PHYTOPLANKTON SPECIES DIVERSITY AND ABUNDANCE IN THE NEAR SHORE WATERS OF TANZANIAN SIDE OF LAKE VICTORIA

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ABSTRACT

The survey was carried out in January/February and July/August 2002 to investigate phytoplankton species diversity, spatial distribution, numerical abundance and total biomass (chlorophyll a concentration) in 10 selected stations on the Tanzanian side of Lake Victoria. At each station, samples for diversity data were collected by plankton net, which was towed at the surface water, while those for spatial distribution and abundance were collected using a 1 l Van Dorn water sampler. A total of 113 species belonging to 52 different genera were identified. Cyanobacteria were the most diverse group in both seasons. The concentration of chlorophyll a ranged from below 0.1 µg/l recorded at Mwanza Gulf to 14.52 µg/l at Bulamba station. The phytoplankton abundance ranged from 245 cells/ml recorded at Baumann's Gulf to 77 cells/ml at Lamadi during January/February sampling; and from 1519 to 276 cells/ml at Bulamba and Mwanza Gulf respectively, during the July/August sampling. Highest numerical abundance was recorded in Mara zone in both samplings. Cyanobacteria species had higher percentage composition, constituting up to 35% and 41% of all identified individuals during January/February and July/August, respectively.

INTRODUCTION

Phytoplanktons are primary producers in aquatic environments and form the base of the energy flow through the various trophic levels. Their physiological studies provide information on photosynthesis, nutritional requirements, roles of vitamins etc. Phytoplanktons also act as the lungs of the aquatic systems by oxygenating the waters in their microenvironments, and are biotic indicators of environmental changes.

The structure of phytoplankton in aquatic ecosystems is dynamic and constantly changes in species composition and biomass distribution. Such changes may indicate environmental changes in an aquatic ecosystem such as Lake Victoria. Witte *et al.* (1992) documented that the lake is facing a problem of environmental siege and that some of the world's great endemic faunas are facing extinction. Some of the reasons for this extinction include the introduction of the piscivore, Nile perch to the lake in the 1950s, over fishing, unregulated gill net-mesh size and explosive fishing techniques. Agricultural activities, deforestation, and devegetation of the catchments areas have increased siltation, and led to loss of suitable habitats and biodiversity. There are increased nutrients from agriculture, sewage, and industrial discharges and combustion process which can cause eutrophication. There are also threats of toxic pollution from industrial waste discharge, mining, pesticides and oil residues and spills. Climate changes may also affect thermal stability of the lakes. These factors may have contributed to the 1980s collapse of

indigenous fish stocks by elimination suitable habitats for certain deep water cichlids and decline of some phytophagous fish species such as Haplochromines and native Tilapines (Goldschmidt and Witte 1992). This in turn reduced the grazing pressure to the phytoplankton while leaving an excess of phytobiomass in the lake. These eventually cause oxygen depletion when they die and decompose in the lake.

Earlier studies in Lake Victoria indicated that there was a flora rich in large diatoms, particularly *Aulacoseira spp.* and *Stephanodiscus* spp. in 1960 and 1961 (Talling 1966). But by the late 1960s, *Aulacoseira* spp. have nearly disappeared and replaced by *Nitzchia* spp. (Hecky 1993). In the recent years however, the lake has been reported to undergo again some ecological changes especially on its chemical characteristics and phytoplankton community (Lung'ayia et al. 2000, Kling et al. 2001). Diatoms have been replaced by cyanobacteria (blue green algae) (Kling et al. 2001). Hecky (1993) has mentioned that this replacement is due to decline in surface silicon (SRSi) (Verschuren et al. 1998), which is required by diatoms for the formation of their cell wall with a typical external Si-skeleton. Among other factors, increase in nutrients input and reduced light penetration due to increased water turbidity may have resulted into the observed changes in phytoplankton community.

