academicJournals

Vol. 7(9), pp. 862-873, September 2013
DOI: 10.5897/AJEST2013.1552
ISSN 1996-0786 © 2013 Academic Journals
http://www.academicjournals.org/AJEST

African Journal of Environmental Science and Technology

Full Length Research Paper

Spatio-temporal variations in phytoplankton community structure in small water bodies within Lake Victoria basin, Kenya

Steve O. Ngodhe*, Phillip O. Raburu, Boaz K. Arara, Patrick O. Orwa and Alfred A. Otieno

Department of Fisheries and Aquatic Sciences, University of Eldoret, P.O. BOX 1125, Eldoret, Kenya.

Accepted 6 September, 2013

Spatio-temporal variations of phytoplankton, expressed in terms of species composition and diversity collected at various sampling sites in small water bodies (SWBs) within Lake Victoria basin, Kenya, were investigated monthly from November 2010 to June 2011, in relation to selected physical and chemical water quality parameters. Temperature, D.O, TN and TP revealed a significant difference between the dams ($p<0.005$) unlike pH and BOD_5. These SWBs were built during the pre-independence era and stocked with various species of fish. The dams provide water for both domestic and agricultural use. A total of 1392 phytoplankton species belonging to four families and 20 genera were identified in Kesses dam whereas in Kerita dam, a total of 376 phytoplankton species belonging to four families and 10 genera were identified. In Siaya dams, Yenga dam had three families of phytoplankton; Chlorophyceae, Euglenophyceae and Cyanophyceae with Mauna also recording four families: Chlorophyceae, Bacillariophyceae, Desmidiaceae and Cyanophyceae. All the SWBs generally registered low species diversity with majority of them recording a value of < 2. Seasonal variations in phytoplankton species composition and diversity were significant ($P < 0.05$) with low species composition and diversity occurring during the dry season, and being maximum following the end of the rainy season from November 2010 to March 2011, suggesting the possible influence of various environmental factors on the SWBs. Overall, water quality seemed to have had effect on the species diversity, dominance and richness of phytoplankton community structure.

Key words: Community structure, small water bodies (SWBs), phytoplankton, species composition and diversity.

INTRODUCTION

Phytoplankton is usually at the base of aquatic food web and is the most important factor for production of organic matter in aquatic ecosystem. Most reservoirs will require significant amount of phytoplankton to have productive and sustainable fisheries. The interplay of physical, chemical and biological properties of water most often lead to the production of phytoplankton, while their assemblage (composition and distribution) is also structured by these factors. The importance of phytoplankton in tropical reservoir ecosystems include its use in estimating potential fish yield (Descy et al., 2005), productivity (Likens, 1975), water quality (Walsh et al., 2001), energy flow (Simciv, 2005), trophic status (Reynolds, 1999) and management (Beyruth and Tanaka, 2000). These reservoirs are increasingly threatened by human activities (Cecchi, 2007; Descy and

*Corresponding author. E-mail: mcomaristeve26@yahoo.com. Tel: +254 723938423.

Sarmento, 2008). In Lake Victoria, phytoplankton species composition, numerical abundance, spatial distribution and total biomass are in a direct relation with the environmental factors (Lung'ayia et al*.,* 2000). Actually, environmental and temporal changes determine the community present in a lake (Levandowsky, 1972). Among the environmental factors are the nutrients availability and light, temperature, alkalinity and mixing depth. Talling (1966) states in the particular, the abundance of algal species changes occurs due to changes in turbulence, illumination per cell and more obviously distribution of nutrients in the water column. Phytoplankton can be divided into size classes that have different physical properties. Picoplankton have the greatest surface:volume ratio compared with nano- and microplankton (Lewis, 1976) and may, consequently, more efficiently assimilate nutrients than nano- and microplankton (Lafond et al., 1990). Smaller cells usually have greater growth potential (Bruno et al., 1983), greater biomass productivity and lower sinking rates (Stockner et al., 1987). Picoplankton is, however, the dominant size class in several environments all over the world, both in marine and oligotrophic freshwater environments (Adame et al., 2008).

Lung'ayia et al. (2001) stated that phytoplankton structure is determined by underwater light availability, wind mixing, precipitation and nutrient input. According to Wetzel (2001), algal community structure and growth rates among species are likely to be limited by different resources, including differing nutrients. Therefore different species can survive on varying nutrient concentrations and others compete for the same nutrients (Sitoki, 2010).

The changes in the nutrient availability can lead to variations in phytoplankton diversity and species composition in aquatic systems. Elevated pH, dissolved oxygen, NH_4-N, NO_2-N and silica favored the growth of Cyanophyceae and Chrysophyceae in the tropical ponds of Pindamonhangaba Brazil (Beyruth and Tanaka, 2000) and the most represented species were *Microcystis* spp*, Anabaena solitaries, Crucigeneilla crucifera* and *Oocystis lacustris*. Furthermore, nutrient concentration level changes due to manuring or fertilizing the aquatic systems, affects the community structure of phytoplankton in the system. The increase in nutrient concentrations leads to differences in phytoplankton community structure.

Competition, exclusion, disturbance and grazing (Lung'ayia et al., 2001) dominate the phytoplankton dynamics too. The phytoplankton community in the small water bodies is affected by the grazers and the physical chemical characteristics. The presence or the feeding behavior of the fish, result in size selection of the phytoplankton in ponds (Beyruth and Tanaka, 2000). For instance, usually *Oreochromis niloticus* ponds were dominated by chlorophyceae and cyanobacteria. In a situation of many fish, phytoplankton feeders will reduce and thus the phytoplankton will increase in case other essential requirements are present. In this way invertebrates and fish possessing size-selective feeding habits on zooplankton can influence zooplankton grazing effectiveness and in turn algal succession (Wetzel, 2001). During rainy season, the water surface temperature is reduced and the water becomes more turbid, this favours the development of volvocales, especially *Eudorina* spp*, Microcystis flos-aquae* and *Aulocaseira granulata* (Beyruth and Tanka, 2000).

Phytoplankton, as primary producers, forms the vital energy source at the first trophic tier. It is reported that over 90% of Kenya's total fish production comes from the Kenya waters of Lake Victoria and its basin (Maithya et al., 2002). The Basin is endowed with numerous perennial rivers that drain into the lake. Along the river drainage basins are important natural (small lakes and swamps) and man-made (reservoirs and dams) small water bodies (SWBs) built during the pre-independence era and stocked with various fish species. As they also serve as food to many aquatic animals, they also have an important role in the material circulation in aquatic ecosystems by controlling the growth, reproductive capacity and population characteristics of aquatic biota. Furthermore, their standing crops exhibit variations that depend on several factors. The supply of major nutrients (mainly phosphorus and nitrogen); light availability; grazing by zooplankton; water mixing regimes; and basin morphometry (Reynolds et al., 2001; Gurung et al., 2006).

