integrity Research Journals

Global Journal of Earth and Environmental Science
Volume 7(2), pages 19-31, April 2022
Article Number: BBF618541
ISSN: 2636-6002
https://doi.org/10.31248/GJEES2022.120
https://integrityresjournals.org/journal/GJEES

Full Length Research

Spatial-temporal composition, abundance and diversity of algal communities in River Malewa of Lake Naivasha Ramsar Basin, Kenya

Beatrice. N. Obegi[1,2]*, James Njiru[3], Albert Getabu[2] and Zippora Gichana[2]

[1]Kenya Marine and Fisheries Research Institute, Naivasha, Kenya.
[2]Departments of Aquatic and Fishery Sciences, Kisii University, Kenya.
[3]Kenya Kenya Marine and Fisheries Research Institute, Mombasa, Kenya.

*Corresponding author: Email: obegibeatrice@gmail.com

Received 21st February, 2022; Accepted 23rd March, 2022

ABSTRACT: Algae and algal communities are potentially vulnerable to climate change and consequently can be depleted or be extinct hence the current debate on global biodiversity. Using a 30 µm phytoplankton net, triplicate samples were picked monthly from 10 stations in River Malewa from November 2020 to December 2021. A total of 360 samples were picked the whole study period. The study examined taxonomy, composition, abundance, diversity, and distribution. Counting and identification was done using Sedwick- rafter cell counting chamber with a Binocular compound microscope. Results indicated 89 species of phytoplankton were identified. 86 species were identified in the river while additional 3 more species were identified in the lake. Bacillariophyceae (Diatoms) dominated in lotic sites with 50%, Cyanophyceae was 17%, Chlorophyceae 16% and Myxophyceae was 6% while the least dominant was Euglenophyceae with 4%, Chrysophyceae (3%), Xanthophyceae, Rhodophyceae and Dinophyceae with 1% each. Two points at the lake showed a high dominance in Chlorophyceae with 63%, Xanthophyceae 21% and Chrysophyceae 14%, while Bacillariophyceae was 1% and the rest of the groups were 0%. The abundance showed RM1 and RM4 had abundance of 4.8 x 10^5 cells/mm^3. Site RM9 and RM10 being lacustrine recorded highest abundance with 1.24 x 10^6 and 1.29 x 10^6 respectively. RM3 recorded abundance of 6.2 x 10^5 cells/mm^3, RM3 was 7.3 x 10^5 cell/mm^3 and RM5, RM6, RM7 and RM8 recorded abundance of 8.5 x 10^5, 9.2 x 10^5, 7.5 x 10^5 and 7.9 X 10^5 cell/mm^3 respectively. High value of Shannon-Wiener's index (H ') was recorded in RM6 (1.556), followed by RM4 (1.521), RM7 (1.504), and lowest was RM 10 (1.141), RM5 (1.299), RM1 (1.398), RM3 (1.403), RM2(1.474) and RM8 (1.473). Management issues and effects of existing human pressures, such as damping, urbanization and nutrient enrichment on river ecosystems should be studied to fill gaps in knowledge on phytoplankton monitoring on rivers and streams.

Keywords: Abundance, algae, composition, distribution, River Malewa, spatial-temporal.

INTRODUCTION

Studies on lotic systems (rivers and streams) have been long omitted or poorly studied comparing the lentic systems (lakes and reservoirs) which have been extensively studied. Riverine ecosystems have high flow rate and velocity; this can be the reason of scanty information. For instance, river Malewa has less literature compared to Lake Naivasha Basin which has been extensively researched. The spatial and temporal pattern and community of phytoplankton are very crucial in understanding ecosystem functioning which reflects major

shifts in changes of environmental factors (Effendi *et al.*, 2016). In lotic systems, contributions to environmental factors is obvious but main factors that contribute to phytoplankton in rivers is unclear. Diversity and distribution usually indicate the status of ecological ecosystems (Indrayani *et al*., 2018; Omondi *et al*., 2021), higher algal biomass and phytoplankton distribution is related to aquatic productivity and so phytoplankton diversity shows the characteristic of the ecosystem habitat. Historically, rivers have served as sources of drinking water, fisheries resources, transportation routes, irrigation supplies, and waste removal systems. In addition, human civilization has many major effects on rivers, dating back more than 5000 years when Egyptians built dams on the Nile to supply water for crops and human consumption (Breuer *et al.*, 2017; Lodang and Kurnia, 2019; Norton et al., 1996; Wehr and Descy, 1998). Today, management of large rivers requires a balance between human needs and ecological integrity, although until quite recently, ecological principles have played a minor role in river management (Huang *et al*., 2004).

Rivers, as in other aquatic systems, primary productivity is generated by phytoplankton. Phytoplankton are primary producers in the food chain, acting as a source of food or primary energy in the ecology of freshwater systems (Leland, 2003; Reavia *et al*., 2010). The study established composition, distribution, abundance and diversity of algae to help in conservation and management. The hypothesis indicates that different species distribution and diversity of phytoplankton in the ten sampling points are uniform. This study focuses on how the phytoplankton growth in rivers can be used in management and growing need for ecosystem protection. Multivariate multiple regression was used to simultaneously analyze multiple species of phytoplankton data collected from the River Malewa belt between November 2020 and December 2021. This paper investigated the phytoplankton diversity, distribution, composition and patterns of assessed groups for a period of one year (November 2020-December 2021) in river Malewa catchment to downstream to the lower catchment. The objectives of the study were to: (1) describe the distribution patterns and biomass of algal communities; (ii) determine the relationship between phytoplankton and selected nutrients; and (iii) identify potential algae species that may act as indicators that affect water chemistry.