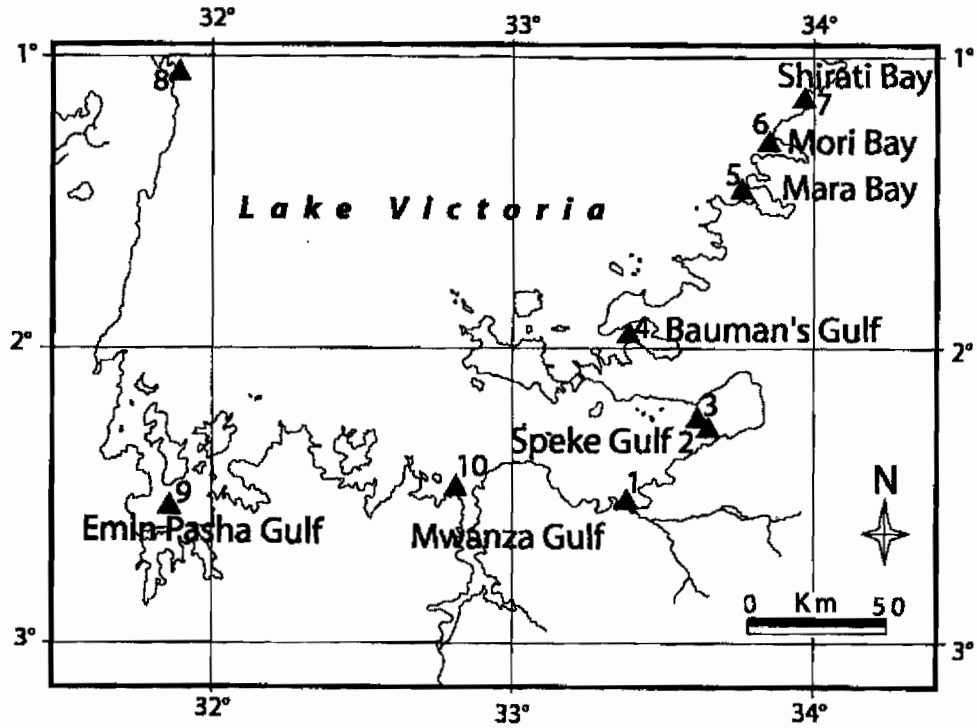

Figure 1: A map of the southern part of Lake Victoria showing the study sites: 1. Magu Bay; 2. Lamadi; 3. Bulamba in Speke Gulf; 4. Baumann's Gulf; 5. Mara bay; 6. Mori Bay; 7. Shirati bay; 8. Rubafu Bay 9. Chato bay and 10 Mawnza Gulf (D = sampling stations

The present study deals with phytoplankton species diversity, abundance and spatial distribution in the near shore waters of Lake Victoria. The occurrences of various species in July/August (dry season) and January/February (end of short rain season) are compared.

MATERIALS AND METHODS

Ten sampling stations were selected in the nearshore waters of the Tanzania side of lake Victoria (Fig.1). These stations were; 1, Magu Bay, 2, Lamadi, and 3, Bulamba in Speke Gulf; 4, Baumann's Gulf, 5, Mara Bay, 6, Mori Bay, and 7, Shirati bay in Mara region; 8, Rubafu Bay in Kagera region; 9, Chato Bay in Emin Pasha Gulf and 10, Mwanza Gulf in Mwanza region.

Samplings were done in rain (January/February 2002) and dry (July/August 2002) seasons. The rains started in December 2001 up to end of Febrary 2002 and therefore January/February 2002 sampling was considered rain season while July/August 2002 was a dry season. At each station, samples for species diversity, spatial distribution and phytoplankton abundance were collected at the surface. However, sampling at different depths (i.e. 0, 5, 10, 15 and 20 m deep) was done in deep stations during January/Febrary samplings. Phytoplankton diversity was analyzed from 100 ml samples collected by towing plankton net (10 µm mesh size) at low boat speed (1.5 knots) for about 5 minutes. Samples for abundance determination were collected at various depths using 1 l Van Dorn water sampler. The samples (100 ml) were preserved using 0.7% Lugol's solution and 2.5% formalin.

In the laboratory, samples for diversity were examined using a light microscope. Identifications were done using various freshwater phytoplankton keys (e.g. Van Meel 1954, Mossile 1984, John et al. 2002). The samples for abundance were homogenized and 10 ml sub–samples were poured into a 10 ml sedimentation chamber for at least 24 h. The phytoplanktons were counted under an inverted microscope at 400x magnification. Different species were counted as numbers of filaments, colonies and cells depending on the nature of the species.

