Relation between phytoplankton composition and abundance and physicochemical characteristics of Chepkanga Dam, Eldoret, Kenya

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Abstract

Physicochemical characteristics and phytoplankton species composition and abundance (chlorophyll-*a* concentration) were measured in Chepkanga Dam during the months of November and December (2007) and February (2008); all sampling months being within the dry season. Three sampling sites (A, B and C) were selected to correspond to different anthropogenic impacts. Triplicate water samples were collected twice per month and analysed in the laboratory (chlorophyll-*a*; phytoplankton species and dissolved oxygen and reactive phosphorus concentrations). *In situ* measurements of water temperature and pH also were taken at the same sampling sites. A total of 39 phytoplankton species were identified, including 15 Bacillriophyceae species, 12 Chlorophyceae species, 7 Desmidiaceae species and 5 Cyanophyceae species. A two-way ANOVA statistical analysis indicated significant differences between months (among stations) for physicochemical parameters ($P < 0.05$), although insignificant changes were observed between stations (among months) ($P > 0.05$). Phytoplankton species (e.g., *Ankistrodesmus falcatus, Staurastrum* sp. and *Pediastrum* sp.) appeared and disappeared between the study months of November to February (Table 1), implying that monthly variations among physicochemical characteristics influenced the phytoplankton abundance, as the different phytoplankton species exhibit different environmental selectivity.

Key words

Chepkanga dam, chlorophyll-*a*, physicochemical characteristics, phytoplankton species.

INTRODUCTION

Although lakes, rivers and other freshwater bodies, including reservoirs and swamps, contain only a very small proportion of the Earth's fresh water, they have played a significant role in the development of human civilization (Lloyd 1992). Water quality is affected by many pollutants that change water temperature, light penetration, pH and electrical conductivity (Kinyua & Pacini 1991). Effluents can affect phytoplankton through their impacts on such water quality variables as dissolved oxygen concentrations on aquatic community changes, water temperature, pH values and nutrient concentrations (Worf 1999). In fact, many industrial effluents are either highly alkaline or highly acidic (Hawks 1979). Bell *et al.* (1991) indicated that water quality characteristics influence phytoplankton abundance, diversity, species richness, distribution and densities, as well as changes in species composition of aquatic communities and high mortality of sensitive life stages of macroinvertebrates (Welch 1980). Thus, the phytoplankton in a dam is an important biological indicator of its water quality (Kuwabara 1984). Although phytoplankton are important primary producers, and the base of the food chain in open water, some species can nevertheless be detrimental to both humans and other vertebrates by releasing toxic substances (hepatoxins; neurotoxins) into the water column (Whitton & Patts 2000). In contrast, the algal density in clean waters can be variable (Archibald 1972). Whitton and Potts (2000) and Wetzel (2001) reported that certain phytoplankton groups, especially blue–green algae, can significantly degrade the recreational value of surface waters by forming surface algal scums, thereby altering its use for contact sports. Large concentrations

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of algae also may cause anoxic conditions in the water column, subsequently leading to fish kills. Although algae forms unique assemblages, based on the existing environmental conditions, each species has a specific niche based on its physiological requirements and environmental constraints (Kuwabara 1984).

Fish populations are remarkably sensitive to primary production at lower trophic levels, there being considerable evidence pointing to a strong link between phytoplankton and fish production (Larkin and Northcote 1969). The final production and biomass of many fish and invertebrates with planktonic larvae are basically determined by the success of the juvenile stages that feed low in the food chain, either on zooplankton or directly on phytoplankton (Weatherly 1972). Muller and Helsel (1999) observed that algae growth is limited by the available supply of phosphorus or nitrogen. Adding excessive quantities of these nutrients to water can result in algae and aquatic plants growing to excessive levels. Studies carried out at Lake Baringo indicated that physicochemical parameters such as temperature and phosphorus have important roles in the life of phytons through the photosynthesis process (Hakan *et al.* 2003). Thus, it is critical to study the dynamics of these plankton, as well as the driving forces behind their population changes. No studies have yet been conducted on Chepkanga Dam to understand the dynamics of its ecosystem, despite its major importance to the status of its riparian communities. Accordingly, this study focused on selected physicochemical parameters, including temperature, pH, dissolved phosphorus and dissolved oxygen concentrations, as well as selected biological parameters, including phytoplankton composition (species) and abundance. The goal is to obtain an overview of the variations of these parameters during the dry season, and their implications regarding phytoplankton species composition and abundance. The findings of this study are important for less-studied small waterbodies such as Chepkanga Dam and should be considered a bench mark for future studies of this type.