METHODS AND METHODS

Study area

River Malewa is located 0˚37' S and 36˚15 E with two tributaries, Wanjohi at the right and Turasha at the left wing (Figure 1). The Malewa River catchment of 1,730 square kilometers (670 sq mi) provides about 90% of the water flowing into Lake Naivasha, (Cheruiyot *et al*., 2018).

Sampling design

Ten sampling sites were identified with a belt of River Malewa. These were two sites from the eastern tributary of River Malewa; Malewa source (RM1), Wanjohi (RM2), Kalaou Malewa (RM3), Nyairoko (RM4), Bush Ventures (RM5), Gatundu (RM6), Karori (RM 7), Malewa Bridge (RM 8), River Mouth (RM 9) and Midlake (RM 10) (Figure 1).

Sampling depended on the size of the river and how deep the river fluctuated monthly. However, the flow rate also played a role to determine the sampling. In months when water is not deep and the water is not fast moving, the water is accessible and easy grab of the sample.

Sampling was done monthly from September 2020 to September 2021.Three points were picked and measured in ten sites making a total of sample size of thirty-six every month. A total of 360 samples were analysed for each parameter. Plankton sample was taken by filtering 40L river water through a plankton net of 30 μm^2, and the filtered water was then stored in a 200 mL bottle. Furthermore, the filtered water was fixed with lugol and brought to the laboratory to be identified and analyzed (Hastuti *et al*., 2018). Phytoplankton identification and analysis were carried out in the Laboratory at Kenya Marine Research Institute (Cellamare et al., 2010; Bellinger and Sigee, 2010).

The phytoplankton was identified and abundance of each was calculated , species diversity and dominance were determined, analysis was done using a multivariate, the abundance calculated (Bellinger and Sigee, 2010) using plankton identification book.

Diversity and dominance were calculated using Shannon and Wiener Index as shown by the formula below:

$$H' = \sum_{i=1}^{n} pi\ In\ pi$$

Where: H' = Shannon-Wiener diversity index; pi = ni/N; ni = number of individual species-ith; N = total number of individuals.

Dominance index was determined by the following formula:

$$D = \sum_{i=1}^{s} (\mathrm{ni/N})2$$

Where: D = Simpson dominance index; ni = number of individuals-ith; N = total number of individuals; S = number of genera.

Phytoplankton abundance was measured as the number of individual cells per unit volume. It was calculated using the following formula;