Phytoplankton biomass, measured as chlorophyll *a* concentration, was determined according to ISO (1992). The determination was done only for the samples collected during July/August period. The amount of chlorophyll *a* (µg/l) was calculated according to Seely and Jensen (1965), as follows:

Chl. *a* (µg/l) = $(E_{665}-E_{750})$ x 12.9 x v / VxL;

Where,

E_{665} = Absorbance at 665 nm wavelength;

E_{750} = Absorbance at 750 nm wavelength;

v = Volume of the extract;

V = Volume of the sample filtered (l);

L = Length of the cuvette

Shannon diversity index (H') (Shannon and Weaver 1949) was used to estimate phytoplankton species diversity as follows:

$H' = -\sum^{S} PiLogPi$; Where,

Pi = ni/N = the proportion of the total population of individuals (N) belonging to the *i*th species (ni);

^{S} = number of species in the sample and Log 10 was used in calculating LogPi.

The obtained diversity indices for the two seasons were compared by Mann-Whitney test (Zar 1999).

Phytoplankton numerical abundance was calculated using the following formula (Greenberg *et al.*, 1992): Individuals or cells/ml.) = C*At /Af *F/V; where, C = number of organisms counted; At = total area of bottom of settling chamber (mm^2); Af = area of field (mm^2); F = number of field counted; V = volume of sample settled (ml). Kruskal-Wallis Nonparametric Analysis of Variance and Mann-Whitney

tests were used to compare phytoplankton numerical abundance in the different stations and between the two sampling periods, respectively.

Table 1: List of phytoplankton species recorded in January/February (rainy season) and July/August (dry season) 2002;

Species	Season		Species	Season	
	Jan/Feb	Jul/Aug		Jan/Feb	Jul/Aug
Cyanobacteria			**Cyanobacteria cont...**		
Anabaena circinalis Rabh. ex Born. & Fl	+	+	*Schizothrix* sp.	+	-
Anabaena flos - aquae Bréb	+	+	*Spirulina* sp.	+	-
Anabaena sp.	+	-	*Spirulina laxissima* G.S. West	+	-
Anabaena spiroides Klebahn	+	-	*Spirulina platensis* Turp. ex Gom.*	+	-
Anabaenopsis tanganikae (G.S.West) Mill	+	-	*Spirulina splendid* Turp. ex Gom.*	+	-
Anacystis sp.*	+	-	*Tolypothrix distorta* Kütz*	+	-
Aphanizomenon flos aquae (L.) Ralfs*	-	+	*Tolypothrix* sp.	+	-
Aphanocapsa delicatissima West & West	+	-			
Aphanocapsa elachista West & West	+	-	**Bacillariophyta**		
Aphanocapsa sp.	+	-	*Amphora* sp.	+	-
Chroococcus minor (Kütz.) Näg. f. dispersus Keissl.	+	+	*Asterionella formosa* Hassall	-	+
Chroococcus minutus (Kütz.) Näg.	+	-	*Asterionella* sp.	-	+
Chroococcus sp.	+	-	*Cyclotella kuetzingiana* Thwaites	+	-
Coelosphaerium kuetzingianum Näg.	-	+	*C. Kuetzingiana* var. *planetophora* Fricke*	-	+
Gomphosphaeria sp.	+	-	*Cyclotella* sp.	+	-
Lyngbya circumcreta G.S. West	+	+	*Epithermia* sp.	+	-
Lyngbya contorta Lemm.*	+	+	*Flagillaria aethiopica* G.S. West	+	-
Lyngbya limnetica Lemm.	+	+	*Flagilaria* sp.	+	-
Lyngbya nyassae Schmidle	-	+	*Frustrulia rhomboides* (Her.) De Toni	+	-
Lyngbya sp.	+	-	*Frustrulia* sp.	+	-
Merismopedia punctata Meyen	+	-	*Gomphonema parvulum* (Kütz) Kütz	+	-
Merismopedia sp.	+	-	*Aulacoseira nyassensis (*var. *victoriae)* O. Müll.	+	+
Merismopedia tenuisima Lemm.	+	+	*Navicula cuspidata (*Kütz.) Kütz.	+	-
Microcoleus vaginatus (Vauch) Gom.	+	-	*Navicula* sp.	+	-
Microcystis aeruginosa (Kütz.) Kütz.	+	+	*Nitzchia acicularis* (Kütz.) W. Smith	+	+
Microcystis flos aquae (Wittr.) Kirchn.	+	+	*Nitzchia lacustris* Hust.	+	+
Microcystis minutus Kütz*	+	-	*Nitzchia palea* (Kütz.) W. Smith	-	+
Microcystis robusta (Clark) Nyg.	+	-	*Nitzschia* sp.	+	-
Microcystis sp.	+	-	*Urosolenia* sp.	+	-
Microcystis viridis (A. Br.) Lemm.	+	-	*U. eriensis (*H.L. Smith) F.E. Round & RM Crawford	+	-
Nodularia sp.	+	-	*Stephanodiscus* sp.	+	-
Nostoc linckia (Roth) Born. *et* Flah.*	+	-	*S. astraea* (Ehr.) Grunow	+	-
Nostoc sp.	+	-	*Surirella linearis* W. Smith	-	+
Oscillatoria limnetica Lemm.	+	-	*Surirella* sp.	+	+
Oscillatoria sp.	+	+	*Synedra cuningtonii* G.S. West	+	+
Oscillatoria splendida Grev. ex Gom.	+	-	*Synedra* sp.	+	-
Oscillatoria tenuis C. Ag. Gom.	-	+	*Synedra ulna* (Nitz.) Ehr.	+	+
Chlorophyta			**Chlorophyta cont...**		
Ankistrodesmus falcatus (Corda) Ralfs	+	+	*Scenedesmus* sp.	+	-
Ankistrodesmus longissimus (Lemm.) Lemm.	+	-	*Scenedesmus acuminatus* (Lagerh.) Chod.	+	-
Ankistrodesmus gracille (Reinsch) Kors.	+	-	*Scenedesmus dimorphus* (Turp) Kütz.	+	-