MATERIAL AND METHODS

Study area

Chepkanga Dam lies within the permanent riverine Chepkoilel Wetland. With a total area of about 5.6 km^2, the wetland is about 10 km long and approximately 700 m wide at its widest point (Land Update, 2006). The dam is located along a stretch of the Sergoir River (Fig. 1), approximately 12 km from the town of Eldoret along the Eldoret-Iten Road. It lies between the latitude 0° 30′–0° 55′ N and longitude 35° 37′–34° 50′ E (Uasin-Gishu District Development Plan 1994–1996. The dam is a medium-sized man-made dam, with a surface area of about 2 ha and a mean depth of 5.5 m. The water within the dam is generally static in regard to flow, with occasional multi-directional water movements resulting from wind effects. The dam is used for livestock watering, irrigation water abstractions for the Equator Flower Farm and small-scale horticulture production of vegetables and tomatoes by the riparian communities. It also supplies water for livestock and domestic purposes.

Measurement of physicochemical and phytoplankton characteristics

Three sampling sites (A, B, C) were selected to correspond to different anthropogenic activities (Fig. 1). Sites B and C are areas from which riparian communities withdraw water for domestic purposes, whereas site A is an area characterized by livestock watering. Triplicate water samples were collected during the morning hours (10.00–11.00 AM) from every sampling site on a twice monthly basis. The first sampling was carried out at the beginning of the month, and the second around the middle of the month, with this pattern continued throughout all the sampling months. The basis for the sampling time was that, during the morning hours, the water in the dam has minimal disturbance from both the riparian communities and livestock watering. Thus, the results from this sampling period should more accurately characterize the dam waters. For the three sampling sites, the water temperature at a depth of 10 cm was determined with a mercury thermometer (4411 Model). The pH levels were determined with a portable digital pH meter (Model 8519; Clarkson Laboratory & Supply Inc., CA, USA).

Triplicate water samples from each sampling site were collected in 250 and 500 mL polyethylene bottles for analysis of dissolved oxygen and nutrient concentrations, respectively. The sample bottles were carefully filled, with the water being allowed to flow into the bottle through a dispensing tube sufficiently long to reach the bottom of the dam. The water samples were allowed to overflow, thereby flushing the bottle with about twice the sample volume, thereby avoiding the entrapment of air bubbles in the sample. The dissolved oxygen concentration was determined on the basis of the procedure outlined by Stirling (1985).

Water samples for measuring dissolved reactive phosphorus and nitrate concentrations were collected from the three sampling sites, using 500 mL sampling bottles. The spectrophotometric methods outlined by Mackereth *et al.* (1978) were used to determine their concentrations.

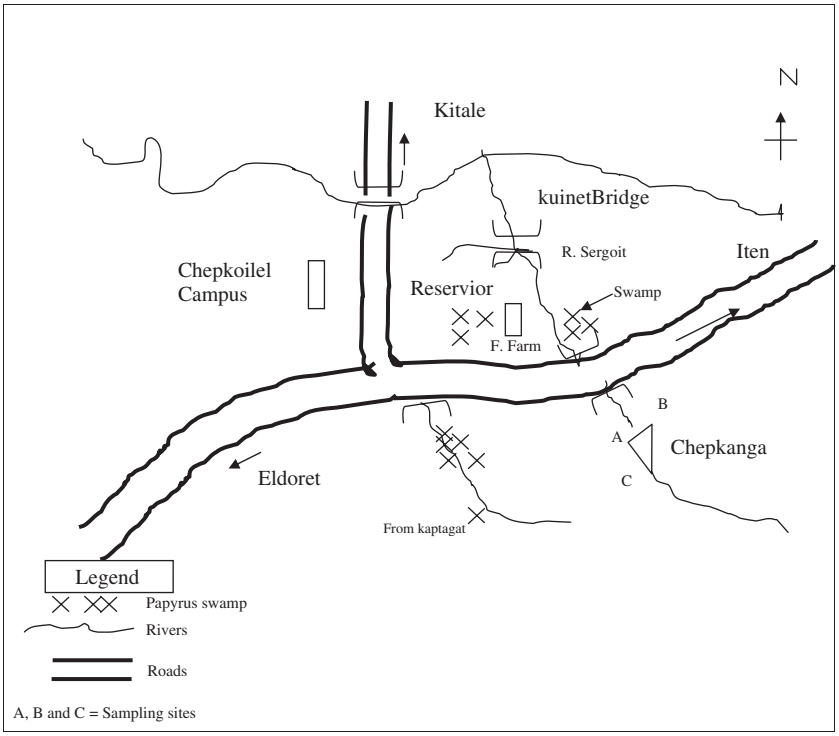

Fig. 1. Location of Chepkanga Dam.

