystis* sp., *Anabaena* sp. and *Planktolyngbya* spp. This should be given a special attention in relation to their cyanotoxin pollution (Sekadende 2002). More studies especially on the status and potential of cyanotoxin pollution, and other that can lead to proper management and conservation of these lakes are recommended.

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