Table 1 (continued)

Species	Season		Species	Season	
	Jan/Feb	Jul/Aug		Jan/Feb	Jul/Aug
Ankistrodesmus sp.	+	-	*Scenedesmus opoliensis* Richt.	+	-
Botryococcus sp.	-	+	*Schroederia setigera* (Schröd.) Lemm.	+	-
Closterium acutum (Lyngb.) Bréb. ex Ralfs	+	-	*Sphinctosiphon polymorphus* G.S. West	-	+
Closterium cynthia De Not.*	+	-	*Staurastrum rotula* Norst.*	+	-
Closterium gracile Bréb.	+	-	*S. cuspidatus* (Bréb. ex Ralfs) Teil	-	+
Closterium kuetzingii Bréb.	+	+	*S. paradoxum* Meyen ex Ralfs	-	+
Closterium navicula (Bréb.) Lütkem.	+	-	*Ulothrix zonata* Kütz.*	+	-
Closterium ralfsii Bréb. ex Ralfs	+	-	*Volvox aureus* Ehrenberg	-	+
Closterium setaccum Ehr.*	+	-			
Closterium sp.	+	-			
Closterium strigosum Bréb	+	-	**Xanthophyta**		
Coelastrum microporum Näg	+	-	*Pseudostaurastrum limneticum* (Borge) Chod.	+	-
Cosmarium sp.	+	-			
C. depressum (Näg) Lund.l	+	-	**Euglenophyta**		
C. obsoletum (Hantzsch) Reinsch	+	-	*Euglenoid* sp.	+	-
C. ralfsii Bréb.*	+	-	*Trachelomonas* sp.	-	+
Gonyostomum semen (Ehr.) Dies*	-	+	*Trachelomonas armata* (Ehr.) Stein	-	+
Kirchneriella sp.	+	-			
Nephorocytium lunatum W. West	+	-	**Dinophyta**		
Pediastrum duplex Meyen	+	+	*Exuviella* sp.	+	-
Pediastrum simplex Meyen	-	+			
Rayssiella curvata (Bohl.) Kom.	+	-			
	Total number of species			**113**	

(+) present;
(-) absent
* These taxa were not reported in the past from Lake Victoria (Cocquyt et al 1993).