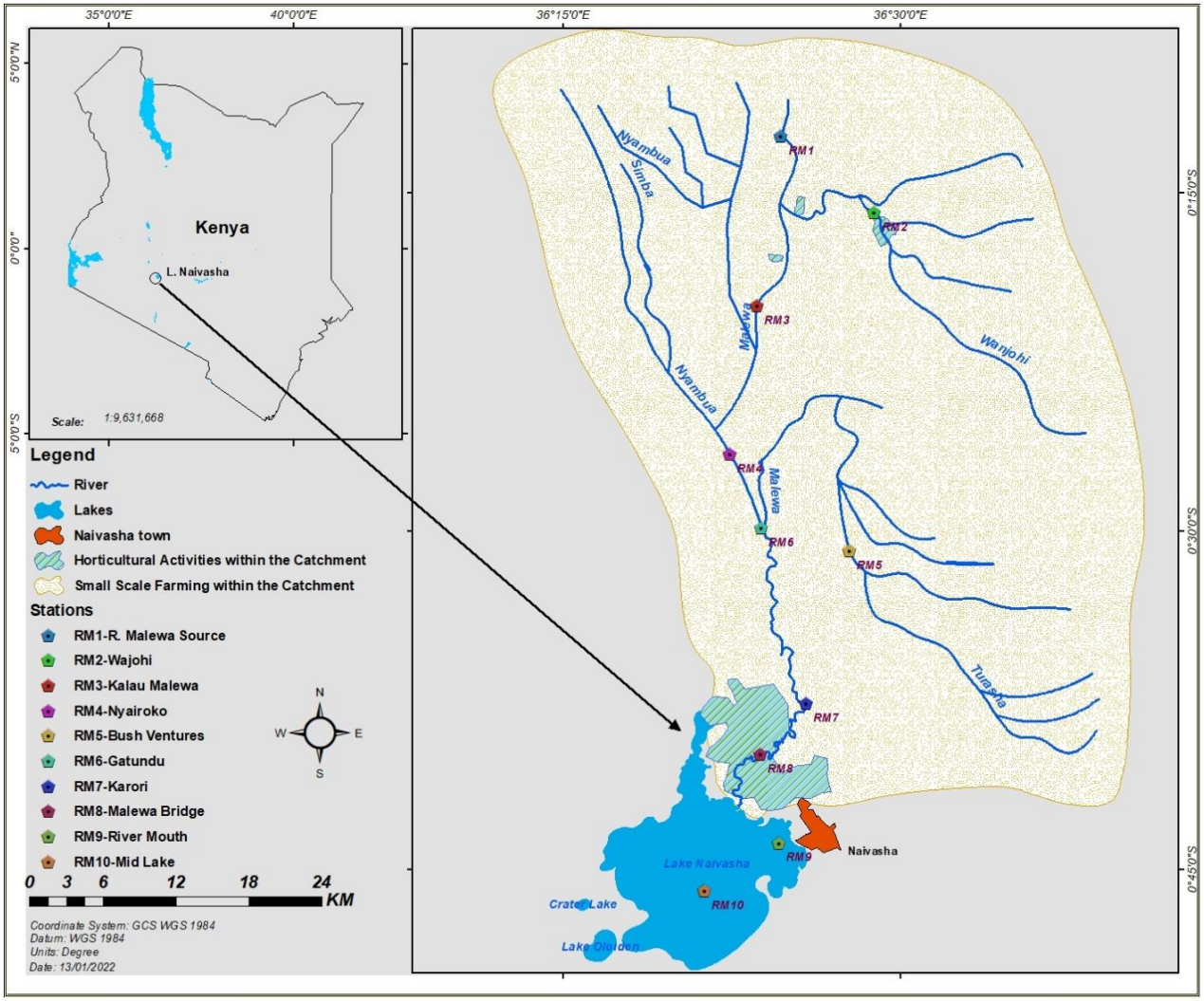

Figure 1. Map showing the ten sampling sites.

$$k = 1/X + Y/Z + \frac{V}{v}n$$

Where: K = phytoplankton abundance (cells/mm²); n = number of observed phytoplankton; X = volume of filtered water sample (40 L); Y = total area/container area of Sedgwick- Rafter Counting cell; Z = Observation area (mm²); V = volume of filtered water (50 ml); v = concentrated volume of Sedgwick-Rafter counting cell (ml).

Data analyses

The species diversity index, dominance index and relative abundances were calculated. Frequency distribution tables, bar charts and scatter plots were used. Regression and calibration models were developed to quantify relations between algal abundances. In this study, all correlation of all stations was analysed using Shapiro-Wilk W statistical tool, to determine normality. Central tendency (mode, mean and median were used to describe where the data lie.

RESULTS

Taxonomic composition and species distribution

During the study, a total of 89 algal species taxa at species level were identified (Tables 1 to 4). Ten algal groups; Bacillariophyceae, Chlorophyceae, Mayxophyceae, Chrysophyceae, Xanthophyceae, Rhodophyceae, Euglenophyceae, Cryptophyceae, Cyanophyceae and Dinophyceae were represented.

Table 1. showing species 1-20; (- =0; +=1-100;++=101-1000; +++=1001-7000)in the ten study sites.

Phytoplankton	Sites									
	RM1	RM2	RM3	RM4	RM5	RM6	RM7	RM8	RM9	RM10
Chrocoocus sp	+	+	+	+	+	+	-	+	-	-
Nitzschia sp	+	+	+	+	+	+	+	+	-	+
Vaucheria sp	+	+	-	+	+	-	+	+	-	+
Ochromonas sp	+	+	-	+	-	-	+	-	-	-
Tribonema sp	+	+	+	+	-	+	-	+	-	+
Nostoc sp	+	+	-	+	-	-	+	-	-	-
Fragilaria sp	+	+	+	+	+	++	+	+	+	+
Tabellaria sp	+	+	+	+	++	+	+	+	+	+
Cymbella sp	+	+	+	+	+	+	+	-	+	-
Meridion sp	+	+	++	+	+	++	++	+	+	+
Uroglena sp	+	+	+	+	+	+	+	+	++	+
Chamasiphon sp	+	+	+	-	+	+	+	+	+	-
Gamphomena sp	+	+	+	+	+	+	+	+	-	+
Batachospermum sp	+	+	+	+	+	+	+	-	-	
Anabaena sp	+	+	++	+	+	++	++	++	+	+
Navicula sp	+	+	+	+	+	-	+	-	-	-
Lemanea sp	+	+	+	+	+	-	+	+	-	+
Dirobryon sp	+	+	+	+	+	+	-	+	+	-
Cocconeis sp	+	+	+	+	+	+	+	+	+	-
Trachelomonas sp	+	+	+	+	+	+	+	+	+	-

Table 2. showing species 1-20; (- =0; +=1-100;++=101-1000; +++=1001-7000)in the ten study sites.