Evaluation of phytoplankton community structure is essential and useful as an indicator of the water quality. To this end, recent studies in Kenya on phyto-plankton community structure, dynamics and productivity, have been conducted in a variety of freshwater lakes, enriching our knowledge and understanding of the phytoplankton ecology and community structures in such lakes. Similar studies in small water bodies of Kenya, however, are rare and sporadic. Several surveys of the phytoplankton populations have been conducted in open waters Lake Victoria (Okely et al., 2010; Krienitz et al*.,* 2001; Lung'ayia et al*.,* 2001, 2000), but no systematic attempt has been made to relate phytoplankton community composition and ambient water quality conditions to land use within the SWBs within the basin, despite the significant implications for integrated ecosystem management. Generalized ecoregion design-nations are assumed to reflect larger scale similarities and differences than individual watersheds in geology physiography, vegetation, climate, soils, and management goals for nonpoint-source pollution. The present study is an absolutely one of the pioneering work for Kenya, and it aims to evaluate both the spatial and temporal scales of the distribution of different phytoplankton community structure and to relate phytoplankton community composition and ambient water quality conditions to land use within the northern Lake Victoria

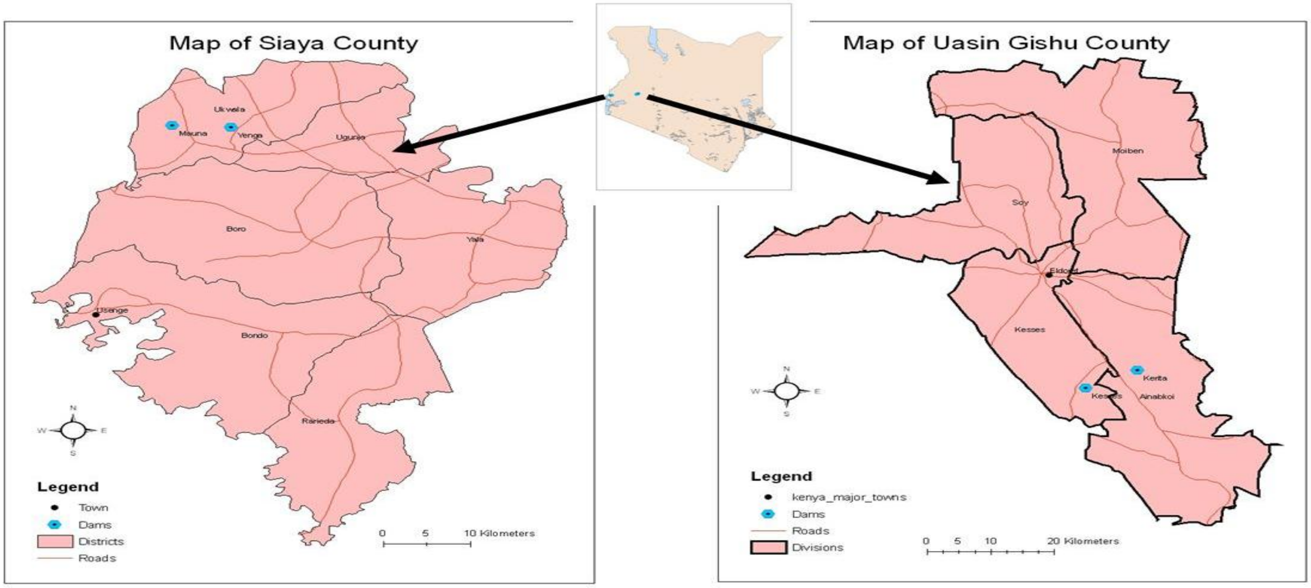

Figure 1. Map of Siaya and Uasin-Gishu counties showing the locations of small water bodies within the northern Lake Victoria basin, Kenya.

basin, Kenya.

MATERIALS AND METHODS

The study was carried out in SWBs within the northern Lake Victoria basin Kenya which was stratified in terms of altitude difference, their sizes and continuous availability of water. The low altitude sites were represented by Yenga and Mauna dams in Siaya county and high altitude by Kesses and Kerita Dams in Uasin-Gishu County (Figure 1).

Kesses dam is located at N00^0 17.263'and E035^0 19.852', at an altitude of about 2, 750 m above sea level (m.a.s.l). The littoral zone is dominated by *Typha latifolia* and *Cyperus papyrus* species. In the shallow littoral areas, water lilies, *Nyphae lotus*, water fern, *Azolla* spp., water cabbage, *Pistia stratoites*, *Salvinia*, *Lemna*, *Ceratophylum dermersum, Potamogeton, Ultricularia* and *Najas* species are found. The dam is drained by two rivers from the east including Endaragwa and Endaragweta. It has a surface area of approximately 2 km^2 and a maximum depth of 4.48 m while Kerita lies at N00^0 19.263'and E035^0 24.329', at an altitude of about 2, 800 m.a.s.l. The most noticeable emergent macrophytes community in the littoral zone is dominated by *Typhae latifolia* and *Cyperus papyrus.* It is also fed by two rivers that is, River Chebolol entering in the south-east direction and Kabiyemit which enters the dam in the south-west direction. It has a surface area of approximately 0.15 km^2 and a maximum depth of 3 m. The main human activities in the drainage basin of Kesses and Kerita dam includes majorly subsistence-crop farming, horticulture, agro-forestry, forestry and livestock rearing.

Yenga is located at N00^0 13$^{'}$ 03$^{''}$ and E034^0 12$^{'}$ 44$^{'}$, at an elevation of about 1, 251 m.a.s.l. It has steep sided edges. The littoral zones are composed of sandy and rocky bottoms with loose macrophytic detrital and animal manure deposits brought in by surface runoff from the catchment characterize the littoral zones. The dam is dendritic in shape, has a seasonal feeder stream called Ugege and a permanent spillway. It has a surface area of approximately 0.08 km^2 and a maximum depth of 4.5 m. Mauna situated at N00^0 12$^{'}$ 358$^{''}$ and E034^0 09$^{'}$ 433$^{''}$, at an elevation of about 1, 217 m.a.s.l. It has steep sided edges. The littoral zones are composed of sandy and rocky bottoms with emergent macrophytes such as *Typha* sp., *papyrus sp*, reeds, and sedges dominated the zone. The main human activities in the drainage basin of Yenga and Mauna are subsistence crop farming and livestock keeping. It has a surface area of approximately 0.2 km^2 and a maximum depth of 4 m. These SWBs become over flooded during heavy down pour and rainy season as they have no direct outlets. The volume capacity depends on the dam's size. Sampling was done in each dam monthly on various sampling sites (Figure 2).

Sampling period covered both dry (November 2010 to February 2011) and rainy (March to June 2011) seasons. Triplicate samples were collected at 10 cm below the water surface in each dam at monthly intervals from November 2010 to June 2011 for the determination of phytoplankton species composition and water quality parameters. Phytoplankton was collected by plankton net (10 µm mesh), transferred into 500 mL polythene bottle and fixed with Lugol's solution and transported in cool box to the laboratory. About 300 mL quantitative samples were fixed in iodine, sedimented for 24 h, and concentrated to 50 ml. Numerical phytoplankton identification was carried out up to genus level with an inverted microscope 400X and 1000X magnifications (IMT-2, Model), using Needham Needham (1962) identification key and illustrations.

The surface water temperature and pH in the different microhabitats were measured *in situ* by a combined pH-and-temperature-meter, (OAKTON^R, Model pH/Mv/ºC METER, Singapore). Two sets of triplicate water samples were collected in glass stoppered bottles at each sampling station for dissolved oxygen (D.O) and biological oxygen demand (BOD_5) using Winkler's method (APHA 1998). The first set used to determine D.O was fixed using 2 ml manganous sulphate followed by 2 ml of Winkler's reagent.