RESULTS

A total of 113 phytoplankton species belonging to 52 different genera were identified. 96 and 37 species were recorded in the January/February and the July/August 2002 samplings respectively (Table 1). Most of the identified species were already reported from Lake Victoria in the past (Cocquyt et al. 1993) but others were not. The "new" reported species (highlighted by star [*] in Table 1) need to be confirmed using more advance techniques and have remained as a subject of future studies. The Cyanobacteria were most diverse in both seasons. Shannon Weaver Diversity Index (H') showed higher values in January/February than in July/August season but the difference was not significant (U'=21.0; P=0.095). The diversity indexes (H') during January/February were 0.123, 0.694, 0.963, 0.738 and 0.476 for Mwanza Gulf, Speke Gulf, Mara zone, Kagera zone and Eminpasha Gulf, respectively; while those for July/August were 0.755, 0.482, 0.700 and 0.559 for Mwanza Gulf, Speke Gulf, Mara zone and Kagera zone respectively. Cyanobacteria were represented by a greater number of species than other groups in all stations. Dinophytes, Xanthophytes and Euglenophytes were rarely observed.

During the January/February sampling, the abundance of phytoplankton varied from a

minimum of 77 to a maximum of 2450 individuals/ml at Lamadi and Baumann's Gulf respectively. In July/August sampling, higher numbers were recorded, ranging from 276 to 5190 individuals/ml at Mwanza Gulf and Bulamba respectively. In general, Mara region showed a significant (P = 0.001) higher phytoplankton numerical abundance than Mwanza and Kagera.

