International Journal of Advanced Research in Management and Social Sciences
ISSN: 2278-6236
Impact Factor: 6.943

SPATIAL AND TEMPORAL VARIATION IN COMMUNITY STRUCTURE OF PHYTOPLANKTON IN CHEBARA RESERVOIR-KENYA

Salome Ojunga, Department of Biological Sciences, University of Eldoret, Eldoret, Kenya

Prof. Augustino Onkware, Rongo University College, Rongo, Kenya

Prof. Julius O. Manyala, Department of Fisheries and Aquatic Sciences, University of Eldoret, Eldoret, Kenya

Abstract: *River impoundments create reservoirs for many of varying, sizes which serve one or more functions, and change transform lotic aquatic systems to lentic ones, with changes in physical and chemical properties, biotic assemblage and productivity. Chebara reservoir is located at 36^{o} E and 22^{o} S and situated within Elgeyo-Marakwet County. The reservoir was formed as a result of damming the Moiben River to supply water to Eldoret town. A study was conducted on composition and relative abundance of phytoplankton in the reservoir from December 2007 to April 2008. Sampling was done every month at six stations distributed over the reservoir; one station at inlet of Moiben River, one station at the outlet, three at minor inlets and one within the reservoir. Phytoplankton were collected using a 28nm diameter plankton net immersed vertically below the photic depth. Photic depth was measured using 25cm diameter Secchi disk. Phytoplankton were identified and enumerated using a compound microscope. All statistical analyses were performed with STATIGRAPHIC 2.1 Plus and STATISTICA 6.0 procedures. Six phytoplankton classes were identified which included Cyanophyceae (22 genera) Bacillariophycae (25 genera), Chlorophyceae (55 genera), Euglenophyceae (3 genera), Rhodophyceae (2 genera) Pyraphyceae (6 genera) and Crysophyceae (8 genera) similar to observations made in tropical oligotrophic lakes. The order of abundance was Pyraphyceae> Cyanophyceae> Chlorophyceae> Bacillariophyceae> Crysophyceae>Euglenophyceae>Rhodophyceae. Members of the Class Chlorophyceae showed the highest species diversity and abundance. The results obtained from this study can be used track the effects of catchment land use in the drainage basin investigate the cumulative, long term effects of climate change, and river impoundment on the algal evolution.*

Key words: *Spatial and Temporal Variation, Community Phytoplankton, Chebara Reservoir*

INTRODUCTION

Phytoplankton species composition and abundance within a water body together with occurrence of certain types of blooms in lakes and reservoirs have been widely studied (Talling and Talling, 1965; Wilson, 1994). Their relationships with physico-chemical characteristics of water have been used by various researchers to describe reservoir dynamics (Wetzel, 1999; Reynolds, 2001; Sole´ and Bascompte, 2006).

The patterns of succession of phytoplankton vary in all reservoirs worldwide because reservoir properties are highly variable and each reservoir is unique in this respect (Kalff, 2002). Some phytoplankton species occur more or less all the time but fluctuate in numbers; many other species show clear seasonality and disappear from plankton population for some part of the year (Sarmento *et al*., 2008). For example, in Lake Elementaita the phytoplankton assemblage was reported to show high seasonality and an abrupt switch from one dominant phytoplankton assemblage to another when salinity increases (Phlips *et al*., 1997). Such variation in phytoplankton composition is greatly influenced by a range of physical factors, grazing processes, and availability, composition and forms of nutrients. Phytoplankton community composition would therefore largely reflect interplay of several factors. Other factors that lead to seasonal changes include thermal stratification over the dry periods and turbulent conditions with elevated inflows in early periods of long rains, potential reduction in one or several nutrients to limiting concentrations, potential reduction in available light due to self-shading effect by the phytoplankton cells themselves, and the build-up of grazer zooplankton populations (Reynolds, 1994; Reynolds, 2001).

In many freshwater ecosystems, the first algal types to increase in concentrations in early rains are the diatoms followed by green algae then cyanophytes and finally the dinoflagellates (Harris, 1996). As thermal stratification breaks down, there can be a resurgence of some of these populations before the phytoplankton numbers fall away to low levels through cool wet seasons. According to Harris (1996), factors underlying seasonal species succession may make it possible to predict the occurrence of particular species. Droughts and floods can switch the phytoplankton characteristics of water bodies between cyanophytes and diatoms (Heaney *et al*., 1995), thereby making weather variability a major factor on the biota and biochemistry of the ecosystem.

Diatoms are favoured by short residence of water, turbulence, deep clear water columns and strong pulses of silicon dioxide from external source (Harris and Baxter, 1996). They

have relatively high sedimentation rates and are physiologically suited to grow under deeply mixed, low light conditions (Harris, 1996). Cyanobacteria are favoured by long residence of the water, quiescent (stratified) states; low dissolved inorganic nitrogen (DIN) in surface watersand, in monomictic systems, strong hypolimnial anoxia, where there is a strong build-up of ammonia, phosphates andsulphides in bottom waters.

Sediment fluxes of nitrogen regulate the form and concentration of N in the surface waters especially Ammonia (NH_3) from anoxic sediments (Harris, 1996). These are important in determining both algal biomass and species composition (Harris, 1996). Blomqvist, *et al*. (1994) showed that species composition of dominant cyanophytes in freshwaters may be manipulated by changing the dominant form of dissolved inorganic nitrogen (DIN) in the system. Small-celled non- nitrogen–fixing cyanophytes, such as *Microcystis*, appear to be more favoured by the presence of high concentrations of NH_3 but low NO_3^- in the water, whereas N-fixing forms, for example *Anabaena* and *Aphanizomenon*, are favoured by low NO_3^- conditions (Reynolds, 2001).

River impoundment creates reservoirs of varying sizes and serve one or many functions. Such functions include water supply for electric power generation, domestic, agriculture or industry and fisheries (Hecky and Kling, 1981; Mustapha, 2009). Small Water Bodies (SWBs) such as reservoirs are influenced by the physical, chemical and biological processes within the entire watershed (Huszar and Reynolds, 1997). As water enters the reservoir, its velocity decreases leading to deposition of suspended matter (Scheffer, 1998). The water becomes clearer and growth of phytoplankton is enhanced (Bowling and Baker, 1996).

Changes within the inflowing waters are likely to affect the physico-chemical status of the entire SWBs since the water that gathers in the reservoirs more often depicts the cumulative effects of the water quality changes originating from the catchment areas (Scheffer, 1998; Sterner and Elser, 2002). For example, nutrients from agricultural land within the drainage basin and compounds introduced through direct precipitation and other human factors such as agriculture can influence the water chemistry and the aquatic biota, thereby affecting species assemblages and aquatic biodiversity (Blomqvist, 1994). Biological assessment of an aquatic system integrates independent and interactive effects of environmental (Sterner and Elser, 2002; A°gren, 2004) and anthropogenic factors on the abiotic component; thus providing a robust indicator of changes in the characteristics of an aquatic environment (Eloranta and Soininen, 2001; Li *et al*., 2001; Allan, 2004).