Samples for determination of total phosphorus (TP) and total nitrogen (TN)) were collected using plastic sampling bottles of 500 ml. The samples were fixed with 3 drops of concentrated sulphuric

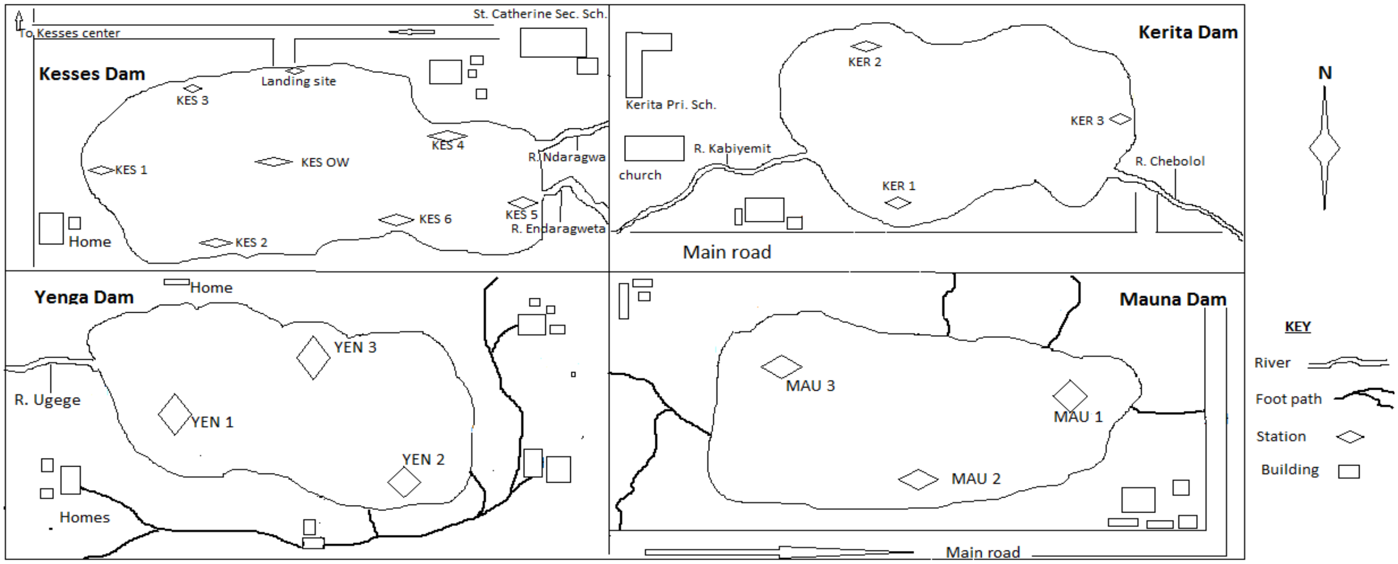

Figure 2. A sketch of the small water bodies showing the sampling sites (KES 1=Kesses station 1, KES 2=Kesses station 2, KES 3=Kesses station 3, KES 4=Kesses station 4, KES 5=Kesses station 5, KES 6=Kesses station 6, KES OW=Kesses open waters, KER 1=Kerita station 1, KER 2=Kerita station 2, KER 3=Kerita station 3, YEN 1=Yenga station 1, YEN 2=Yenga station 2, YEN 3=Yenga station 3, MAU 1=Mauna station 1, MAU 2=Mauna station 2 and MAU 3=Mauna station 3); **NB**- Not drawn to scale

acid in the field and transported in a cool-box to maintain the nitrogen balance to the laboratory for further analyses. Total nitrogen and phosphorus were determined using the Kjeldahl and Persulfate digestion methods, respectively in the laboratory (APHA, 2000).

Data analysis

The mean and standard errors of the physico-chemical parameters were determined. Species diversity (Shannon-Weinner index, $H^{'}$) was calculated for comparison and prior analysis of any uniqueness or difference in the sampled biological community at different space and time (Microsoft excel 2013 and Minitab 16). General linear model (GLM) was used to determine if there were any significant difference in surface water temperature, D.O, BOD_5, TN, TP and pH among the sampling stations and months. Further analysis of the above six water quality parameters related to the species composition was done using Spearman's correlation. The Shannon-Weiner diversity index was calculated as (Roy et al*.,* 2001);

$H^{'} = -\Sigma p_i \ln * p_i$;

Where, $H^{'}$ = Shannon diversity,
ln = natural logarithm
p_i = Proportion of the ith species (n/N)
n = Number of individuals of one taxon
N= Total number of individuals in a station of all taxa

RESULTS

Water quality

The mean monthly values of physico-chemical parameters and nutrients recorded among the dams during this study are summarized in Figures 3 to 8. Mean pH change fluctuated at the four dams and at different months. Kesses dam reached its peak during January 2011 and April 2011 but recorded low values during December 2010 and June 2011. In Kerita dam the highest value was registered during the months of March and April 2011 with small variation during other months. Yenga dam also fluctuates during the sampling periods with the peak during January 2011 and the same trend was also seen in Mauna dam with the highest value registered during November 2010 and lowest in April and May 2011. General linear model did not show significant difference in pH between and within the dams.

The temperature values were relatively high in the low altitude dams (Yenga and Mauna). The temperature values were recorded during the last three months (April, May and June, 2011) in Yenga dam while it was highest and lowest during the months of February 2011 and December 2010 respectively in Mauna dam. In the high altitude dams (Kesses and Kerita), there was no clear trend with high values recorded during November 2010 and May 2011 in Kerita while in Kesses the highest was registered during the months of March and June 2011. There was significant difference between the low and high altitude dams (F=31.24; p=0.002).

Mean D.O concentration change also revealed a similar trend in all dams and at different months. There was a similar trend in Kerita and Yenga with slight differences in values recorded in all months sampled. Mauna dam was different from other three dams (F=42.24; p=0.00). It registered the lowest D.O concentrations throughout the study period with its highest recorded during the month of

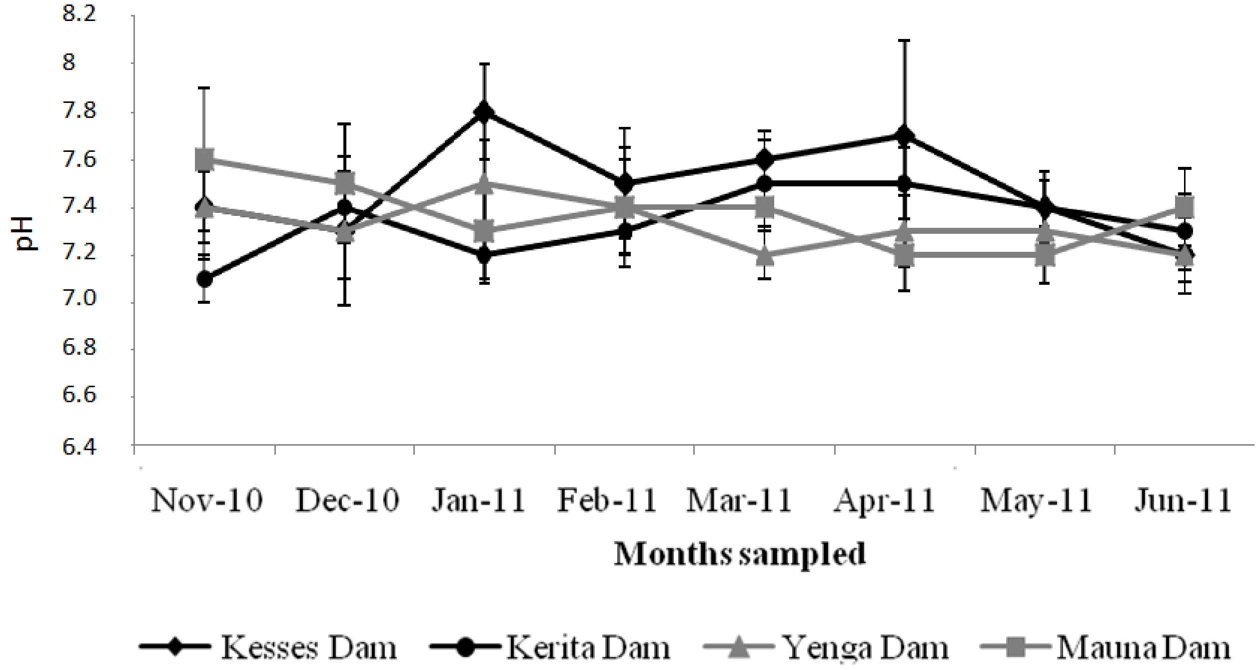

Figure 3. Mean monthly variation of surface water pH values in small water bodies during the study period (Kesses, n=56 while Kerita, Yenga and Mauna, n=24).