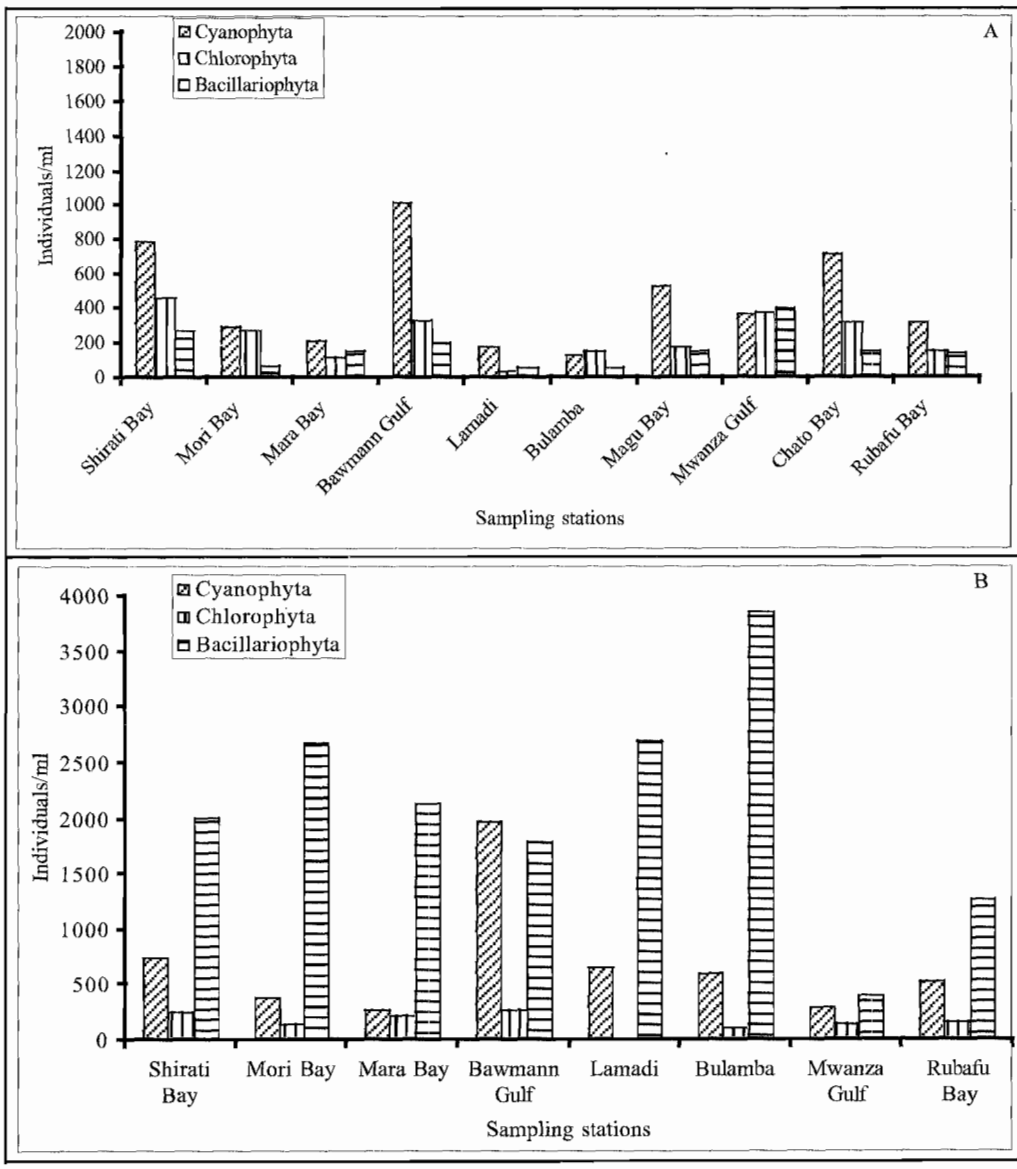

Figure 2: Abundance of major taxa of phytoplankton at various stations during January/February (A) and July/August (B), samlings

When comparing the three dominant phyla (Cyanobacteria, Chlorophyta and Bacillariophyta) it became clear that during January/February cyanobacteria dominated in almost all stations while Bacillariophyta dominate during July/August period (Fig.2). However, the numbers of cyanobacteria were not significantly different during January/February and July/August samplings. The numbers of Bacillariophyta in July/August were on average of 20 times higher than in January/February. The total abundance of phytoplankton species was significantly (U'=315; P=0.009, Mann-Whitney *U*-test) higher during July/August than those of January/February samples. Cyanobacteria *Microcystis* spp., *Lyngbya* spp. and *Anabaena* spp. were the most dominant cyanophytes species throughout the lake. The diatoms were dominated by *Nitzschia acicularis*.