Many different methods have been used to estimate phytoplankton abundance, but the most common methods include chlorophyll-a, primary production and direct enumeration (Prescott, 1954; Margalef, 1976). A close relationship exists between concentration of chlorophyll-*a* in water and total abundance of phytoplankton (Phlips*et al*., 1997; Reynolds, 2001).

The importance of primary production in the reservoirs and lakes has been described in many studies (Scheffer, 1998; Blomqvist, 2000; Reynolds, 2006). Shallow reservoirs show very high primary production (Scheffer, 1998; Thomas *et al*., 2000). Such shallow water habitats may have extensive growth of higher aquatic plants, but phytoplankton dominate primary production in most of these aquatic ecosystems (Belland Kalff, 2001).

Phytoplankton are rarely uniformly distributed in the water column. They also show considerable horizontal and vertical patchiness, with varying scales from less than 1 millimetre to several kilometres (Platt and Denham, 1980). Both vertical and horizontal distributions may change with time. These temporal changes are also affected by the scale of measurement which may be diel, seasonal or long-term changes occurring over many years. A phytoplankton assemblage must therefore be thought of as a three-dimensional patch of space, water depth, being influenced by time as well as physical and chemical gradients (Zohary, *et al*., 1996; Reynolds, 2006).

Diel fluctuations in phytoplankton cell biology are endogenous (Sweeney, 1989; Agawin, *et al*, 2000). Phytoflagellates, such as *Mallomonas and Chroomonas,* migrate downwards by night but return to the upper water layers during the day (Harpley-Wood, 1976). Under clear sky these phytoplankton occur in the subsurface waters but are found on the surface in cloudy sky. The non-motile green alga,*Oocystis*, shows active movement due to the circulation in water column.

Tropical lakes generally appear to support a higher biomass of phytoplankton, but with less species diversity. Little seasonal change and a dominance of chlorophytes were observed in lakes in the Philippines whereas Lake George, Uganda, is dominated by cyanophytes, although chlorophytes also contribute a significant part of the remaining biomass (Lewis, 1986) and diatoms are rare. Such lakes have shown only a twofold annual variation in phytoplankton biomass, with slight peaks occurring during periods of maximum rainfall (Chalar & Tundisi , 2001). Tropical lakes show less successional variation than temperate lakes (Nwanko, 1996; Iban˜ ez, 1998; Pirlot, *et al*., 2005; (Chalar & Tundisi , 2001). Many

tropical lakes are eutrophic due to rapid remineralization occurring due to higher water temperature. These tropical lakes are also characterised by the occurrence of pinnate diatoms such as *Nitzchia* (Soininen and Niemela 2001).

A summary of phytoplankton abundance and diversity for Chebara reservoir for different stations and dates is presented in Table 1 and 2 below respectively.

METHODOLOGY

Climate, Geology and Hydrology

The study area has mean maximum temperature range of 18 C to 28 C, and minimum range of 8 C to 12 C. The mean annual rainfall is 1,000 mm. Long rains occur between March and May, and short rains occur between September and October. Dry months occur between November and March (Land update, 2006).

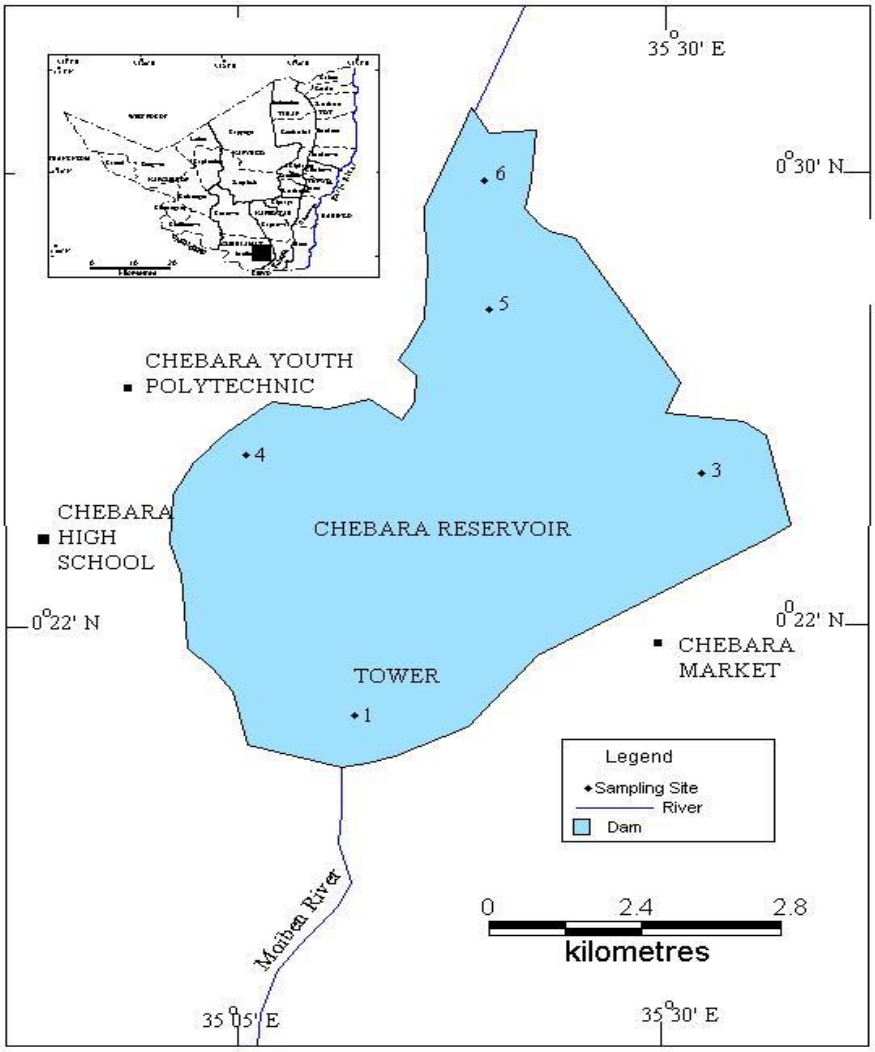

Figure 1:Location ofChebara Reservoir Showing SamplingStations (Author, 2008)

Sampling

Stratified sampling was carried out during the study period. Six stations were selected for sampling during this study (Fig 1). Stations 3 and 4 were situated at two minor inlets, and drain water from farmland and human settlement respectively. These stations were thus chosen on the basis of possible impacts, and the extent of the impacts, of farming and settlement on the physico-chemical characteristics of water in the reservoir. A brief description of each of the sampling stations is provided below:

Sampling station 1

This sampling station was situated 10m away from the reservoir outlet in the open waters and was not frequented by aquatic birds at the time of study. The water in this region is subject to turbulence as it moves out through the outlet. Turbulence and the wind action bring about mixing of the water in this area.

Sampling station 2

Station 2 was situated about 100m east of the reservoir outlet. The area has dense vegetation in the littoral zone and is protected from wind action. The emergent vegetation was predominantly *Typhus* spp. There was also a dense vegetation of both submerged and floating plants including Elodea and *Nymphea* species. The waters here remained relatively calm during all the sampling sessions.