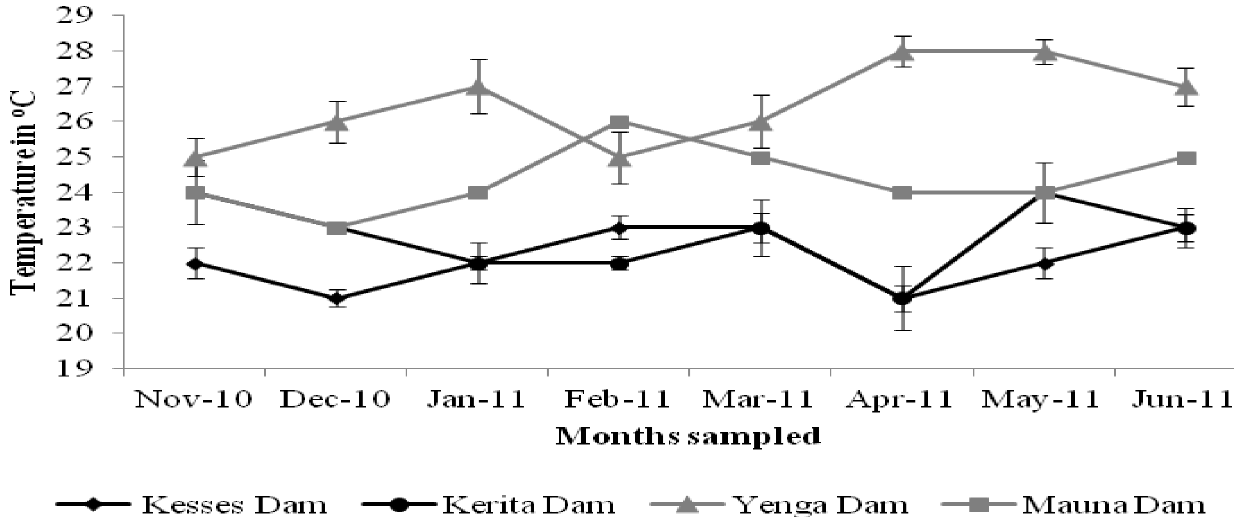

Figure 4. Mean monthly variation of surface water temperature values in small water bodies during the study period (Kesses, n=56 while Kerita, Yenga and Mauna, n=24).

January 2011 with almost the same value during the other months (Figure 5).

Kesses and Yenga dams registered the highest BOD_5 values and reached their peak during the month of May 2011 while their lowest values were recorded during the months of December 2010 and February 2011 (Figure 6). On the other hand Kerita dam had intermediate values with the highest value registered during the months of January 2011 and May 2011 while Mauna dam had the lowest BOD_5 concentration in all of the studied months except during the month of February and April 2011 where the value was above what was seen in Kerita dam. Both Mauna and Kerita registered the same BOD_5 during the month of March 2011.

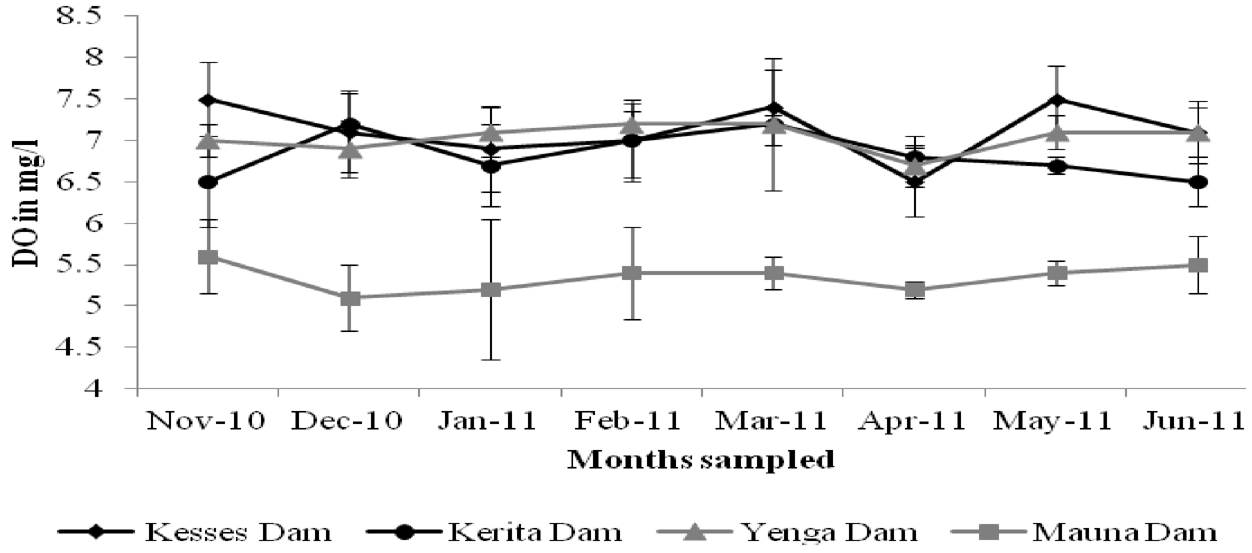

Figure 5. Mean monthly variation of surface water D.O concentration in small water bodies during the study period (Kesses, n=56 while Kerita, Yenga and Mauna, n=24).

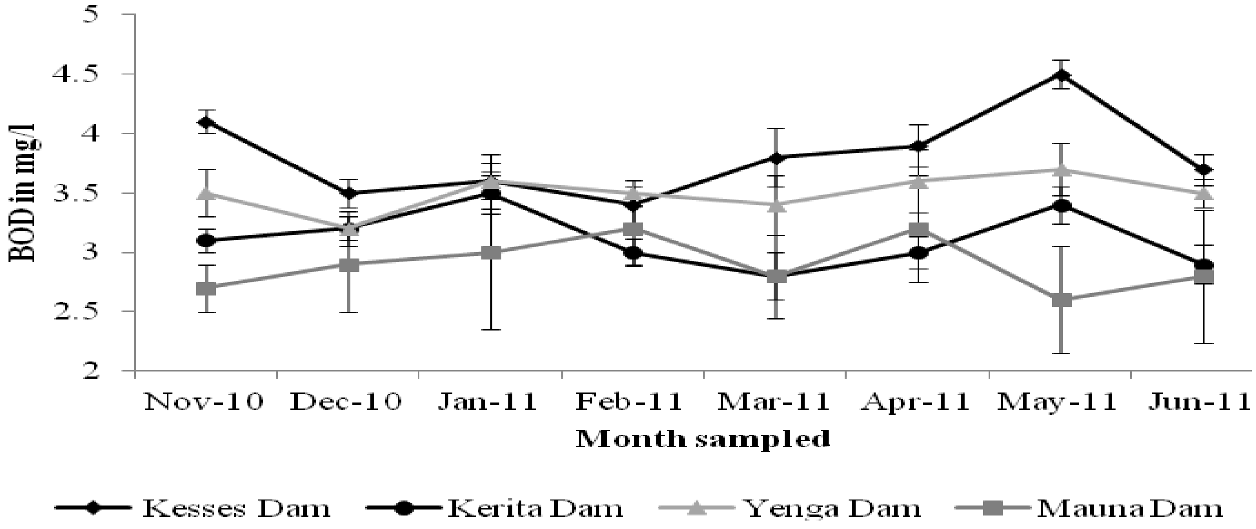

Figure 6. Mean monthly variation of surface water BOD_5 concentration in small water bodies during the study period (Kesses, n=56 while Kerita, Yenga and Mauna, n=24).