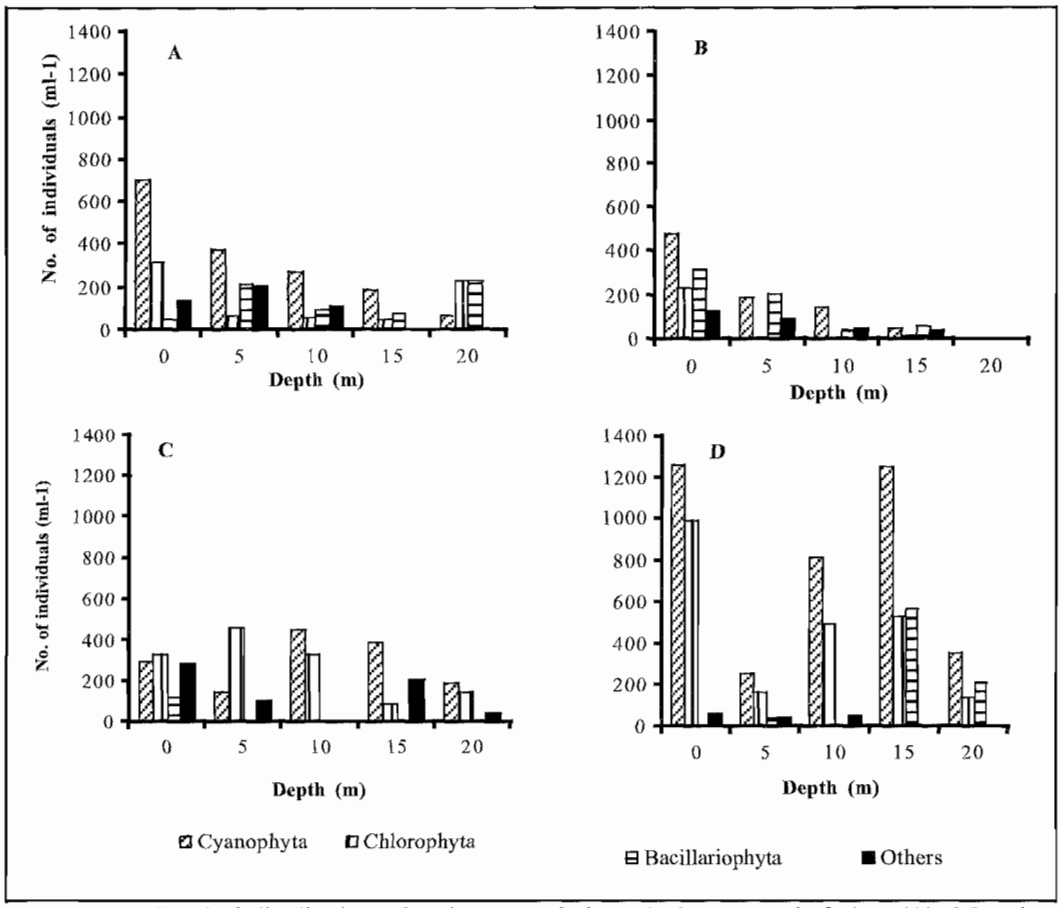

Figure 3: Vertical distribution of major taxa of phytoplankton at Rubafu bay (A), Mara bay (B), Mori bay (C) and Shirati bay (D) during January/February sampling

The vertical distribution (to 20 m depth) of phytoplankton was assessed at deep stations (Rubafu, Mara, Mori and Shirati Bays) during January/February sampling only

(Fig. 3). In general, there were no significant differences of phytoplankton abundance at different depths. However, in Rubafu and Mara Bays, there was a clear decrease of phytoplankton abundance with depth.

The phytoplankton biomass at the surface, measured as chlorophyll *a* concentration during July/August period ranged from very low (< 0.1 µg/l) at Mwanza Gulf to highest value of 14.5 µg/l in Bulamba (Fig. 4). The values were in correspondence with the numerical abundance during this period.

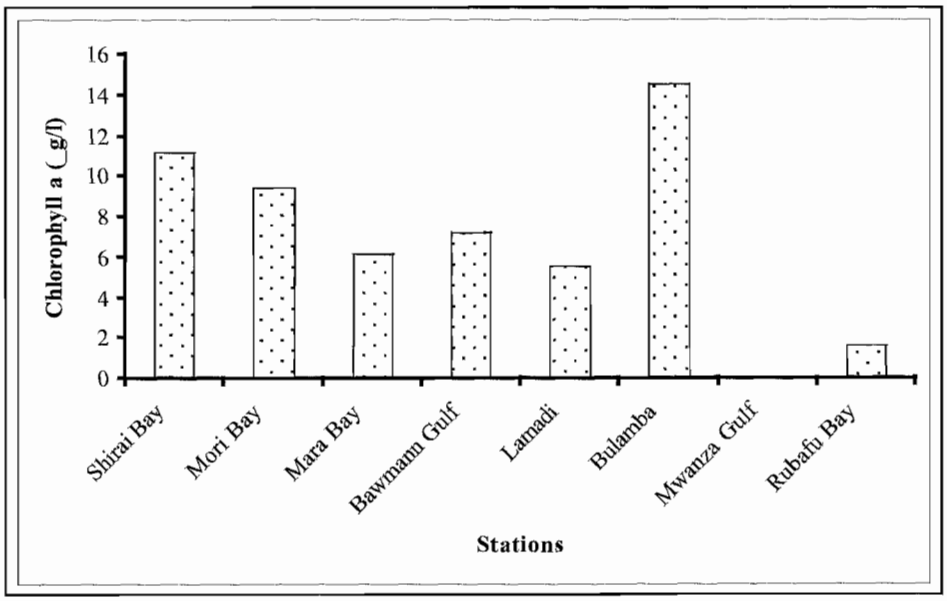

Figure 4: Chlorophyl *a* concentrations measured at surface water in July/August 2002.

DISCUSSION

General observations of the results reveal some similarities with other reports (e.g. Ochumba and Kibaara 1989, Lowe-McConnel 1992, Hecky 1993, Lung'ayia et al. 2000, Kling et al. 2001, Lyimo and Sekadende 2003). The major similarity is the predominance of Cyanobacteria during thermal stratification of the lake, and predominance of diatoms during isothermal mixing of the whole water column. Lake Victoria undergoes thermal stratification during October- March and isothermal mixing in June – August (Lung'ayia et al. 2000 and Kling et al. 2001). During thermal stratification, phytoplankton distribution pattern is a function of the excess density of the organisms. Cyanobacteria have buoyancy vesicles that enable them to remain in the surface waters during thermal stratification conditions. This in turn assists the Cyanobacteria to trap more sunlight for photosynthesis than other phytoplankton groups; and in addition to that they are more efficient light harvesters than eukaryotic algae (Reynolds 1984), hence a reason for their predominance.