Sampling station 3: Minor stream inlet

This sampling station was selected where one of the inlet streams enters the reservoir. This minor stream lies south of the reservoir and drains from farmlllilitreand, as opposed to the main inlet that flows through the forest.

Sampling station 4: Minor inlet stream

This sampling station is also an inlet stream and lies to the south eastern side of the reservoir. The area was near human settlement that included a learning institution. This sampling station has sparse terrestrial and aquatic vegetation, with the presence of waterfowl. This was selected for study to in order to determine if there in significant effects of settlement on the physico-chemical conditions of the reservoir.

Sampling station 5: Open waters

The station was situated 1km inward away from the main inlet. Water at this sampling station was very clear and devoid of vegetation. The area was open and subject to wind action.

Sampling station 6: Main inlet of Moiben River

The Moiben River drains into the reservoir through a thick protected forest basically free from much human activity. The station had dense vegetation, which gave significant shading. Terrestrial plants include forest species that grew on land overlying the river mouth. The water was turbid and shallow and slow moving.

Phytoplankton Analysis

Sample collection and preservation

Phytoplankton were collected using a plankton net of 28nm mesh and 25 cm diameter. The net was immersed vertically below the photic depth of the water as determined using secchi disk (Wetzel 1999). The volume of the water sampled was calculated as follows:

Volume of water sampled = $\pi r^2 d$..... (i)

where:

r = radius of plankton net

d= the photic depth (in meters)

The concentrated samples, measuring 100millilitre each, were then put in plastic bottles, preserved in 0.15 millilitre of Lugol's iodine (APHA, 1998) and transported to the laboratory for algal species identification and enumeration.

Phytoplankton enumeration

1 millilitre aliquot of the concentrated sample was pipetted into the Sedgwick-Rafter cell. Counting of the phytoplankton was carried out using a Sedgwick-Rafter cell under an inverted microscope (Olympus® Model CK2) at a magnification of X400 (APHA, 1998). Phytoplankton were counted in at least ten cells of 1 mm x 1mm and numerical estimations of the phytoplankton abundance done using the drop method (Margalef, 1976).

Phytoplankton millilitre^{-1}= (N) x (50 x 20 x 1)..... (ii)

where,

N = number of phytoplankton counted in 1 Sedgwick-Rafter cell

(50 x 20)mm^2 = total area of the Sedgwick-Rafter chamber

1= 1 millilitre aliquot of the concentrated sample pipetted.

The relative abundance of the various taxa was then calculated according to Margalef (1976) using the formula given below:

$$\text{Relative Abundance} = \frac{\text{No. of inviduals in a species x 100}}{\text{total number of individuals}} \quad \text{..... (iii)}$$

Phytoplankton diversity indices were determined according to Shannon-Wiener (1949).

$H' = -\Sigma P_i \text{Ln } P_i$ .....(iv)

where,

H' = Shannon-Wiener diversity index

P_i= the relative importance of species *i*, derived from cell numbers (Ni/Nt).

N*i* = number of individuals in a genus in the i^{th} sample

i^{th} = the sample

N = total number of individuals in a sample

All statistical analyses were performed with STATIGRAPHIC 2.1 Plus and STATISTICA 6.0 (StaSoft, 2001) software. Normality of data distribution was checked by means of the skewness and kurtosis (Zar, 2001).

RESULTS

Six phytoplankton classes were identified including Cyanophyceae (22 genera) Bacillariophycae (25 genera), Chlorophyceae (55 genera), Euglenophyceae (3 genera), Pyraphyceae (6 genera) and Crysophyceae (8 genera) on the different sampling dates. The order of abundance was Pyraphyceae> Cyanophyceae> Chlorophyceae> Bacillariophyceae> Crysophyceae>Euglenophyceae>Rhodophyceae.

Most phytoplankton populations are rather short-lived and show marked seasonal periodicity, sometimes being dorminant for 2-4 weeks and then disappear. In some cases the species occur in the water body in low populations throughout the year, or the cells may be brought by fresh inflow, re- suspended from the bottom of the waters or perrenated from resting stages. From Figure 2 and 3 below, it was observed that all phytoplankton genera were present at sampling stations and dates. Rhodophytes were very scantily represented, only appearing at station 3 (Figure 2) and during sampling done on 14/12/07 and 28/03/08 (Figure 3). Cyanophytes, diatoms and chlorophytes showed the low abundance especially at station six, while pyraphytes (*Ceratium, Peridinium, Straustrum*and *Dinobryon*) were highly abundant. Diatoms showed highest and equal abundance at stations 2, 4 and 5 followed by station 3. The diatoms at station six occurred primarily as attached to sediments and detritus at this station.

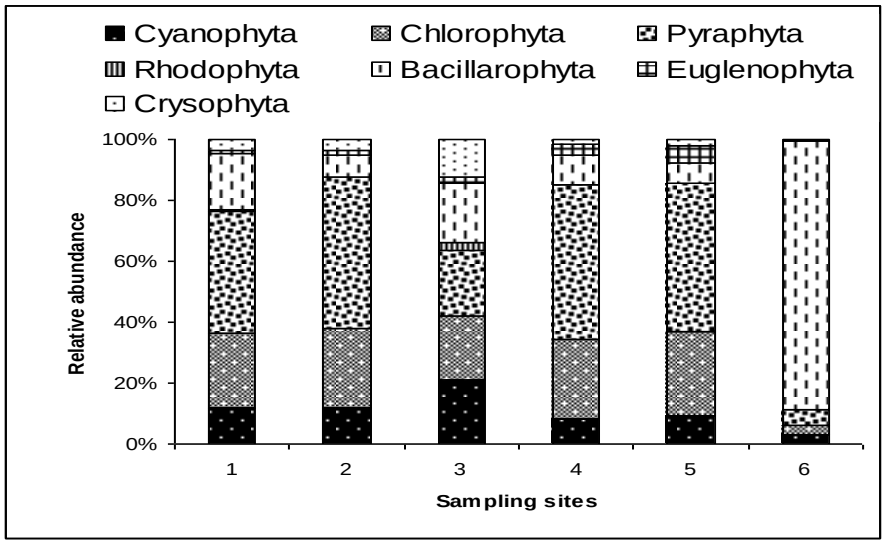

Figure 2:Variation in mean spatial abundance of different phytoplankton genera in Chebara reservoir during the study period between Decembers 2007 and June 2008

Different phytoplankton classes reached peak populations at different times (Figure 2). Cyanophytes were highest in number in December 2007 but their abundance decreased in the wet seasons. Chlorophytes reached their peak in Februaryand April 2008, diatoms and euglenophytes in April 2008. Crysophytes and dinoflagellates showed seasonal succession such that while crysophytes were abundant in March, dinoflagellates showed higher populations in wet seasons.