Monthly total nitrogen (TN) concentrations were high in high altitude dams with the highest values recorded in Kerita during the months of December 2010 and February 2011 while the low altitude dams registered moderately high figures with a similar trend (Figure 7). There was a significant difference between the dams (F=12; p=0.003). Total phosphorus (TP) concentration did not follow the same trend as the values were highest in Kesses and Mauna dams, Yenga dam recorded the lowest concentrations during the months of January and May 201. The GLM did not reveal significant difference between dams (Figure 8).

Phytoplankton species composition

A total of 1392 phytoplankton species belonging to four families and 20 genera were identified in Kesses dam while in Kerita dam a total of 376 phytoplankton species belonging to four families and 10 genera were sampled

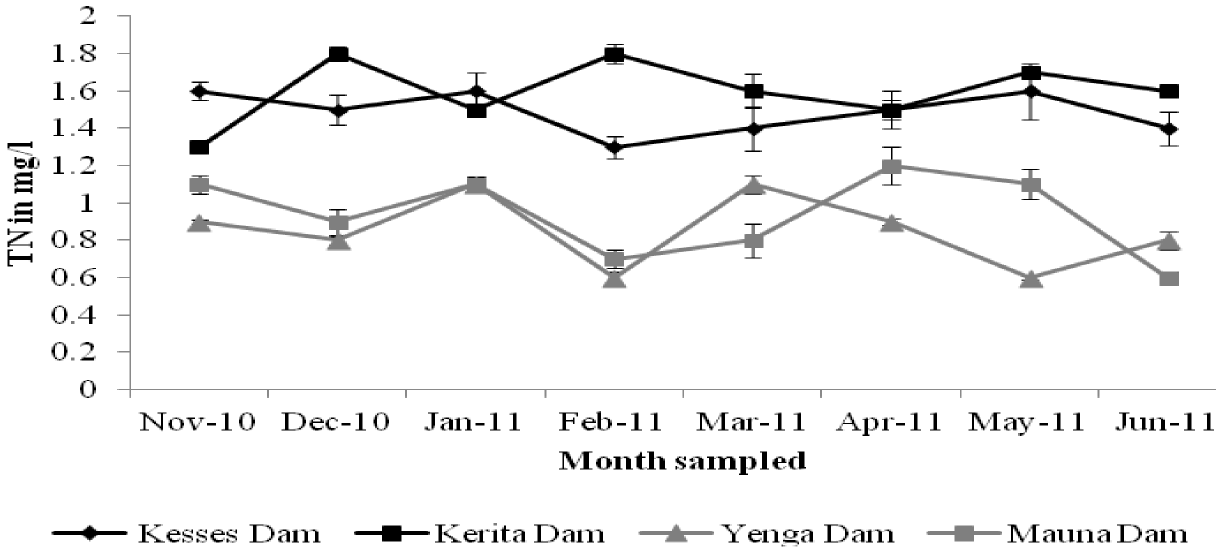

Figure 7. Mean monthly variation of surface water total nitrogen (TN) concentration in small water bodies during the study period (Kesses, n=56 while Kerita, Yenga and Mauna, n=24).

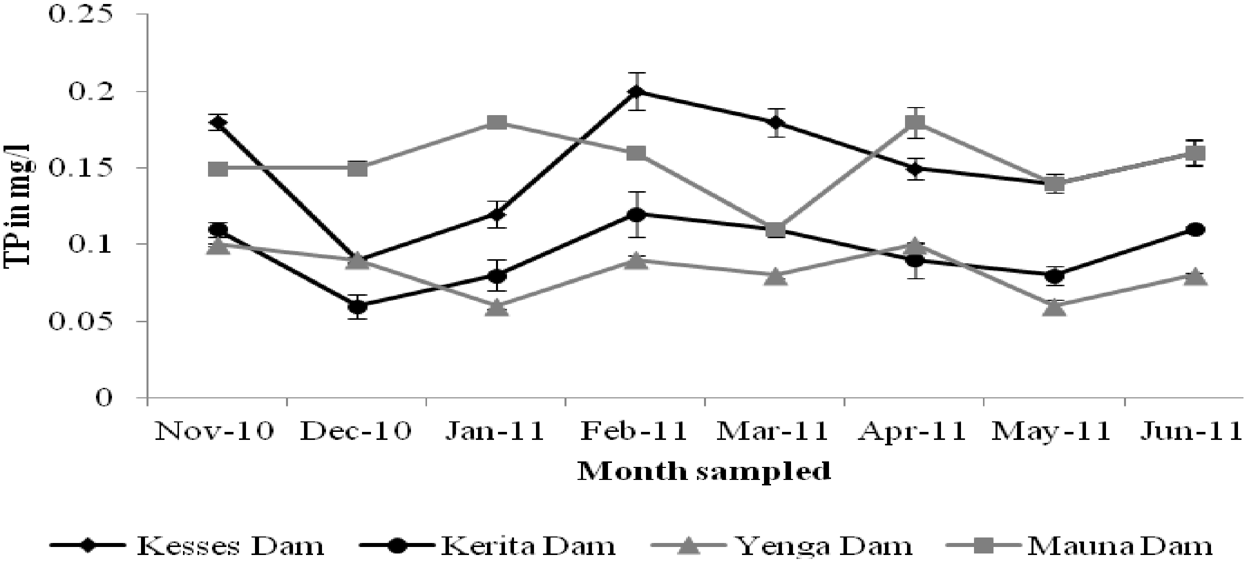

Figure 8. Mean monthly variation of surface water total phosphorus (TP) concentration in small water bodies during the study period (Kesses, n=56 while Kerita, Yenga and Mauna, n=24)

(Table 1).

In Kesses dam a total of four families of phytoplankton were found. They were Bacillariophyceae, Chlorophyceae, Cyanophyceae and Desmidiaceae. There were seven genera under Bacillariophyceae, one under Cyanophyceae, while Desmidiaceae composed by three with Chlorophyceae being the richest family with nine genera. In Kerita Dam, the same number of families (four) was sampled (Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae). Unlike Kesses, Bacillariophyceae was the richest consisting of six genera. The family Cyanophyceae and Euglenophyceae had only one genus each (*Phormidium* sp., and *phecus* sp., respectively), Chlorophyceae had two genera (*Botryoccoccus* sp. and *Scenedesmus sp.).*

In the Siaya dams, Yenga dam had three families of phytoplankton; Chlorophyceae, Euglenophyceae and Cyanophyceae. Chlorophyceae had three genera. The

Table 1. List of phytoplankton taxa identified in Kesses, Kerita, Yenga and Mauna Dams during the study period (Blank space=Genus missing; x=present).