Predominance of Cyanobacteria in lake Victoria especially *Microcystis* and *Anabaena* species may also be linked to the high fertility (eutrophication) of the lake as stated by Hecky (1993). *Microcystis* spp. and *Anabaena* spp. are known to prevail in nutrient enriched lakes (Wetzel 1983, Moss 1998). Some species of *Microcystis* and *Anabaena* are able to tolerate turbid water with low light intensity due to presence of

different light harvesting pigments. Most of the surveyed stations were bays and gulfs, with low depth (<5 m) and are close to river mouth or land inflows that bring terrestrial particles including nutrients during the rain season, which reduce light intensity greatly. The utilization of artificial fertilizer in agriculture and lack of sewages treatment plants in the urban areas of Lake Victoria results into high input of nutrients. On the other hand, the cyanobacteria *Microcystis aeruginosa* and *Anabaena flos-aquae* possess large amounts of carotenoids, which serve as accessory pigments in photosynthesis and provide protection to chlorophyll from photoxidation (Paerl et al. 1983). Due to this, these species can survive in areas with high light intensity and can attain high photosynthetic efficiencies. It is therefore likely that such species have a competitive advantage over the others. In addition, Hutchinson (1967) mentioned that, dense populations of cyanobacteria are often associated with fairly high water temperatures, which ranged from 22.3 to 25.1°C during our survey, a typical tropical regions temperature. These altogether are some of the main reasons that can explain for the predominance of cyanobacteria in Lake Victoria during a period of the year.

A problem associated with cyanobacteria prevalence in a lake is their mass occurrences (water blooms), a condition that may kill other organisms especially during the night, when oxygen is depleted by the excessive growth. Moreover, mass occurrences of cyanobacteria are frequently (between 25 –75 % of the blooms) toxic in fresh, brackish and marine waters throughout the world (Sivonen 1996). Such blooms have constituted a health hazard to humans and animals. After ingestion (by drinking water or consuming affected fish) of toxins from cyanobacteria, acute poisoning leading to death has been reported from animals and humans. Chronic ingestion of sublethal doses (of e.g. microcystins) has been further epidemiologically linked to primary liver cancer and colorectal cancer in humans. Some strains of cyanobacteria such as *Microcystis aeruginosa, Anabaena* species and *Lyngbya* species are known to produce toxins. The presence of these species calls for further studies in order to evaluate whether they are toxic producing strains or not.

The results showed significant higher phytoplankton abundance in July/August; this was certainly contributed by high influx of nutrients into the Lake, which is expected to occur due to mixing from the sediments. During the July/August it is expected that the Lake Victoria experienced isothermal mixing of its whole water column (Kling et al. 2001). Vertical distribution of phytoplankton becomes then a function of turbulence. During our sampling there was an increase in diatom abundance, which agrees with the fact that diatoms prefer the mixing condition of the whole water column in a lake (Moss 1998). During this mixing, silicon (SRSi) in the sediments is likely to be re-suspended in the water column and become available for diatoms for the formation of their cell walls. The prevalence of the diatom *Nitzschia acicularis* in this period was probably favored by the presence of SRSi in the water column. Other phytoplankton groups (green algae and dinophytes) were of less important, because they were found in lower abundances and diversity.

CONCLUSION

This study reports predominance of cyanobacteria during January/February and July/August 2002 in the near shore waters of Tanzanian side of Lake Victoria. Despite their significant role of increasing nutrients in the lake through nitrogen fixation, cyanobacteria can kill fish (due to oxygen depletion in the night and/or by producing toxins) and decrease water transparency. Although not well documented, there are many stories on fish kills from villages surrounding Lake Victoria. In the early 1990's, massive fish kills were observed in the Nyanza Gulf of Lake Victoria, Kenya.

Ochumba (1990), working on the possible causes, attributed the massive fish-kills to general blooming of cyanobacteria. However, no attempts were made to identify and isolate the toxin producing cyanobacteria. Because of such harmful effects and their widespread, cyanobacteria threat the survival and life of different flora and fauna in the lake. It is therefore important to conduct more studies about the status and potential of cyanotoxin pollution in the lake and the risk associated with the consumption of aquatic resources of the Lake Victoria.

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