For measuring chlorophyll-*a* concentrations, about 500 mL of water from the sampling sites was filtered through a Whatman GF/C glass fibre, utilizing a filtration unit and suction pump. About 0.2 mL saturated magnesium carbonate ($MgCO_3$) suspension was added to each sample after collection (GEMS, 1992). The light extinction of the chlorophyll-*a* extract was measured with a digital spectrophotometer at wave lengths of 665, 645 and 630 nm. The extinctions were corrected for turbidity by subtracting the corresponding spectrophotometer reading at 750 nm. The corrected value is being used to calculate the chlorophyll-*a* concentration, based on the method of Strickland & Parsons (1968).

For the analysis of phytoplankton species composition, 250 mL of water was collected in a polyethylene bottle and immediately fixed with Lugol's iodine solution. The samples were then left undisturbed for 48 h to allow the particulate matter to settle. The lower water layer (20–25 mL) containing the settled algae was decanted into a glass vial and stored in a cool, dark room for subsequent analysis. The known volume of the concentrated sample was used to identify and count the phytoplankton, utilizing an inverted microscope (IMT-2, Model). The phytoplankton species were identified using methods of Huber-Pestalozzi (1938) and Komárek and Anagnostidis (1986, 1989) for Cyanobacteria, those of Hustent (1942) and Lange-Bertalot and Krammer (1989), Lange-Bertalot (2001) Krammer and Lange-Bertalot (1991) for Bacillariophyceae, those of Ettl (1983) for Chlorophyceae, and those of the APHA (2003), for Demidiaceae.

Statistical analysis of the data was performed with two-way ANOVA (Statistica version 6). The mean values of the water temperature, dissolved oxygen concentration, pH and soluble reactive phosphorus and chlorophyll-*a* concentrations for the sampling sites and months were tested independently for each parameter at a significance level ($\alpha = 0.05$).

RESULTS

A total of 39 phytoplankton species belonging to four families (Cyanophyceae, Chlorophyceae, Bacillariaphyceae and Desmidiaceae) were detected from Chepkanga Dam (Table 1). Out of the 39 species detected, 15 species were diatoms, 12 were green algae, 7 were desmids and 5 were blue–green algae. The phytoplankton abundance for the month of November varied between sampling sites (Fig. 2). The abundance of Bacillariophyceae at sampling site A was 380 cells L^{-1}, 300 cells L^{-1} for sampling site C and 280 cells L^{-1} for sampling site B. The Desmidiaceae abundance for sampling site B was 200 cells L^{-1}. Both Chlorophyceae and Cyanophyceae were present at relatively low abundances (<100 cells L^{-1}) at all three sampling sites, however, during the month of November. During the month of December (Fig. 3), the Chlorophyceae abundance at sampling site A

Table 1. Phytoplankton species in Chepkanga Dam during the dry season

Family	Species	Month		
		November	December	February
Chlorophyceae	*Ankistrodesmus falcatus*	–	–	+
	Bulbochaete sp.	–	–	+
	Cladophora sp.	–	–	+
	Dictyosphaerium sp.	+	+	+
	Kirchneriella malmeana.	–	–	+
	Pediastrum sp.	+	–	–
	Protococcus sp.	+	+	+
	Spirogyra sp.	–	–	+
	Zygnema sp.	+	+	+
	Mougeotia sp.	–	+	+
	Tetraspora sp.	–	–	+
	Closterium sp.	–	+	–
Cyanophyceae	*Aphanizomenon* sp.	–	–	+
	Aphanocapsa sp.	–	–	+
	Coelosphaerium sp.	–	–	+
	Polycystis sp.	–	–	+
	Rivularia sp.	–	–	+
Bacillariophyceae	*Campylodiscus clypeus*	+	–	+
	Cyclotella stelligera	+	–	+
	Diatoma vulgaris	+	+	+
	Eunotia sp.	+	+	+
	Flagilaria sp.	–	–	+
	Gomphonema sp.	+	+	+
	Gyrosigma kutzingii	+	+	–
	Melosira ambigua	+	+	+
	Navicula cuspidata	–	+	+
	Nitzschia sp.	+	+	+
	Pinnularia sp.	+	+	+
	Stephanodiscus sp.	–	–	+
	Surirella sp.	–	–	+
	Synedra sp.	+	+	+
	Tabellaria fanestrata	+	+	+
Desmidiaceae	*Closterium acutum*	+	+	+
	Docidium sp	–	–	+
	Gonatozygon sp.	+	+	+
	Netrium sp.	+	–	–
	Penium sp.	+	–	+
	Spirotaenia sp.	+	+	–
	Staurastrum sp.	–	+	–