Phytoplankton	Sites									
	RM1	RM2	RM3	RM4	RM5	RM6	RM7	RM8	RM9	RM10
Diatoma sp	+	++	+	-	+	+	+++	+	+	+
Lobomonas sp	+	+	-	+	-	-	+	-	-	-
Euglena sp	-	+	+	+	+	+	-	+	-	-
Synura sp	-	+	+	+	+	+	+	+	-	-
Chlorella sp	+	+	+	+	+	+	+	+	+	-
Coeachaete sp	-	-	+	-	+	+	-	+	-	+
Cyptomonas sp	-	-	+	-	-	-	-	+	-	-
Cymbella sp	+	-	+	+	+	-	+	++	-	-
Trentepholia sp	-	+	+	+	+	+	-	+	+	-
Stigeochonium sp	-	-	-	+	+	+	-	+	-	-
Microcystis sp	-	-	+	+	+	+	+	+	+	-
Botrydium sp	-	-	-	+	+	+	-	-	-	+
Euastrum sp	-	-	-	+	+	+	-	-	-	-
chlorogium sp	+	-	+	+	+	+	-	-	-	-
Aphanizomenon sp	-	-	+	+	++	+	-	-	++++	++++
Cymatopeura sp	-	-	-	-	+	+	-	-	-	+
Aphanochaete sp	+	+	+	-	+	+		+	-	+
Peridiunium sp	-	-	+	-	+	+	+	-	-	+
Ceratium sp	-	-	-	-		+	+	+	++++	
Akistrodesmus sp	+	-	+	-	-	+	+	+	+	++
Cyclotella sp	-	-	+	-	+	+	-	+	-	+
Gloeocapsa sp	-	+	-	-	-	+	-	-	-	+

Phytoplankton's collection from each study sites are represented on Tables 1 and 2. Results of each group were varying. The total number of phytoplankton listed in each of the ten sites represented 89 taxa and varied considerably. Bacillariophyceae (2652), Dinophyceae (50), Chlorophyceae (827), Cyanophyceae (914), Myxophyceae (289), Euglenophyceae (185), Chrysophyceae 144, Xanthophyceae (99) and Cryptophycea (9). Bacillariophyceae (376), Dinophyceae (9), Chlorophyceae (10800), and Cyanophyceae (3496), Myxophyceae (64), Euglenophyceae (77), Chrysophyceae (130), Xanthophycea (51). The highest number of taxa

Table 3. showing species 1-20; (- =0; +=1-100;++=101-1000; +++=1001-7000)in the ten study sites.

Phytoplankton	Sites									
	RM1	RM2	RM3	RM4	RM5	RM6	RM7	RM8	RM9	RM10
Gloeotrichia sp	-	-	-	-	-	+	-	-	+	+
Gynosigma sp	-	+	-	-	-	+	-	-	-	+
Mollomonas sp	-	-	+	-	-	+	+	-	+	-
Oscillatoria sp	+	+	-	+	-	-	-	-	-	+
Pinnularia sp	-	-	-	-	+	+	-	+	-	-
Rivularia sp	+	+	+	-	-	+	-	-	+	-
Mougeotia sp	-	+	-	-	-	+	-	+	-	-
Enteromorpha sp	-	-	+	-	-	+	+	+	+	+
Hydrodictyon sp	-	-	-	-	-	+	-	+	-	-
Surirella sp	+	+	+	-	-	+	-	+	-	+
Prasola sp	-	-	+	-	-	+	+	+	-	+
Staurastrum sp	-	+	-	-	+	+	+	+	-	-
Chaetophora sp	-	+	+	-	-	+	+	+	-	-
Stichococcus sp	-	-	+	-	-	-	+	-	+	-
Pleuroterium sp	-	+	-	-	-	-	+	+	-	-
Synedra sp	+	+	+	-	+	-	+	+	+	-
Trebouxia sp	-	-	-	-	-	-	+	-	+	+
Botryococcus sp	-	-	+	-	+	-	+	-	-	-
Urothrix sp	-	-	-	-	-	-	+	-	-	++++
Brachiomonas sp	-	-	-	-	-	-	+	-	-	-
Characium sp	-	-	-	-	-	-	+	-	-	+
Cymptomonas sp	-	+		+	-	-	+	+	-	-

Table 4. showing species 1-20; (- =0; +=1-100;++=101-1000; +++=1001-7000)in the ten study sites.

Phytoplankton	Sites									
	RM1	RM2	RM3	RM4	RM5	RM6	RM7	RM8	RM9	RM10
Micospora sp	-	-	-	-	+	-	+	-	-	-
Mallomonas sp	-	+	-	-	-	-	+	+	+	-
Oedogonia sp	+	-	+	-	-	+	+	+	-	-
Protozoa sp	-	-	+	-	-	-	+	-	-	-
Spirogyra sp	-	-	-	+	-	-	+	-	-	-
Rivularia sp	-	+	-	-	+	+	+	+	-	-
Phacotus sp	-	-	-	+	-	-	-	+	-	+
Spirogyra sp	-	-	+	-	-	-	+	+	-	
Melosira sp	-	+	-	-	+	-	-	+	+	+
Cosmariam sp	-	-	+	-	-	+	-	+	-	-
Tetrahedron sp	-	+	-	-	+	-	-	+	+	-
Tolyprothrix sp	-	+	-	+	-	+	-	+	-	-
Periastrum sp	-	-	+	-	+	-	+	+	+	++++
Asterionella sp	-	+	-	-	+	-	-	+	+	
scenedesmus sp	-	-	-	-	+	-	+	-	+	+
Zygnema sp	-	-	-	-	-	-	-	-	+++	++
Micrasteries sp	-	-	-	-	-	-	+	-	+++	-
Gomphosphaeria sp	-	+	-	-	-	-	-	-	+	-
Cladophora sp	-	-	-	-	-	-	-	-	-	-
Closterium sp	-	+	-	-	+	-	+	-	+	+
Astericystis sp	-	-	-	+	-	-	-	-	-	+
Tetastrum sp	-	+	-	-	+	-	-	-	-	-
coelastrum sp	-	+	-	-	-	+	-	+	-	-
ophicytium sp	-	-	-	-	-	+	+	+	+	-