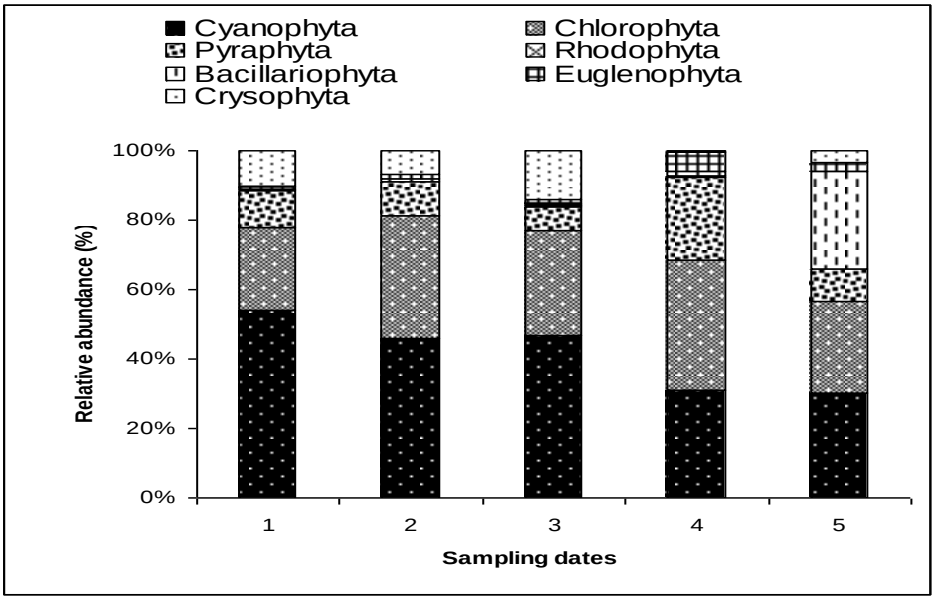

Figure 3: Variation in mean temporal abundance of different phytoplankton genera in Chebara reservoir during the study period between December 2007 and June 2008

KEY: Date1-5 represents sampling dates from December 2007- June 2008 respectively.

The dinoflagellates were the most abundant of the groups observed in the reservoir, with a temporal relative abundance of 151.98 (Table 1) and 181.49 on spatial scale (Table 2). On both temporal and spatial scale *Ceratium* and *Peridinium*were the most abundant, followed by *Microcystis* (Table 2 and 3). Three phytoplankton classes, Chlorophyceae, Bacillariophyceae and Cyanophyceae showed the highest species variety of genera, and accounted for over 50% of the total phytoplankton assemblage. Members of Chlorophyceae showed lower species abundance. Chlorophyceae showed greater number of genera (55genera) than the Cyanophyceae (22 genera) (Table 1). Cyanophytes showed the highest density of all the classes, with *Microcystis* showing the greatest abundance of all cyanophytes.

A summary of phytoplankton abundance and diversity for Chebara reservoir for different stations and dates is presented in Table 1 and 2 below respectively.

Table 1: Temporal Variations in Relative Abundance of Various Phytoplankton Genera in Chebara Reservoir over the Study Period

Class	Genus	Date1	Date2	Date 3	Date 4	Date 5	TOTAL
Cyanophyta	*Anabaena*	0.03	0.089	0.05			**0.175**
	Anabaenopsis	0.43	0.58	0.601	0.27		**1.886**
	Aphanocapsa	0.33	0.28	1.18	1.84	2.07	**5.686**
				3.35		0.0560	**3.411**
	Aphanothece					22	
	Chlorococcus	3.46	0.89	4.84			**9.189**
	Chroococcus	2.8	6.15		0.27	0.06	**9.283**
	Coelosphaerum	0.86	0.66	0.45	0.48		**2.441**
	Coenococcus	0.20	0.09	0.11	0.68	1.23	**2.306**
	Cyanercus	0.36			0.07		**0.431**
	Dactylococcopsis	2.0	4.91	11.04	8.77	5.43	**32.149**
	Glaucocystis		1.86		0.07		**1.938**
	Gleocapsa	1.25	1.15	2.93			**5.337**
	Gleothece	0.20					**0.20**
	Holopedium	0.07					**0.074**
	Microcystis	3.72	9.65	7.15	16.0	10.92	**47.412**
	Merismopedia		2.12	1.83	0.48	0.23	**4.671**

Class	Genus	Date1	Date2	Date 3	Date 4	Date 5	TOTAL
	Nostoc	0.03					**0.037**
	Oscillatoria	2.54	0.18	0.818	3.0	2.017	**8.533**
	Phormidium	0.033					**0.0337**
	Schizothrix						**0**
	Synechococcus	0.56	0.22	0.58			**1.3667**
	Synechocystis		0.04				**0.048**
		18.83	**28.85**	**34.91**	**31.88**	**22.017**	**136.50**

	TOTAL						**1**
Chlorophyta			0.04	0.03			**0.079**
	Actinastrum						
	Ankistrodesmus	0.17	0.09	0.05	0.75	0.28	**1.337**
	Asterococcus	0.03	0.04		0.07		**0.156**
	Botryococcus	0.03			0.34	0.39	**0.779**
	Carteria	0.033					**0.0337**
					0.6118		**0.6118**
	Cerasterius				29		**29**
	Chaetophora	0.13	0.73				**0.876**
	Characium	0.20	0.04				**0.240**
	Chlorella	1.0	0.04	0.03	0.34	0.28	**0.798**
				0.2617			**0.2617**
	Cladophora			12			**12**
		0.04		0.074	0.0560		**0.107**
	Closteriopsis				22		
	Coelastrum	1.0	0.04	0.13		1.12	2.302
	Cosmarium		1.02	0.58	0.618	0.73	**2.935**
	Cylindrocystis	0.07	0.49	0.21			**0.769**
	Dactylococcus	0.23		0.03			**0.302**
	Docidium		0.040	0.03		0.06	**0.131**
	Elakatothrix		0.09	0.13			**0.221**
	Geminella			0.03			**0.031**
	Gleocystis	0.03	1.46	0.92	1.09	0.06	**3.553**
	Golenkinia	0.13					**0.139**
	Hyalotheca		0.27	0.03			**0.308**
	Hydrodactyon	0.07					**0.074**
	Kirchneriella	0.037	0.137	0.057	0.61		**0.832**
	Lagerheimia	0.03		0.10			**0.142**
	Mesotaenium				0.06		**0.062**
	Mougeotia			0.03			**0.031**
	Nephrocytium	0.20	0.62	0.89	0.07		**1.773**
	Nitella	0.36				0.06	**0.42**
	Oedegonium	0.07					**0.074**
	Ooocystis			6.83	6.39	7.73	**21.0**
	Palmella	9.30	4.03			0.06	**13.342**
	Palmodactyon	0.4		0.14			**0.539**
	Palmellococcus	0.72	0.181		1.22		**2.138**

Class	Genus	Date1	Date2	Date 3	Date 4	Date 5	TOTAL
	Pediastrum	1.09		0.05	0.1		**1.283**
	Protococcus		0.044	0.03			**0.079**
	Pseudoulvella		0.75				**0.752**
	Quadrigula	0.044	0.026				**0.808**
	Scenedesmus	0.26	0.22	0.05		0.06	**5.085**
	Schitococcus	3.56					**3.561**
	Schroederia		0.13				**0.133**
	Selenastrum	0.033		0.65	0.14	0.06	**0.881**
	Sphaeriella	0.033					**0.0337**
	Sphaerocystis	0.033					**0.0337**
	Spirogyra	0.10	1.33			0.11	**1.546**
	Spondilosum					0.06	**0.062**
	Stigeoclonium		0.04	0.86	2.10	2.63	**5.659**
	Tetradesmus		0.04			0.11	**0.163**
	Tetraedron	0.165	0.18	0.05	0.07	0.06	**0.523**
	Tetraspora	0.03	0.4				**0.437**