was 580 cells L^{-1}, the Cyanophyceae abundance was 300 cells L^{-1} and the Bacillariophyceae abundance was 250 cells L^{-1}, whereas the Desmidiaceae abundance was 200 cells L^{-1}. Both Chlorophyceae and Bacillariophyceae

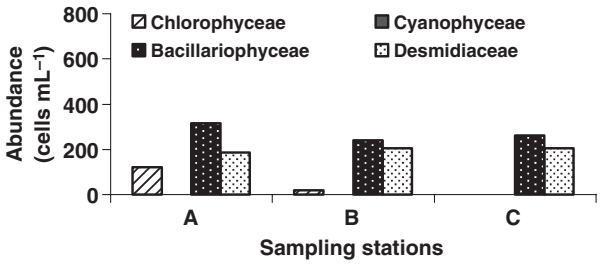

Fig. 2. Phytoplankton abundance during November, 2007.

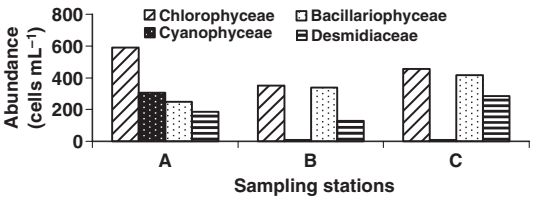

Fig. 3. Phytoplankton abundance during December, 2007.

exhibited a similar abundance (380 cells L^{-1}) at sampling site B, while the Desmidiaceae abundance was 100 cells L^{-1}. For sampling site C, the Chlorophyceae abundance was 500 cells L^{-1}, the Bacillariophyceae abundance was 480 cells L^{-1}, the Desmidiaceae was 250 cells L^{-1} and the Cyanophyceae abundance was <50 cells L^{-1}.

In February (Fig. 4), the Chlorophyceae abundance at sampling site A was 300 cells L^{-1}, the Bacillariophyceae abundance was 280 cells L^{-1} and the Desmidiaceae abundance was 20 cells L^{-1}. The Bacillariophyceae abundance at sampling site B was 320 cells L^{-1}, Desmidiaceae was 200 cells L^{-1} and Chlorophyceae was 100 cells L^{-1}. Both the Chlophyceae and Bacillariophyceae were equally abundant (150 cells L^{-1}) at sampling site C, whereas the Desmidiaceae abundance was <50 cells L^{-1}. The Cyanophyceae abundance was generally low (<20 cells L^{-1}) at all three sampling sites in February.

The highest mean temperatures were recorded for the month of February (20.67 ± 0.167 °C), followed by December (20.00 ± 0.000 °C) and finally November

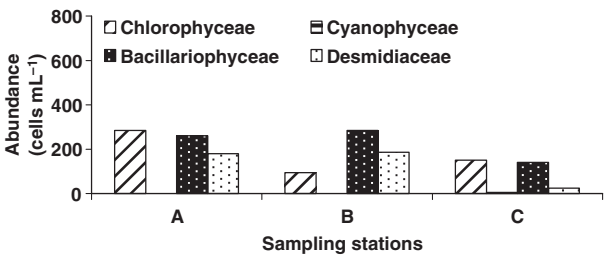

Fig. 4. Phytoplankton abundance during February, 2008.