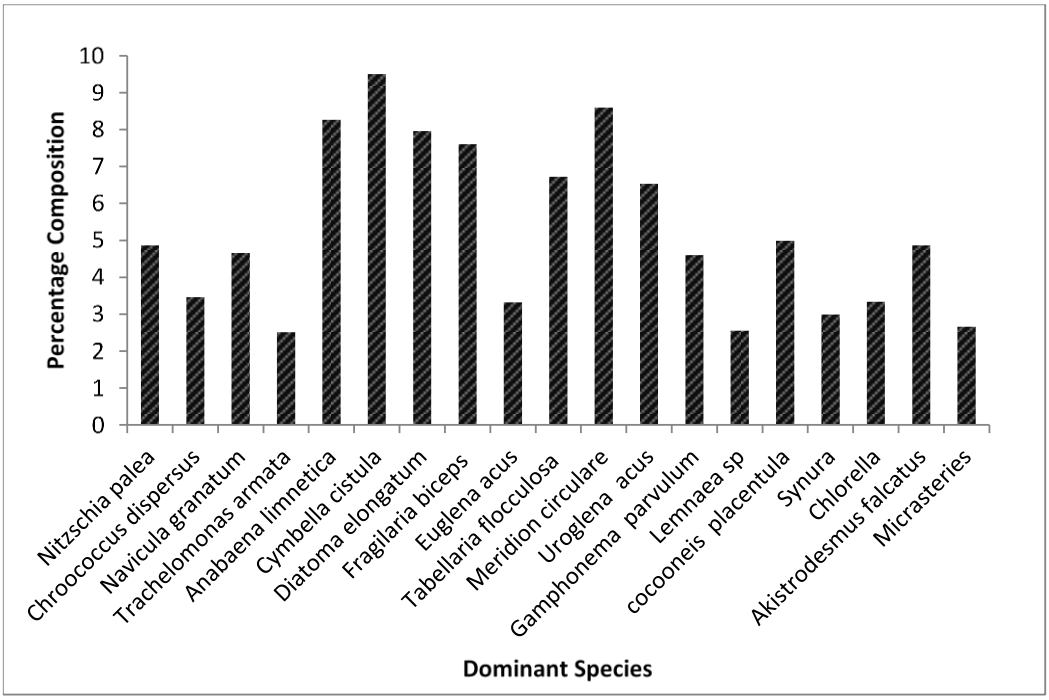

Figure 2. Graph showing top ranked species on the frequency in all study sites.

was recorded at RM7, followed by RM4, RM8, RM5, RM3, RM1 and RM2 respectively. Chlorophycea was was highest in lake sites RM10 and RM9 being dominated with *Ceratium, Zygnema Aphizomenon and Ulothrix sp*. The result was similar with others research indicating that Bacillariophyceae as the dominant genera on rivers and Chlorophycea dominant in lakes and reservoirs.

Selected most top racked phytoplankton species in the river

Cymbella cistula (9.5%), Meridion circulae (8.59%), Anabaena limnetica (8.26%), Diatoma elongatum (7.95%), Flagilaria biceps (7.6%), Tabellaria flocculosa (6.72%), Uroglena acus (6.53%), Cocooneis (4.98%), Nitzschia Palea and Akistrodesmus falcatus both (4.86%), Navicula granatum (4.65%), the rest Gaphonema parrvulum, Chroococcus sp, Chlorella sp, were below 4.5% (Figure 2).

Species distributions in the site stations

Diatoma sp. was highest in RM7 and lowest in RM1 followed by *Meridion sp,* highest in RM6 and lowest in RM1, *Flagilaria sp* was highest in RM6 and lowest in RM7, *Tabrllaria* was highest in RM4 and lowest in RM8 and *Uroglena sp* was highest in RM5 and RM6 and lowest in RM7 (Figure 3).

Selected most top racked phytoplankton species in the lake

The results revealed that five most species that dominated the lake with high frequency were *Amphizomenon flosquae, Ceratium hindunella, Urothrix subflaccida, Zygnema ornatum, Pediastrum boryanum (*Figure 4).

Frequencies of the top ranked species

Cymbella sp, Anabeana sp, Flagilaria, Tabellaria sp, Aphizomenon sp, Meridion sp, Chlorella sp were among the more than twenty species of algae that distributed evenly in the eight stations of River Malewa (Figure 5a), while *Akistrodesmus sp, Urothrix sp, Ceratium sp, Pediatrum sp* were well distributed with high numbers in lake (Figure 5b).

Phytoplankton percentage composition River Malewa

Bacillariopheceae (Diatoms) dominated with 50%, Cyanophyceae was 17%, Chlorophyceae 16% and Myxophyceae was 6% of the total area in lotic sites while the least dominant were Euglenophyceae (4%), Chrysophyceae (3%) and Xanthophyceae Rhodophyceae and Dinophyceae with 1% each (Figure 6).