Family	Taxa	Kesses	Kerita	Yenga	Mauna
Bacillariophyceae	*Synedra* sp.	x	x		
	Navicula sp.	x	x		x
	Aulacoseira sp.	x	x		x
	Frustilia sp.	x	x		x
	Diatoma sp.	x	x		x
	Cyclotella sp.	x	x		
	Tabellaria sp.	x			
Desmidiaceae	*Cosmarion* sp.	x			x
	Gonatozygon sp.	x			
	Closterium sp.	x			
Chlorophyceae	*Botryoccoccus* sp.	x	x	x	x
	Crucigenia sp.	x			
	Cladophora sp.	x			
	Coelastrum sp.	x		x	
	Tetraspora sp.	x		x	
	Spirogyra sp.	x			x
	Pediastrum sp.	x			
	Scenedra sp.	x			
	Scenedesmus sp.	x	x		x
Cyanophyceae	*Phormidium* sp.	x	x	x	x
	Coelosphaerium sp.				x
Euglenophyceae	*Phecus* sp.		x	x	
	Euglena sp.			x	

family Euglenophyceae composed of two genera. The Cyanophyceae had a single genus. The family Desmidiaceae which was missing in Yenga was an extra taxon in Mauna dam which registered a total of four families of phytoplankton was found, that is, Chlorophyceae, Euglenophyceae, Cyanophyceae and. The family Chlorophyceae had three genera. The Botryococcus was the richest family with four). Desmidiaphyceae had a single taxon (*Cosmarion sp.)* while the family Cyanophyceae had two genera (Table 1).

Species monthly diversity index

The mean Shannon Weiner diversity index (H') in the small water bodies is given in Figure 9. The highest value of H' was obtained during the rainy season (March to June) in all small water bodies while dry season (November to February) had low species diversity. Kesses dam registered the highest diversity index in all sampled months, followed closely with Yenga dam then Mauna and lastly the lowest was recorded in Kerita dam in most of the sampled months. The diversity indices in all dams were generally low (Figure 9).

Spearman's correlations between phytoplankton and physico-chemical parameters in SWBs (Kesses, n=56, Kerita, Yenga and Kerita, n=24)

Phytoplankton community relative abundance in Kesses dam revealed different relationship with most physico-chemical parameters and nutrients (Table 2). The family Bacillariophyceae was negatively related to temperature, BOD_5, D.O and a significant negative and positive correlation to TP and pH (r=-0.29; p=0.000; r=0.372; p=0.013) respectively. Cyanophyceae was negatively related to all parameters except pH and BOD_5 with chlorophyceae showing significant negative relationship with temperature, D.O and TN r=-0.15, -0.18, -0.07; p=0.000) respectively. Desmidiaceae had an significant negative relationship with the D.O (r=-0.26; p=0.025).

In Kerita dam the relative abundance of phytoplankton families showed some significant negative and positive

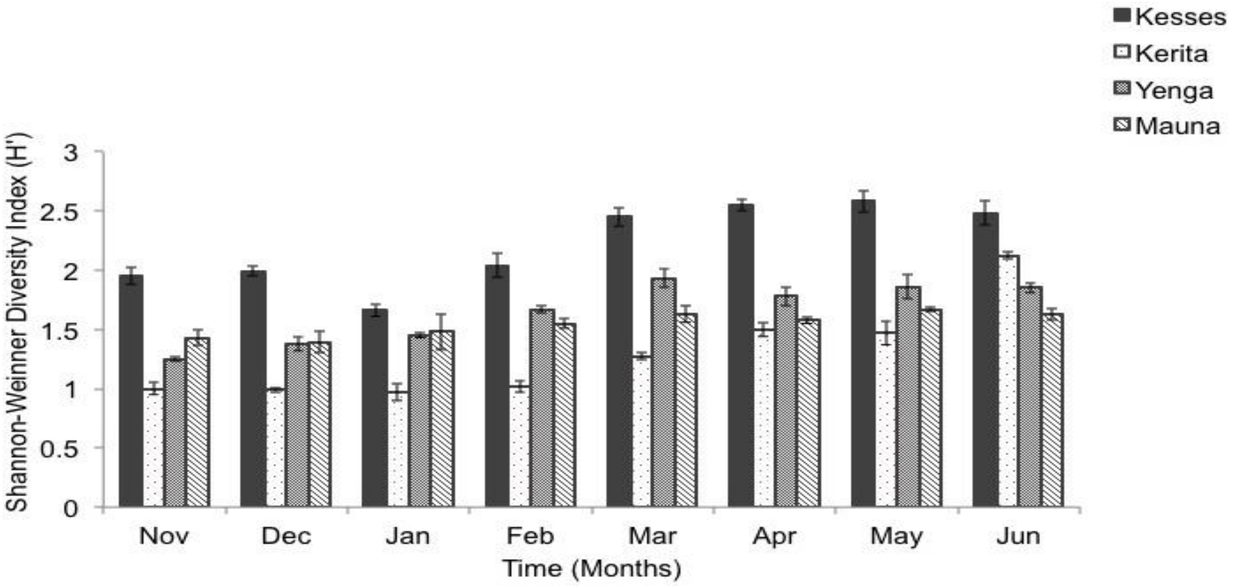

Figure 9. Spatio-temporal variations in phytoplankton diversity indices in SWBs during November 2010 to June 2011 (Kesses, n=56 while Kerita, Yenga and Mauna, n=24).

Table 2. Spearman rank order correlation coefficients between physicochemical parameters and taxa community structure attributes (***** = significant correlation at α = 0.05) (Kesses, n = 56 while Kerita, Yenga and Mauna, n = 24).

County	Dam	Physico-chemical parameter						
		Taxa	**pH**	**Temp**	**BOD$_5$**	**D.O**	**TN**	**TP**
Uasin-Gishu	Kesses	Bacillariophyceae	0.372*	-0.114	-0.052	-0.074	0.117	-0.29*
		Chlorophyceae	0.095	-0.013	0.051	0.024	-0.013	-0.289
		Cyanophyceae	0.188	-0.15*	0.03*	-0.18*	-0.07*	-0.131
		Desmidiaceae	-0.108	0.053	-0.235	-0.26*	0.265	-0.227
		Euglenophyceae	-	-	-	-	-	-
	Kerita	Bacillariophycaea	0.079	-0.284	-0.11*	0.075	0.533*	-0.309
		Chlorophyceae	0.20*	-0.006	0.389	0.17	-0.502	-0.364
		Cyanophyceae	0.609	-0.026	0.135	0.024	-0.336	-0.342
		Desmidiaceae	-	-	-	-	-	-
		Euglenophyceae	0.125	0.11*	0.064	-0.271	0.28*	-0.284
Siaya	Yenga	Bacillariophyceae	0	0	0	0	0	0
		Cyanophyceae	-0.135	-0.209	0.03	-0.199	-0.168	0.256
		Chlorophyceae	0.374	-0.358	0.2*	0.323	-0.065	-0.472
		Euglenophyceae	-0.089	0.155	-0.09	0.016	-0.102	0.32*
	Mauna	Bacillariophyceae	0.34	0.163	0.024*	0.115	-0.188	-0.223
		Chlorophyceae	0.1*	0.316	-0.205	-0.179	-0.198	0.258
		Cyanophyceae	0.17*	-0.282	-0.337	-0.497	0.005*	-0.02*
		Desmidiaceae	-0.462	0.198	-0.13*	-0.225	0.241*	0.619*

relationship with physico-chemical parameters and nutrients. The family Bacillariophyceae was positively related to only pH, D.O and a significant relationship with TN (r=0.533, p=0.0042) with an insignificant negative relationship with all other parameters except BOD_5 (r=-0.11, p=0.000). Cyanophyceae showed an insignificant positive related to pH, BOD_5 and D.O (r=0.609, 0.135 and 0.024) respectively. Chlorophyceae was negatively related to temperature and both nutrients and positively related to the other parameters. It revealed a significant positive relationship with pH (r=0.20, p=0.035). Euglenophyceae had a weak significant positive relationship with temperature and TN (r=0.11, P=0.029 and r=0.28, p=0.001) respectively and a weak insignificant positive relationship with BOD_5 and pH and weak negative relationship with D.O and TP.