(18.83 ± 0.167 °C) (Table 2), with a significant variation ($F_{0.05(2,3)}$ = 62; P = 0.00). The mean dissolved oxygen concentration was high during the months of November (11.16 ± 1.172 mg L^{-1}), followed by February (5.98 ± 0.242 mg L^{-1}) and finally December (5.19 ± 1.466 mg L^{-1}), with a significant variation ($F_{0.05(2,3)}$ = 24.77; P = 0.005). The mean pH for February was 9.17 ± 0.289, for December was 6.83 ± 0.439 and for November was 6.67 ± 0.167, with a significant variation ($F_{0.05(2,3)}$ = 16.69; P = 0.011). The mean phosphorus concentration was high during the months of February (0.043 ± 0.003 mg L^{-1}), followed by December (0.036 ± 0.003 mg L^{-1}) and finally November (0.022 ± 0.003 mg L^{-1}), with a significant variation ($F_{0.05(2,3)}$ = 16.57; P = 0.011). The mean chlorophyll-*a* concentrations were high during February (2.074 ± 0.008 μg L^{-1}), followed by November (1.948 ± 0.018 μg L^{-1}) and finally December (1.936 ± 0.032 μg L^{-1}), with a significant variation ($F_{0.05(2,3)}$ = 17.37; P = 0.01).

The mean values for the five estimated parameters at the dam for the three sampling sites (A, B and C) during the whole sampling period (Table 3) indicated that sampling site A had relatively higher temperatures (20 ± 0.58 °C) than sites B (19.83 ± 0.44 °C) and C (19.67 ± 0.60 °C). There were no significant variations in temperature, however, between sampling sites (among months) ($F_{0.05(2,3)}$ = 2; P = 0.25). The dissolved oxygen concentrations were higher for sampling site A (9.273 mg L^{-1} ± 2.01), followed by site C (6.94 ± 1.99 mg L^{-1}) and finally site B (6.047 ± 1.76 mg L^{-1}), although the differences were insignificant ($F_{0.05(2,3)}$ = 6.472; P = 0.557).

Sampling site B exhibited a mean pH value of 7.867 ± 0.63, while that for site A was 7.4 ± 0.67 and site C was 7.2 ± 1.16, with this variation being insignificant ($F_{0.05(2,3)}$ = 0.62; P = 0.58). The dissolved reactive phosphorus concentrations were generally similar for both sites A (0.035 ± 0.67 mg L^{-1}) and C (0.035 ± 0.004 mg L^{-1}), although it was different for site B (0.029 ± 0.63 mg L^{-1}), with no significant variation between sampling sites ($F_{0.05(2,3)}$ = 2.55; P = 0.19). Finally, the chlorophyll-a concentration for site B was 2.015 ± 0.037 μg L^{-1}, while that for site C was 1.994 ± 0.045 μg L^{-1}, that for site A was 1.953 ± 0.056 μg L^{-1}, with no significant variation ($F_{0.05(2,3)}$ = 2.86; P = 0.16) between sampling sites.

DISCUSSION

The present of 39 phytoplankton species in Chepkanga Dam indicated a high phytoplankton species composition, which was not an unexpected result as the dam is located within the tropics, which exhibit a greater heterogeneity of ecological habitats. This observation is relatively similar to that of Hakan *et al.* (2003), who did similar studies for Lake Naivasha. The lower dissolved reactive phosphorus concentrations (0.035 ± 0.004 mg L^{-1}) have significant implications for nutrient dynamics and phytoplankton composition for Chepkanga Dam (Raymont 1980; Paerl & Tucker 1995). However, the observed variations in the pH levels and the dissolved reactive phosphorus and dissolved oxygen concentrations could

Table 2. Physicochemical parameters estimated for the entire Chepkanga Dam during the 3-month study period (expressed as mean value ± standard error)

Months	Temperature (°C)	Dissolved oxygen concentration (mg L^{-1})	pH	Phosphate-phosphorus concentration (mg PO_4–P L^{-1})	Chlorophyll-*a* concentration (μg L^{-1})
November	18.83 ± 0.167	11.16 ± 1.172	6.67 ± 0.167	0.022 ± 0.003	1.948 ± 0.018
December	20.00 ± 0.000	5.19 ± 1.466	6.83 ± 0.439	0.036 ± 0.003	1.936 ± 0.032
February	20.67 ± 0.167	5.98 ± 0.242	9.17 ± 0.289	0.043 ± 0.003	2.074 ± 0.008

Table 3. Physicochemical parameters estimated for three sampling sites during study period (expressed as mean value ± standard error)