	Volvox	2.57	0.4	0.4		0.11	**3.56**
	Zoochlorella		0.31	0.34		0.06	**0.712**
	Zygnema	0.33	0.44	0.26	0.07	0.06	**1.125**
	Zygnemopsis	0.10	0.8	0.71	1.70	0.50	**3.819**
	TOTAL	**24.50**	**14.34**	**14.50**	**20.9**	**14.629**	**88.811**
Bacillarophyta		0.033	0.4		3.6709	1.794	**5. 907**
	Acnanthes				72		
			0.09	0.036	0.27	0.6162	**1.007**
	Amphora					46	
	Bacillaria		0.300	0.030	0.07	0.11	**0.507**
	Cocconeis	0.03	0.66	0.05	0.68	0.17	**1.603**
	Coscinodiscus		0.13	0.08			**0.217**
	Cyclotella	0.53	0.043	0.03	0.07		**0.676**
	Cymbella	0.4	0.09	0.03	0.34	0.17	**1.026**
	Denticula		0.04	0.105	0.68	0.06	**0.884**
	Epithemia		0.13				**0.133**
	Eunotia		1.0	0.37	1.70	0.95	**3.993**
	Frustulia		0.22	0.24		0.11	**0.574**
	Gomphonema			0.03	0.07	0.11	**0.217**
	Gomphocymbella	0.03					**0.037**
	Gyrosigma	0.032			0.61	6.0	**6.644**
	Hanztchia		0.75	0.55			**1.307**
	Melosira	0.95	2.03	0.293	6.12		**9.48**
	Navicula	0.79	0.97	1.39	2.11	1.79	**7.053**
	Niztchia		0.13	0.76	0.48	0.56	**1.938**
	Opephora	0.03	0.09			0.11	**0.238**
	Pinnularia	0.03	0.4	0.08	0.27	0.50	**1.334**
	Rhaphidonema		0.35			0.11	**0.477**
	Rhoicosphenia	0.03	0.09		0.07		**0.194**
	Rhopalodia	0.03	0.04				**0.085**

Class	Genus	Date1	Date2	Date 3	Date 4	Date 5	TOTAL
	Strauroneiss	0.07	0.09	0.45	1.97	2.13	**4.79**
	Synedra	0.43	0.04	1.15	1.43	2.19	**5.237**
	TOTAL	**3.42**	**8.10**	**5.63**	**20.60**	**17.50**	**55.238**
Rhodophyta	*Erythrotrichia*		0.04	0.11			**0.152**
	Porphyridium				0.07	0.45	**0.526**
	TOTAL		**0.04**	**0.12**	**0.07**	**0.45**	**0.673**
Pyraphyta	*Ceratium*	19.6	14.11	14.9	9.04	15.35	**73.07**
	Closterium	0.033	0.09	0.08	0.27		**0.476**
	Glenodium	0.07	0.23				**0.331**
	Peridinium	19.10	13.67	15.65	6.59	16.41	**71.423**
		0.79	1.54	2.01	2.2433	0.11	**6.712**
	Straustrum				72		
	Cystodinium		0.04	0.026			**0.0709**
	TOTAL	**39.58**	**29.74**	**32.64**	**18.158**	**31.88**	**151.98**
Euglenophyta		0.461	0.31	0.11			**0.884**
	Euglena						
	Phacus	0.07	0.13	0.05		0.22	**0.483**
	Trachelomonas	0.96	0.89	1.94	0.20	2.6	**6.565**

	TOTAL	**1.48**	**1.33**	**2.09**	**0.20**	**2.80**	**7.91**
Crysophyta	*Characiopsis*	0.56	2.66	0.03			**3.241**
	Chlosteriopsis		0.03				**0.03**
	Chrysidiastrum	1.35		2.43		1.18	**4.965**
	Dinobryon	0.17	8.98	4.95	0.61	2.97	**17.673**
	Goniochloris	0.10					**0.10**
	Mallomonas	0.07					**0.074**
	Pleurogaster	0.03					**0.10**
	Synura	0.10					**0.10**
	TOTAL	**2.40**	**11.64 7**	**7.41**	**0.61**	**4.15**	**26.208**

Table 2: Spatial Variations in Relative Abundance of Various PhytoplanktonGenera in Chebara Reservoir over the Study Period

		Abundance						
Class	**Genus**	**Stn 1**	**Stn 2**	**Stn 3**	**Stn 4**	**Stn 5**	**Stn 6**	**Total**
Cyanophyta	*Anabaena*	0.19					0.05	**0.24**
	Anabaenopsis	0.71		0.78	0.05	0.12	0.9	**2.57**
	Aphanocapsa	0.67	0.32	1.45	0.11	3.67	0.12 54	**6.31**
	Aphanothece	0.19	2.15		1.60	2.01	1.86	**7.80**
	Chroococcus	9.67	3.11	4.46	3.038	1.67	0.38	**22.30**
	Coelosphaerum	0.33	0.18	0.27	1.12	0.17	1.38	**3.46**
	Coenococcus	0.05	0.32	0.20	0.32	0.17	1.33	**2.38**
	Cyanercus		12.70	0.16			0.27	**13.12**
	Dactylococcopsis		0.18	6.41	7.5	5.4	4.41	**23.95**
	Glaucocystis	0.05		0.39		0.06	1.65	**2.14**
	Gleocapsa	2.24		1.49	1.12	1.95	1.81	**8.59**
	Gleothece	0.29						**0.29**
	Holopedium			0.08				**0.08**
	Microcystis	6.00	6.03	5.71	12.40	14.17	8.81	**53.10**
	Merismopedia	1.10	0.82	0.94	1.44	1.04	2.02	**7.34**
	Nostoc		1.51	0.04			1.27	**2.82**
	Oscillatoria	1.19		1.84	0.48	3.21		**6.71**
	Schizothrix					0.06		**0.06**
	Synechococcus			0.16	1.38		0.16	**1.70**
	Synechocystis	0.43		0.12				**0.55**
	TOTAL	23.10	27.32	24.48	30.556	33.68	26.3 8	**165.5**
Chlorophyta	*Actinastrum*	0.10		3.29	0.32			**3.70**
	Ankistrodesmus	3.29	0.09	0.12	0.05		0.58	**4.13**
	Asterococcus		0.09	0.04	0.59		0.05	**0.77**
	Botryococcus	0.05						**0.05**
	Carteria		0.05		0.05			**0.10**
	Cerasterius					0.12	0.05	**0.17**