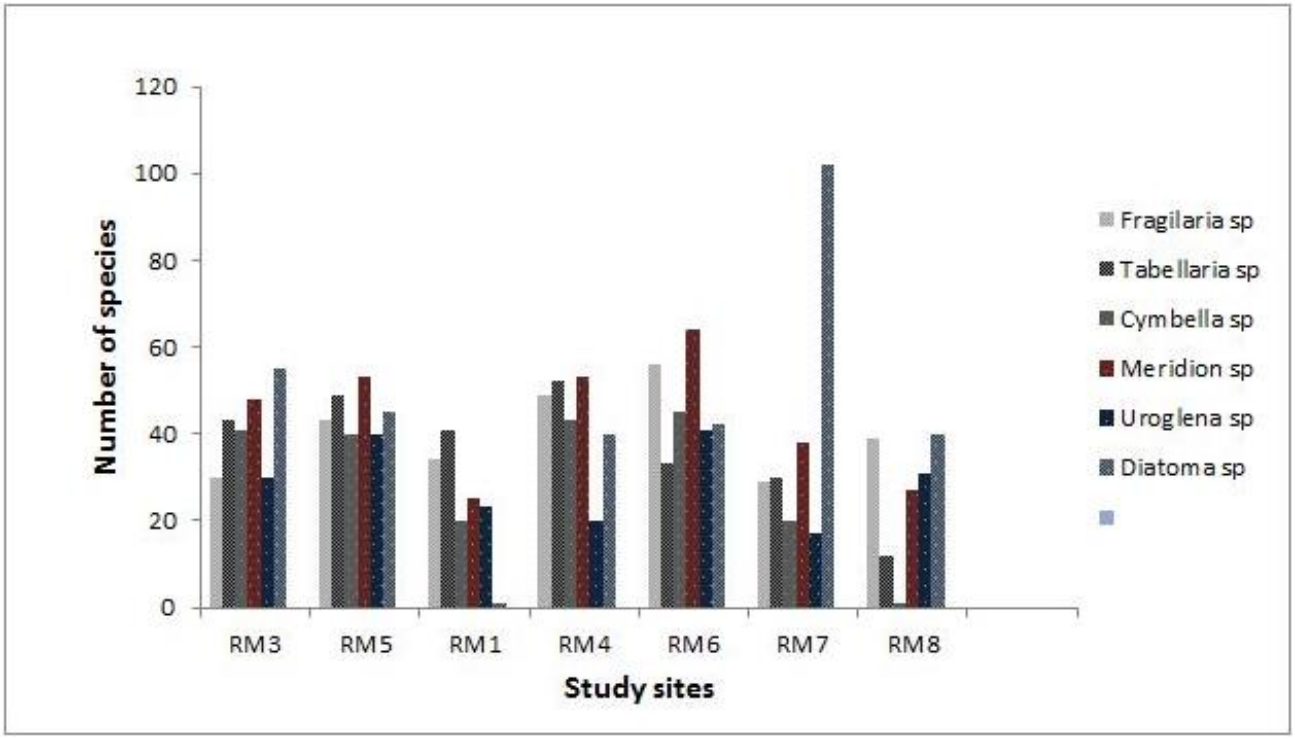

Figure 3. Five dominant species according to stations.