Sampling Site	Temperature (°C)	Dissolved oxygen concentration (mg L^{-1})	pH	Phosphate-phosphorus concentration (mg PO_4–P L^{-1})	Chlorophyll-*a* concentration (μg L^{-1})
A	20.00 ± 0.58	9.273 ± 2.01	7.4 ± 0.67	0.035 ± 0.67	1.953 ± 0.056
B	19.83 ± 0.44	6.047 ± 1.76	7.867 ± 0.63	0.029 ± 0.63	2.015 ± 0.037
C	19.67 ± 0.60	6.94 ± 1.99	7.2 ± 1.16	0.035 ± 0.004	1.994 ± 0.045

be a result of interactions, as observed by Whitton and Patts (2000). The homogeneity in the physicochemical parameters between sampling sites (Table 3) is thought to be a consequence of the dam's shallow water depth, and the complete mixing within the water column, the latter being a phenomenon of shallow tropical waterbodies, an observation in agreement with the observations of Schageri and Oduor (2004) for Lake Baringo.

The variations in the composition of the phytoplankton species, with corresponding variations in environmental conditions (i.e., nutrient concentration, temperature, pH, dissolved oxygen concentration), suggest the relative importance of interactions between these factors on phytoplankton can vary considerably among different phytoplankton families (Reynolds 1984a,b; Hakan *et al.* 2003; Wetzel 2001; Roelke & Buyukates (2002)). The interaction of physicochemical parameters is responsible for the appearance and disappearance of phytoplankton species, including *Cladophora* sp., *Closterium acutum*, *Docidium* sp., *Flagilaria* sp., *Kirchneriella malmeana*, *Polycystis* sp., *Rivularia* sp., *Spirogyra* sp., *Stephanodiscus* sp., *Surirella* sp. and *Tetraspora* sp. These species were present during the month of February, while *Netrium* sp. and *Pediastrum* sp. appeared during the month of November (Table 1). There generally was an episodic community change throughout the study period, which was attributable to "new" phytoplankton species ascending to dominance. This alteration could have resulted from several contributing mechanisms, the relative extent of which also is variable (Reynolds 1984a). These include the appearances of "new" species which, as shown in Table 1, could be related to changed environmental selectivity. Furthermore, the disappearance of phytoplankton species (whether through sinking, grazing or death) also is related to the same environmental change (Reynolds 1984a). It is noted that Cyanobacteria typically can proliferate, forming noxious blooms under conditions of nutrient enrichment (eutrophication) As nutrient concentrations were relatively low throughout this study, the abundance of Cyanobacteria also was low, a finding consistent with that of Reynolds (1984a,b). According to Reuter and Petersen (1987), compared to Desmidiaceae, Chlophyceae and Bacillariophyceae, Cyanobacteria have higher requirements for trace elements, which could possibly explain the observations of this study.

According to Kilhalm and Kilhalm (1980), and Sommer (1981), Chlorophyceae exhibit an '*R*' developmental strategy that requires abundant nutrients, less light energy, high reproductive rates and short life cycles. Thus, they cannot compete efficiently with Cyanophytes, which exhibit a '*K*' developmental strategy, therefore being able to survive and bloom, even under conditions of high light intensities and low nutrient concentrations. Cyanophytes also exploit nutrients at the bottom of the euphotic zone by buoyancy regulation of their gas vacuoles (Reynolds 1984b). The phytoplankton species variation observed in this study is attributed to the combination of these unique physiological attributes under different environmental conditions. The phytoplankton composition also depends on the dam's retention time, type and age of waterbody, as well as calm weather conditions with low water turbulences (Bucka & Wilk-Wozniak, 1999).

The wide variations observed for dissolved oxygen concentration, pH and dissolved reactive phosphorus and chlorophyll-*a* concentrations may be due to the fact that the sampling for this study occurred during the early dry/rainy season periods (November, December and February). The possible trends in these parameters during the rainy season remain unclear. The present findings, however, are clear indications of the characteristics of Chepkanga Dam, as the water sampling was conducted during the early hours of the day, when the water column characteristics presumably exhibited few impacts from human disturbances. The significant differences in the values of the study parameters between any 2 months could be attributable to climatic changes between months or seasons (Worf 1999). Marked variations in temperature and rainfall between seasons for tropical systems can influence a waterbody's physicochemical characteristics (Adebisi 1981; Chapman & Kramer 1991; Schageri & Oduor 2004).

This study provides a first limnological description of Chepkanga Dam in Kenya. This study provides initial information on environmental parameters and phytoplankton composition and abundance. This initial study, therefore, can form the basis for further research on Chepkanga Dam, and the results provided herein should be validated and used as benchmarks for managing the impacts of human activities with the dam's watershed.

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