Chlamydomonas	3.39			0.1			**3.39**
Chaetophora	0.86	0.41	0.23		0.06	0.11	**1.67**
Characium		1.55	2.46	0.32			**4.34**
Chlamydomonas				0.05			**0.05**
Chlorella	0.33	0.05				0.32	**0.70**
Cladophora						0.53	**0.53**
Coelastrum	0.05				0.06	0.64	**0.74**
Cosmarium		0.09	0.43	0.21	0.17	0.96	**1.86**
Cylindrocystis	1.10	0.69	0.47	0.69	0.23	0.58	**3.75**
Dactylococcus		0.05	0.31	0.05	0.06		**0.47**
Docidium	0.33			0.05		0.05	**0.44**
Elakatothrix	0.05		0.20	0.05			**0.30**
Geminella	0.10						**0.10**
Gleocystis		0.05	0.04		0.29	0.80	**1.17**
Golenkinia	2.62	0.46					**3.08**
Hyalotheca		0.18	0.04	0.32		0.27	**0.81**
Hydrodactyon			0.08				**0.08**
Kirchneriella					0.06		**0.06**

Table 2 (Contd.): Spatial Variations in Relative Abundance of Various Phytoplankton Genera in Chebara Reservoir

		Abundance						
Class	**Genus**	**Stn 1**	**Stn2**	**Stn3**	**Stn4**	**Stn5**	**Stn6**	**Total**
	Lagerheimia	0.62	0.05		0.21			**0.88**
	Mougeotia	0.05						**0.05**
	Nephrocytium	0.10		0.27	0.11	0.12	0.64	**1.23**
	Nitella	0.95	0.55	0.08	0.11			**1.69**
	Oedegonium	0.19	0.18					**0.37**
	Ooocystis	0.10		9.27	6.65	0.29	8.39	**24.69**
		5.00	10.7			0.52		**16.25**
	Palmella		4					
	Palmellococcus	0.05		0.74	0.05	0.12		**0.96**
	Palmodactyon	0.43	0.59					**1.02**
	Pediastrum	0.19		0.16	0.11		0.11	**0.37**
	Protococcus	1.38						**1.38**
	Pseudoulvella	0.10				0.69	0.27	**1.05**
	Quadragula			0.20	0.59	0.06		**0.84**
	Radiofilum	0.10	0.27					**0.37**
	Scenedesmus	0.05			2.39			**2.44**
	Schitococcus	0.67	0.23	1.84			0.96	**3.69**
	Schroederia		2.79	0.04				**2.83**
	Selenastrum	1.05	0.14		0.16	0.06		**1.40**
	Sphaeriella			0.04			0.11	**0.15**
	Sphaerocystis							
	Spirogyra			0.04	0.11		0.05	**0.20**
	Spondilosum	0.05					1.65	**1.69**
	Stigeoclonium	0.05	0.05	0.94	0.80	1.32		**3.15**

	Tetradesmus	1.43	0.64	0.12			0.32	**2.50**
	Tetraedron			0.04	0.16	0.06		**0.26**
	Tetraspora	0.10	0.27			0.52		**0.88**
	Volvox	0.71	0.46	2.31	0.48	0.06	0.06	**4.07**
	Zoochlorella		0.46	0.16	0.11		0.53	**1.25**
	Zygnema	0.86	0.27	0.12	0.16	0.12	0.27	**1.79**
	Zygnemopsis	0.95	0.96	0.43	0.85	0.57	0.21	**3.98**
		24.00	**22.4**	**24.4**	**15.9**	**5.50**	**18.4**	**110.4**
	TOTAL		**0**	**8**	**1**		**7**	**5**
Bacillarophyta		0.57			1.38			**1.96**
	Acnanthes			0.04		3.26	0.05	**3.36**
	Amphora						3	
	Bacillaria	0.33	0.09	0.23		0.92	0.27	**1.84**
	Cocconeis	0.38		0.20	0.75		0.16	**1.48**
	Coscinodiscus	0.19				0.06	0.11	**0.35**
								56
Cyclotella			0.37	0.35			0.11	**0.82**
Cymbella		0.19	0.14	0.35	0.27		0.11	**1.05**
Denticula		0.05			0.11	0.17	0.53	**0.86**
Epithemia						0.17		**0.17**
Eunotia		0.19	0.59	0.70	1.54	0.80	1.06	**4.90**
Frustulia		0.10	0.14		0.27	0.17		**0.67**
Gommphocymbella							0.05	**0.05**
Gomphonema				0.04			0.16	**0.20**
Gyrosigma		0.05		0.08	0.48	0.23	0.53	**1.36**
Hantchia		1.81						**1.81**

Table 2 (Contd.): Spatial Variations in Relative Abundance of Various Phytoplankton Genera in Chebara

		Abundance						
Class	**Genus**	**Stn 1**	**Stn2**	**Stn3**	**Stn4**	**Stn5**	**Stn6**	**Total**
	Melosira	0.86	0.91	2.78	3.51	4.35	1.70	**14.11**
	Navicula	1.76	2.06	0.20	0.11	0.12	2.92	**7.15**
	Niztchia	0.38		0.90	0.21	0.75	0.05	**2.29**
	Opephora	0.05	0.73			0.11	0.11	**1.00**
	Pinnularia	0.10	0.18	0.51			0.43	**1.21**
	Rhaphidonema			0.08	0.27	0.06	0.05	**0.45**
	Rhoicosphenia	0.05		0.16				**0.20**
	Rhopalodia		0.05	0.04				**0.08**
	Strauroneiss	1.14	0.27		0.69	3.78		**5.89**
	Synedra	0.76	1.19	2.82	0.11		1.91	**6.78**
		8.95	**6.72**	**9.46**	**9.69**	**14.9**	**10.3**	**60.06**
	TOTAL					**5**	**0**	
Rhodophyta	*Erythrotrichia*	0.1		0.12				**0.22**
	Porphyridium	0.05		0.31				**0.36**
	TOTAL	**0.15**		**0.43**				**0.58**
Pyraphyta	*Ceratium*	14.62		11.18	18.52	19.93	14.6	**78.85**
	Closterium	0.14	0.05		0.05	0.06		**0.3**

	Cystodinium	0.1	1.6					**1.7**
	Glenodium		13.43	0.08			0.27	**13.78**
	Peridinium	16.9	0.09	10.05	17.35	18.6	16.9	**79.99**
				5	5	7	3	
	Straustrum	2.86		0.31	1.01	1.09	1.6	**6.87**
	TOTAL	**34.62**	**15.17**	**21.62**	**36.93**	**39.75**	**33.4**	**181.49**
Euglenophyta	*Euglena*	0.05		0.23	0.16	0.06	0.74	**1.24**
	Phacus		0.09	0.12	0.11	0.06	0.16	**0.54**
	Trachelomonas	0.95	1.19	0.43	1.06	2.06	3.13	**8.82**
	TOTAL	**1.00**	**1.28**	**0.78**	**1.33**	**2.18**	**4.03**	**10.60**
Crysophyta	*Characiopsis*			0.31	0.05		3.13	**3.49**
	Chlorellidiopsis		0.05	0.31			0.16	**0.52**
	Chrysidiastrum	0.05	9.78					**9.83**
	Dinobryon	3.48		13.26	1.01	1.89	1.91	**21.55**
	Goniochloris		0.14					**0.14**
	Mallomonas						0.11	**0.11**
	Pleurogaster			0.05	1.06			**1.11**
	Synura		0.09	0.04				**0.13**
	TOTAL	**3.53**	**10.06**	**13.97**	**2.12**	**1.89**	**5.31**	**36.88**