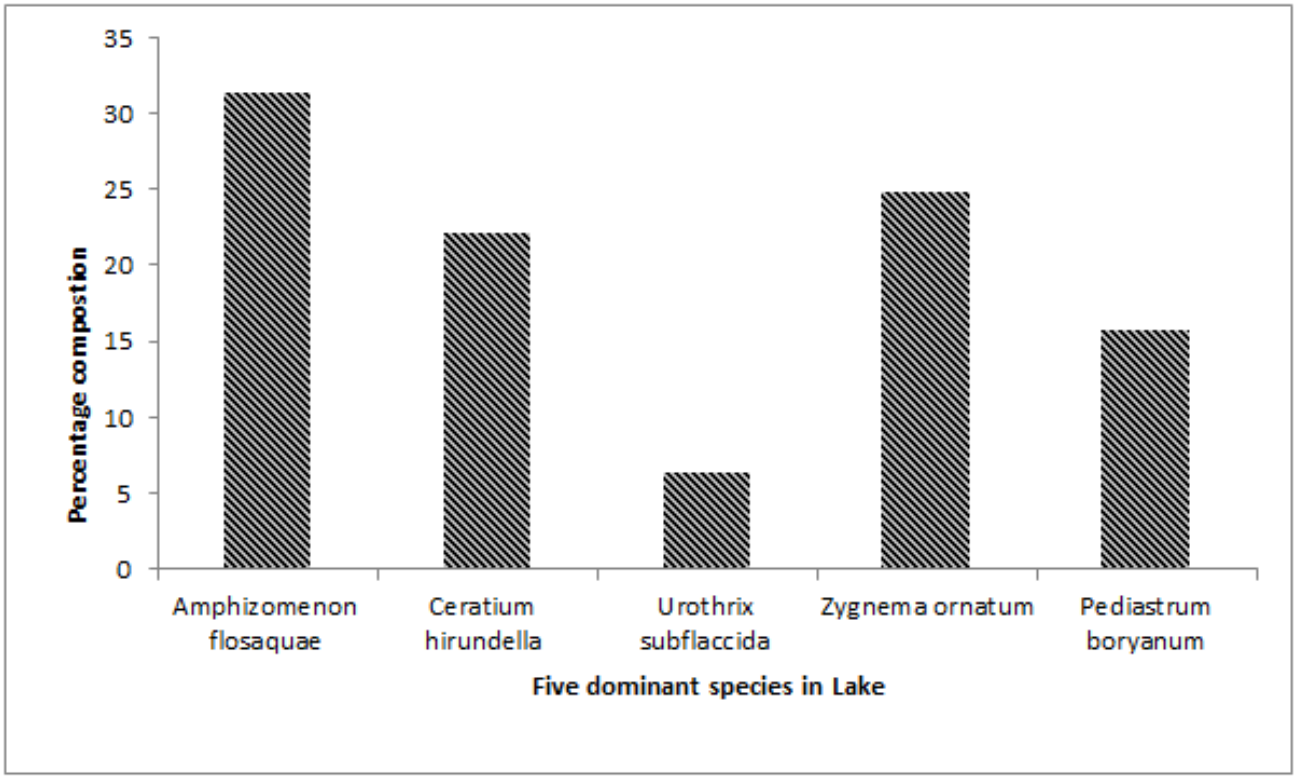

Figure 4. Five dominant species in RM9 and RM10.

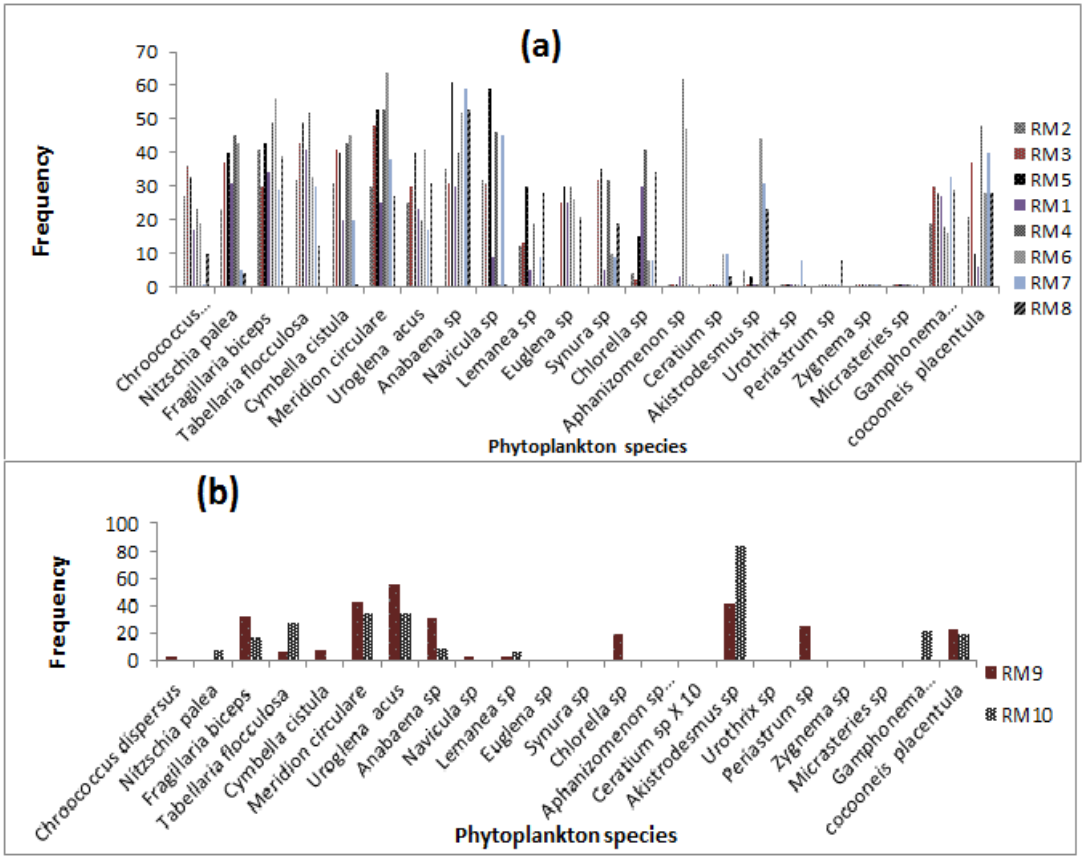

Figure 5. Graph showing the top ranked species in frequency in the lotic (a) and lentic (b) study sites.