Phytoplankton relative community abundance in Siaya dams revealed different significant relationship with physico-chemical parameters and nutrients. In Yenga the family Bacillariophyceae revealed no relationship between phytoplankton, physico-chemical parameters and nutrients. Chlorophyceae revealed a significant positive relationship with BOD_5 (r=0.2, p=0.002) respectively, pH and D.O showed a weak positive relationship. The family Cyanophyceae showed no significant relationship with pH, temperature, D.O, and TN. The family Euglenophyceae revealed a positive relationship with temperature, D.O and TP with a negative relationship with the rest of the parameters. There was a significant positive relationship with TN (r=0.32, p=0.000). In Mauna the trend was the same with different phytoplankton families showing different relationships with physico-chemical parameters and nutrients. The family Chlorophyceae and Bacillariophyceae showed a significant relationship with pH and BOD_5 (r=0.100, p=0.045 and r=0.024, p=0.014), respectively. Cyanophyceae was positively related to pH and TN while negatively correlated to other parameters while Desmidiaceae had both weak negative and positive relationship with physico-chemical parameters.

DISCUSSION

The physicochemical environment of SWBs within Lake Victoria Basin, Kenya displayed considerable spatial and temporal variation in relation to prevailing environmental conditions. Some physicochemical parameters examined in this study were considerably outside the ranges reported for other similar SWBs (Maithya, 2008) this is a clear indication that these ecosystems have undergone fundamental shifts over time. Possible explanation for this involves variations in the frequency of lotic nutrient loading and the rates of mineralization of organic matter for lentic self-loading. High altitude regions generally recorded higher nutrient concentrations as compared to low altitude regions. This could be due to high nutrient concentration that is eroded from the catchment of high altitude regions which is a prime agricultural zone as opposed to low regions with no fertilizer-intensive agricultural activities located in its catchment and this accounts for moderately low total nitrogen and total phosphorus level recorded in Siaya dams. These extreme variations in SWBs physicochemical parameters give these water bodies the distinction of displaying an extreme physical and chemical environment, which seem to interact in determining the nature and structure of the autotrophic assemblages of organisms in them. This is in line with Carpenter et al. (1998) who stated that nutrient availability in an aquatic environment is primarily influenced by seasonal application of fertilizers among other physical factors.

Although there was optimal temperature, pH, D.O concentration and nutrient availability in SWBs, offering good conditions for high algal composition and diversity, only five algal families were observed in the samples collected during the Eight months sampling period, indicating that the SWBs were poor in species richness, and suggesting that its extreme water quality together with the presence of phytophagous fish species fundamentally shapes the ecological functioning of these dams. The SWBs' taxa composition also indicates a low species number which, although exhibiting some degree of similarity to other studies such as Oyoo et al. (2009). The observed low species number in SWBs, particularly for the more tolerant Cyanophyceae and Bacillariophyceae taxa, could be attributed to changes in habitat quality resulting from water quality changes originating from catchment areas that have undergone more land conversion to agriculture. Cyanophyceae have particular preferences for polluted environments because they grow in competitive interactions, with their enhanced ability to utilize carbon (mainly in polluted environments) at high pH levels, giving them an advantage over other phytoplankton species (Atici and Olcay, 2006). This observation seems to suggest that the water draining into Lake Victoria, Kenya from its catchments has some degree of pollution resulting from both point and non point sources. This possibility could explain the decline of sp., *Crucigenia* sp., *Cladophora* sp., *Coelastrum* sp., *Tetraspora* sp., *Spirogyra* sp., *Pediastrum* sp., *Scenedra* sp. and *Scenedesmus* sp with species from the family Euglenophyceae and Desmidiaceae missing completely from the phytoplankton populations during the rainy seasons, it is possible the population pressures in the catchment is leading to massive water quality changes that could alter the quality of the water draining into the SWBs, with subsequent impacts (alterations) on the species assemblage in these SWBs. This observation is supported by (Lung'ayia et al*.,* 2000) who stated that phytoplankton species composition, numerical abundance, spatial distribution and total biomass are directly affected by the environmental factors.

The phytoplankton species variation observed in this study can therefore be attributed to a combination of these unique physiological attributes under different environmental conditions. The presence of large numbers of diatoms at some sampled stations indicates that these

SWBs are constantly changing, putting a recurring ecosystem balance between eutrophism and meso-trophism. This was reflected in this study by the alternate seasonality of occurrence of some few genera or species of Bacillariophyceae. The seasonality of occurrence is a function of nutrients availability or resurgence in the water bodies (Reynolds et al., 2001).

Seasonal variations in phytoplankton composition and diversity were significant. The peak composition and diversity corresponded to the onset of the rainy seasons. Composition of *Synedra* sp., *Navicula* sp., *Aulacoseira* sp., *Frustilia* sp., *Diatoma* sp. and *Cyclotella* sp increased during the rainy seasons. This observation is in line with Oyoo et al. (2009) who also reported increased phytoplankton composition and diversity during rainy season. Thus, current changes in the phytoplankton composition appear to be directly related to the prevailing environmental conditions. Precipitation can play a critical role in determining limnological properties and plankton dynamics of water bodies (Kalff, 2002) by washing a substantial quantity of allochthonous materials and nutrients from the catchment into the SWBs that can stimulate the growth and sustenance of phytoplankton populations, thereby also increasing phytoplankton composition. In contrast, the increased water inflow into the SWBs from the streams feeding it during the rainy season could decrease the water transparency, thereby reducing the availability of light in the water column to stimulate phytoplanktonic growth, especially for phytoplankton species residing some distance below the water surface.

Spatial variability is a structural character of an ecosystem. Spatial distributions allow for complex population interactions involving energy transfer, competition and niche apportionment (Brower et al. 1990). It is generally expected that less-disturbed sites exhibit higher species diversity (Jones et al., 2002). Anthropogenic impacts from changes in land-use practices are known to affect phytoplankton diversity patterns in lakes receiving drainage from modified stream water quality from the catchments (Death, 2000), often leading to decreased abundance of taxa, as well as shifts to a more unevenly distributed community containing only one or two numerically dominant taxa (Jones et al., 2002). The high level of dominance by a few taxa at sampling sites that experience water inflows compared to the more evenly distributed taxa in inshore sites, suggests that human activities already are shaping SWB's phytoplankton communities. Sitoki (2010) reported a wide range of land-use activities in the upper catchments of L.Victoria. These human activities can ultimately affect spatial variations of species assemblage in SWBs.

The observed correlation variations could be attributed to variations in the degree of anthropogenic activities resulting into different concentrations of chemical discharge into the different SWBs. Other studies support this present result, such as Sabater et al. (2004) who noted that changes in the structure of the microbial components did not significantly affect the organisms community (where only a few taxa showed changes because of the nutrient addition).

Although most of the phytoplankton families have not been found to produce toxic secondary compounds, other cyanobacteria species (for example, *Microcystis*; *Anabaena*) have produced cyanotoxins under conditions of changed water quality that can cause death, when consumed by the SWB's biodiversity, for example, birds. This underscores an urgent need for continuing monitoring of the SWBs' phytoplankton populations, as well as a closer collaboration between the government and the communities along the rivers draining to these water bodies to avoid polluting it. The urbanization process characterizing the nearby towns also should be better studied as a means of avoiding direct pollution effects that could influence water bodies' phytoplankton community structure. Furthermore, nutrient reduction strategies should be used to control the excessive phosphorus load to the SWBs, especially during the rainy seasons. In order to manage other water bodies, ecological approaches concerned with the phytoplankton community structure, and prevention of activities or measures through which this structure can be modified, should be used. With the use of such initiatives, water quality changes likely to cause adverse changes to the biotic assemblages can be discerned sufficiently early to allow corrective measures to be developed and implemented before irreparable ecological damages to the aquatic system occur.