Table 3: Temporal and Spatial Variations in Abundance, Dominance, and Evenness and Diversity Indices for Phytoplankton in ChebaraReservoir over the Study Period

Sampling Dates	**December**	**February**	**March**	**April**	**June**
No .of Genera	86	90	78	56	58
Abundance	3037	2260	3821	1471	1785
Dominance	0.096	0.068	0.079	0.068	0.85
Evenness	0.38	0.42	0.37	0.43	0.39
Shannon diversity	3.02	3.27	3.05	3.11	2.91
Stations	**1**	**2**	**3**	**4**	**5**	**6**
No. of Genera	80	63	76	66	58	79
Abundance	2100	2189	2557	1879	1746	1884
Dominance	0.07	0.09	0.07	0.1	0.11	0.08
Evenness	0.42	0.38	0.40	0.39	0.37	0.42
Shannon diversity	3.23	2.93	3.17	2.92	2.77	3.16

Species diversity and richness were high on both temporal and spatial scales, although mean spatial abundance was slightly lower than temporal abundance (Table3). Species evenness and dominance were low for sampling dates and stations, indicating heterogeneity and patched distribution of phytoplankton.

Phytoplankton diversity and abundance were higher in December, March and February (Table 3), and at stations 3, 2 and 1 in that order. At station 3, nutrient input from farm and could have been a factor in stimulating phytoplankton development.

DISCUSSION

The results from the study show that phytoplankton assemblage in Chebara reservoir was heterogeneous on both temporal and spatial scales. Some processes, which include wind action, seasonal changes in temperature, external hydraulic loads, light availability and nutrient dynamics are some of the factors which influenced phytoplankton community periodicity in Chebara reservoir. Wind, rain and cloudiness, and meteorological and hydrological events, such as water inputs and withdrawal, and water level fluctuations, act on time periods of days to weeks (Gasse, *et al*., 1983; Nwanko, 1996; Huszar *et al*.,2000). Depending on their intensity and frequency, these processes may drive non-equilibrium dynamics and enhance the species diversity of the ecosystem (Margalef, 1958).

In very large lakes and reservoirs, the phytoplankton community patchiness may result from water masses of different chemical status and effect of water curents (Dufour*et al*., 2006; Reynolds, 2006). However, in small water bodies the horizontal variation in phytoplankton community composition is slight with the greatest difference in the shallow littoral region where there is the possibility of input from benthic flora, and in the inflow region where the new water may contain species from the inflow (Scheffer, 1998).

Phytoplankton diversity and abundance were higher in December, March and February in that order. This corresponded with dry seasons during which light intensity and transparency are high, and possibly with high flushing rates (Floder and Burns, 2005). During the dry period, reduced water level in the reservoir seems to be a key factor controlling the access of sediment nutrients by phytoplankton ((Chalar & Tundisi , 2001).

Phytoplankton diversity and abundance were higher at stations 3, 2 and 1 in that order (Figure 3). At station 3, nutrient input from farm and could have been a factor in stimulating phytoplankton development. Agricultural activities around a catchment can contribute significantly to phosphorus load via erosion ((Chalar & Tundisi, 2001). However, at station 1, high transparency, and possibly high flushing rates could contribute to high phytoplankton diversity and abundance (Floder and Burns, 2005).

Phytoplankton abundance and diversity were lowest at stations 2 (Table 2and3). Both stations were shaded by dense vegetation in the littoral zone and protected from wind action. In water columns with low transparency, light limitation forces competition and maintains phytoplankton diversity under natural regimes of light fluctuations (Huisman *et al,* 1999a, Floder and Burns, 2005). In stable aquatic ecosystem, species with the lowest critical light intensity will exclude all others (Floder and Burns, 2005). Under high flushing rates as in station 6 (table 2), in-lake processes are weak, and the biomass is maintained low but dominated by species adapted to permanent water mixing, high turbidity and low retention time (Reynolds, 1993).

Species evenness was low for both sampling stations and dates. Different phytoplankton genera only showed patchiness on spatial scales, with no significant difference in spatial phytoplankton abundance. In stable ecosystems, phytoplankton densities are low, and diversity values are moderate and correspond to species limited to light and retention time (Roelke and Buyukates, 2002). However, as conditions become favorable, community abundance increases and diversity reaches maximum, until where resource competition sets in.

Seasons are also a major agent of change in the structure of phytoplankton communities. Seasons bring about fluctuations in various environmental factors including temperature, salinity, conductivity, pH and available nutrients that determine phytoplankton growth patterns (Harris, 1996). There was significant difference in seasonal phytoplankton abundance, with a peak observed in December, March, and February. These were dry months and probably reflected the effect of high light intensities on algal photosynthesis and growth (Heaney *et al*., 1995). The month of March also marked transition between dry and wet seasons, which could bring changes in nutrient inputs.

Different phytoplankton classes attained peak abundance at different times. Cyanophytes were highest in number in December 2007 but their abundance decreased in the wet seasons. Chlorophytes reached their peak in February and April 2008, while diatoms and euglenophytes reached their peak in April 2008. Crysophytes and dinoflagellates showed seasonal succession such that while crysophytes were abundant in March, dinoflagellates showed higher populations in wet seasons. Droughts and floods tend to switch fresh water bodies between cyanophytes which either regulate their buoyancy or float to diatoms-

which sink rapidly (Harris, 1995). The first three months of sampling corresponded with the dry season when discharge into the reservoir was lowest. There is little or no water input; therefore, nutrients concentrations are also low and the reservoir remained generally clear. Dinoflagellates such as *Ceratium* and *Peridinium*, and chloropytes such as *Scenedesmus*, *Ankistrodesmus*, *Pediastrum*, *Cosmarium*, *Selenastrum*, *Zygnema*and *Chlorella* which are adapted to low nutrient conditions flourish in dry season (Huisman , 1999a, Roelke and Buyukates, 2002).

CONCLUSION

Phytoplankton assemblage at Chebara reservoir was heterogeneous throughout the study period, although there were distinct temporal and spatial surges and disappearances. Whereas diatoms dominated the colder nutrient rich waters (as at station 6), the green algae were more abundant in warmer oligotrophic and open waters, and dinoflagellates were more uniformly distributed in all stations. The productivity of the reservoir was low (approx. 0.8 µg millilitre^{-1}), which is similar to many tropical oligotrophic reservoirs. In small water bodies the variation in composition is usually slight with the greatest difference in the shallow littoral region, where there is the possibility of contamination from benthic flora and in the inflow region where the new water may contain species washed from the inflow. The reservoir is also characterised by narrow litoral and sublitoral zones, but an extensive profundal zone. This reservoir generally supports majority of green algae and diatoms, but very few cells of each species, giving low standing crop.

RECOMMENDATIONS

This study provides the first limnological information on Chebara reservoir, and can form a basis for further research on the reservoir. The results of this study can be further used to investigate the cumulative and long term effects of such factors as climate change, catchment land use and river impoundment on the algal evolution.

ACKNOWLEDGEMENT

I wish to thank my supervisors, Professor Augustino Onkware of Department of Biological Sciences and Professor Julius O. Manyala of Department of Fisheries and Aquatic Sciences, both of University of Eldoret for academic guidance. I also wish to acknowledge the staff of Departments of Fisheries and Aquatic Sciences and Biological Sciences of University of

Eldoret, and Eldoret Water and Sanitation Services (ELDOWAS) Company Ltd. for their technical assistance.

REFERENCES

1. Agawin, N., Duarte, C. and Agustı´, S. (2000), Nutrient and temperature control of the contribution of picoplankton to phytoplankton biomass and production.
2. Allan J.D. (2004) Landscapes and river scapes: the influence of land use on stream ecosystems. *Ann*. *Rev*. *of Ecol. and Syst*. 35:257–284.
3. Blom G., van Duin E.H.S. and Lijklema L. (1994) Sediment resuspension and light conditions in some shallow Dutch lakes. *Wat*.*Sci*. *and Tech*.30:243–252.
4. Bowling, L. C, and Baker, P. D. (1996) Major cyanobacterial bloom in the Barwon-Darling River, Australia, in 1991, and underlying limnological conditions. *Mar*.*Freshwat*.*Res*.47:643–657.
5. Chalar, G., Tundisi, J.G., 2001. Phosphorus fractions and fluxes in the water column and sediments of a tropical reservoir (Broa – SP). *Int. Rev. Hydrobiol.* 86: 183–194.
6. Eloranta, P. A. and Soininen. Ecological Status of Finnish Rivers Evaluated using Diatom Indices-*Verh*. *Intnat*.*VereinLimnol*. In press (2001).
7. Harpley-Wood, C.M. (1976) Vertical migration patterns inn phytoplankton of mixed species composition. *Phycol. J*. 11: 355-69.
8. Harris, G.P., 1996: Catchments and Aquatic Ecosystems: Nutrient ratios, flow regulation and ecosystem impacts in rivers like the Hawkesburry – Nepean, CRC for freshwater Ecology, Discussion Paper.
9. Heaney, S.I., Parker, J.E., Butterwick, C. and Clarke, K.J., (1996) 'Interannual variability of algal populations and their influences on lake metabolism '*Freshwater Biology*: 35:561-578.
10. Hecky, R.E. and, Kling, H.J. (1981). The phytoplankton and protozooplankton of the euphotic zone of Lake Rev. Biol. Trop. (Int. J. Trop. Biol. ISSN-0034-7744) Vol. 57 (4): 1009-1025, December 2009 1025 Tangayinka: species composition, biomass, chlorophyll content and spatio-temporal distribution. *Limnol*. *Oceanog*.26:: 548-564.
11. Iban˜ ez, M. S. R. (1998) Phytoplankton composition and abundance of a central Amazonian floodplain lake. *Hydrobiol*. 362: 79–83.

12. Kalff J. (2002) *Limnology: Inland Water Ecosystems.* Prentice Hall Inc. Upper Saddle River, NJ.
13. Land Update (2006) A survey into the management and use of wetlands in Kenya.Newsletter of Kenya Land Alliance5 (1) : 1-16.
14. Lewis, W.M.: 1986: A compositional phytogeographical and elementary structural analysis of phytoplankton in a tropical lake, Lake Lanao, Phillipines. *J. Ecol*. 66:213-26.
15. Li J., Herlihy A., Gerth W., Kaufmann P., Gregory S., Urquhart S. and Larsen D.P. (2001) Variability in stream macroinvertebrates at multiple spatial scales.*Freshwat*. *Biol*.46:87–97.
16. *Limnol*.*Oceanogr*.45:591–600.
17. Margalef, R. (1976) *Limnology of the Spanish Reservoirs.* Publication No. 123, Centro de EstudiosHidrograficos,Madrid, Spain.
18. Mustapha, M. K. (2009) Assessment of the water quality of Oyun Reservoir Offa, Nigeria, using selected physico-chemical parameters. *Turk.J.Fish. Aquat.Sci*. 8: 309-319.
19. Nwanko, D. I. (1996) Phytoplankton diversity and succession in Lagos Lagoon, Nigeria.Arch. *Hydrobiol*. 135: 529–542.
20. Phlips, E. J., et al. (1997) Relationship between phytoplankton dynamics and the availability of light and nutrients in a shallow sub-tropical lake. *J. Plankt*. *Res*.19: 19–342.
21. Pirlot, S., et al. (2005) Abundance and biomass of heterotrophic micro-organisms in Lake Tanganyika. *Freshwat. Biol*., 50, 1219–1232. (Corrigendum: correction of biomass estimates for heterotrophic micro-organisms in Lake Tanganyika.*Freshwat*. *Biol*.51:984–985).
22. Platt, T. and Denham, K. (1980) Patchiness in phytoplankton ecology. *Can*. *Bull*.*Fish*.*Aquat*. *Sci*.210:1-346.
23. Prescott G. W. (1954) *How to Know Freshwater Algae*. Brown Co.,Dubuque, IA.
24. Reynolds, C. S. (1984) *The Ecology of Freshwater Phytoplankton*. Cambridge University Press, Cambridge.
25. Reynolds, C.S., 2001. Emergence in pelagic communities. *Scie*. *Mar*. 65, 5–30.

26. Sarmento, *et al.* (2008) Abundance and distribution of picoplankton in tropical, oligotrophic Lake Kivu,eastern Africa. *Freshwat*.*Biol*. 53, 756–771.-13.
27. Scheffer M. (1998) *Ecology of Shallow Lakes*.Chapman and Hall, London.pp. 357.
28. Soininen, J. And Niemala, P. Inferring Phosphorus levels in rivers from benthic diatoms using weighted averaging-*Arch*. *Hydrobiol*. In press (2001).
29. Sole´, R.V., Bascompte, J., (2006). *Self-organization in Complex Ecosystems*. Princeton University Press, Princeton, NJ.
30. Sterner, R. W. and Elser, J. J. (2002). *Ecological Stoichiometry. The Biology of theElements from Molecules to the Biosphere*. Princeton University Press, Princeton,New Jersey, pp. 466.
31. Sweeney, B.M. and Burgese, M.B. (1989). A circadian rhythm in cell division in a prokaryote: the cyanobacterian*Synechococcus* WH 7803, *J. Phycol*., 25,183-86.
32. Talling J. F. and Talling I. B. (1965) The chemical composition of African lake waters.*Int. Rev*.*Hydrobiol*.50:1-32.
33. Wetzel, R.G. (1999) Biodiversity and shifting energetic stability within freshwater ecosystems. *Arch*. *Hydrobiol*. *Spec*. *Issues Advances in Limn*. 54: 19-32.
34. Wilson, J. B. (1994) *The ‘‘Intermediate Disturbance Hypothesis’’*ofspecies coexistence is based on patch dynamics. N. Z. *J*. *Ecol*. 18: 176–181.
35. Zohary, T., Pais-Madeira, A. M., Robarts, R. D. K. et al. (1996) Interannual phytoplankton dynamics of a hypertrophic African lake. *Arch*. *Hydrobiol*. 136:105–126.