ACKNOWLEDGEMENT

The authors wish to thank National Council of Science and Technology (NCST) for funding this study and also Department of Fisheries and Aquatic Sciences of University of Eldoret for provision of both laboratory space and technical support during the entire study period.

REFERENCES

Adame MF, Alcocer J, Escobar E (2008). Size-fractioned phytoplankton biomass and its implications for the dynamics of an oligotrophic tropical lake. Freshwater Biol. 53:22-31.

APHA (1998) (American Public Health Association) Standard methods for the examination of water and wastewater, 20th edn Washington, D.C USA.

APHA (2000). (American Public Health Association) Standard methods for the analysis of water and wastewater, 15th Ed. American Public Health Association and Water Pollution Control Federation. Washington DC, USA. p. 44.

Atici T, Olcay O (2006). Seasonal variations of phytoplankton and value of chlorophyll a in the Sariyar Dam Reservoir (Ankara, Turkey). Turk.. J. Bot. 30:349-57

Beyruth Z, Tanka M (2000). Biovolume of the phytoplankton in aquaculture tropical ponds. Verh. Internat. Verein. Limnol. 27:689-695. Brower JE, Zar JH, von Ende CN (1990). Field and Laboratory

Methods for General Ecology. William C. Brown Publishers, New York.

Carpenter SR, Caraco NF, Correll DL, Howarth RW, Sharply AN, Smith VH (1998). Non-point Pollution of Surface Waters with Phosphorus and Nitrogen. Ecological Applications. 8:559-568.

Cecchi P (2007). L'eau en partage: les petits barrages de Côte d'Ivoire. IRD (éd.). Collection latitudes 23. Paris: 2007, p. 295.

Death RG (2000). The effect of land use on the speciesarea relationships in benthic stream invertebrates. Verh. Int. Ver. Theor. Angew. Limnol. 27:2519-2522.

Descy JP, Hardy MA, Stenuite S, Pirlot S, Leporcq B, Kimirei I., Sekadende B, Mwaitega SR, Sinyenza D (2005). Phytoplankton pigments and community composition in Lake Tanganyika. In: Freshwater Biology. Vol. 50, 2005. pp. 668-684.

Descy JP, Sarmento H (2008). Microorgansms of the East African Great Lakes and their response to environmental changes. In Freshwater Reviews. Vol. 1, 2008. pp. 59-73.

Gurung TG, Dhakal RP, Bista JD (2006). Phytoplankton primary production, chlorophyll-a and nutrient concentration in water column of mountainous Lake Phewa, Nepal. Lake Reserv. Manage. 11:141-148.

Jones C, Palmer RM, Matkaluk S, Walters M (2002). Watershed Health Monitoring: Emerging Technologies. CRC Press, Boca Raton, FL.

Kalff J (2002). Limnology: Inland Water Ecosystems. Prentice Hall Inc. Upper Saddle River, NJ.

Krienitz L, Ballot AA, Wiegand C, Kotut K, Codd CA, Phlugmacher S (2001). Cyanotoxin-producing Bloom of Anabaena flos-aquae, Anabaena discoidea and Microcystis aeruginosa (Cyanobacteria) in Nyanza Gulf Lake Victoria, Kenya. J. Appl. Bot. Angewandte Botanik 76. pp. 179-193.

Lafond MB, Pinel A, Ross P (1990). Biomass and photosynthesis of sizefractionated phytoplankton in Canadian Shield lakes. Hydrobiologia. 196:25-38.

Levandowsky WM (1972). Tropical Limnology. Ann. Rev. Ecol. Syst. 18:159-184.

Lewis WM (1976). Surface/volume ratio: implications for phytoplankton morphology. Science 192:885-887.

Likens GE (1975). Primary production of inland aquatic ecosystems. In: Primary productivity of the biosphere. Lieth RH, Lieth & RH Whittaker (eds.): 185-202. Springer Verlag, New York.

Lung'ayia H, Sitoki L, Kenyanya M (2001). The nutrient enrichment of Lake Victoria (Kenyan waters). Hydrobiologia. 458:75-82.

Lung'ayia, HBO, M'Harzi A, Tackx M, Gichuki J, Symoens JJ (2000). Phytoplankton community structure and environment in the Kenyan waters of Lake Victoria. Freshwater Biol. 43:529-543.

Maithya J, Charo H, Ouma H (2002). Aquaculture potential of small water bodies in Lake Victoria basin, Kenya. Kenya Marine and Fisheries Research Institute Annual Report, 2001/2002.

Maithya JM (2008). Ecology, Biology and Aquaculture potential of (Oreochromis variabilis) (Boulenger 1906) in Lake Victoria basin, Kenya PhD thesis Moi University, Kenya.

Needham JG, Needham PR (1962). A guide to the study of freshwater biology.

Okely P, Imberger J, Antenucci JP (2010). Processes affecting horizontal mixing and dispersion in Winam Gulf, Lake Victoria. Limnol. Oceanogr. 55:1865-1880.

Oyoo EO, Muchai M, Shivoga WA, Miller NS, Rasowo J, Ngugi CC (2009). Spatial and seasonal variations in phytoplankton community structure in alkaline-saline Lake Nakuru, Kenya. Lakes & Reservoirs: Res. Manage. 14:57-69.

Reynolds CS (1999). Non-determinism to probability, or N:P in the community ecology of phytoplankton: Nutrient ratios. In Archiv für Hydrobiologie, Vol. 146, 1999. pp. 23-35.

Reynolds CS, Irish AE, Eliot JA (2001). The ecological basis for stimulating phytoplankton responses to environmental change (PROTECH). Ecol. Model. 140:271-91.

Roy AH, Rosemond DA, Leigh DS, Paul MJ, Wallace JB (2001). Efforts of changing land use on macroinvertebrate integrity. Georgia Water Resource Conference. University of Georgia, Athens, G.A. March 2001. p. 47.

Sabater S (2004). Diatom communities as indicators of environmental stress in the Gaudiamar river, S-W. Spain, following a major mine tailing spill. J. App. Phycol. 12:113-124.

Simciv T (2005). The role of plankton, zoobenthos, and sediment in organic matter degradation in oligotrophic and eutrophic mountain lakes. In Hydrobiologia, vol. 532, 2005, pp.69-79.

Sitoki LM (2010). Phytoplankton and eutrophication in Nyanza Gulf (with special reference to toxic cyanobacteria and planktonic diatoms). Ph.D. thesis, University of Innsbruck, Faculty of Biology, Institute of Botany p.106.

Stockner JG, Suttle CA, Harrison PJ (1987). Effects of nutrient pulses on community structure and cell size of a freshwater phytoplankton assemblage in culture. Can. J. Fish. Aqua. Sci. 44:1768-1774.

Talling JF (1966). Photosynthetic behavior in stratified and unstratified lake populations of a plankton diatom, Freshwater Biology. 54:99-127.

Walsh CJ, Sharpe AK., Breen PF, Sonneman JA (2001). Effects of urbanization on streams of the Melbourne region, victoria, Australia. I. Benthic macroinvertebrate communities. In Freshwater Biol. Vol. 46, 2001. pp. 535-551.

Wetzel RG (2001). Limnology: Lakes and River Ecosystems. Academic Press, San Diego. p. 1006