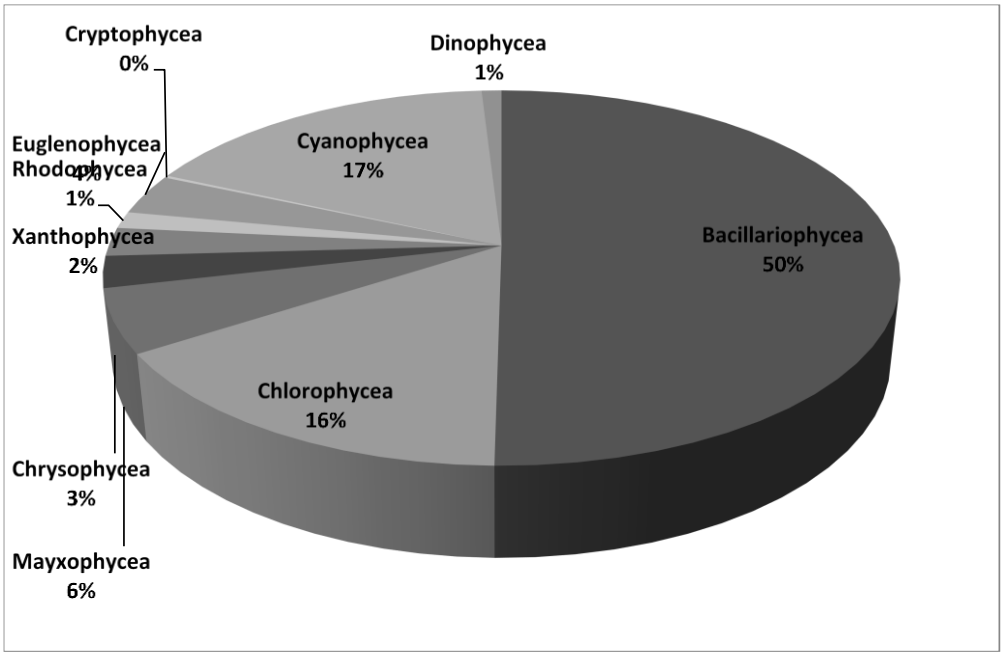

Figure 6. Pie chart showing percentage composition of phytoplankton groups in River Malewa study points.

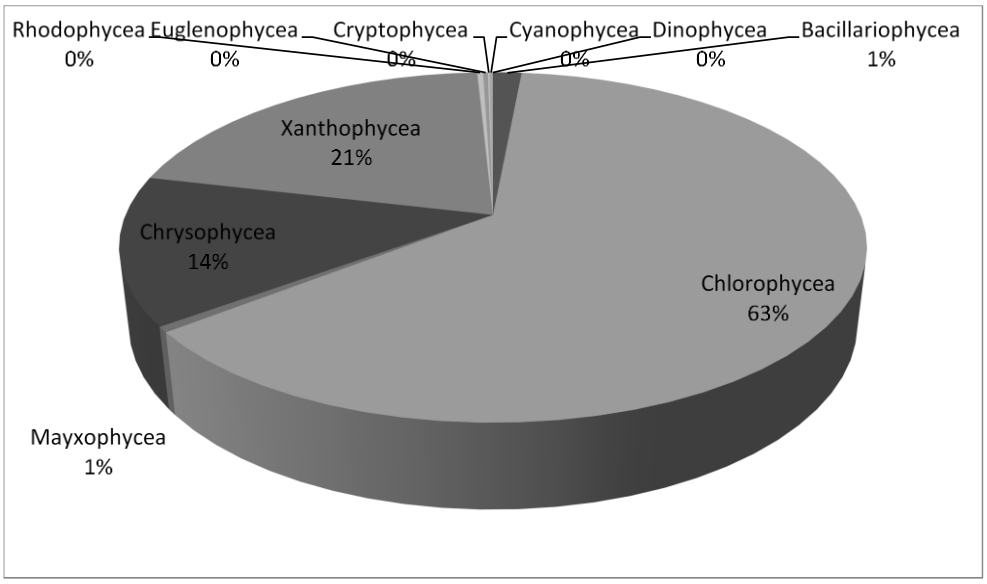

Figure 7. Pie chart showing the percentage composition of phytoplankton groups in the river mount and Midlake points.

Phytoplankton percentage composition at lake and river mouth

Two points at the RM9 and RM10 study showed a high dominance in Chlrophyceae with 63%, Xanthophyceae 21% and Chrysophyceae 14%, while Bacillariophyceae was 1% and the rest of the groups were 0% (Figure 7).

Phytoplankton abundance and distribution

Phytoplankton abundance in River Malewa belt ranged from 4.8.0 x 10^5 cells/m^3 to 1.29 x 10^6 cells/m^3. The highest abundance was found in the lentic site and with two species holding higher composition, *Zygnema* and *Ceratium.* Diatoms are majority in rivers while in lentic system lakes chlorophytes were majority. RM1 and RM4 had abundance of 4.8 x 10^5 cells/mm^3. Site RM9 and RM10 being lacustrine recorded highest abundance with 1.24 x 10^6 cells/mm^3 and 1.29 x 10^6 cells/mm^3 respectively. RM3 recorded abundance of 6.2 x 10^5 cells/mm^3, RM3 was 7.3 x 10^5 cell/mm^3 and RM5, RM6, RM7 and RM8 recorded abundance of 8.5 X10^5, 9.2 x 10^5, 7.5 x 10^5 and 7.9 x 10^5 cell/m^3 respectively. *Chrocoocus* recorded 2.1 x 10^5 cells/mm^3, *Euglena* sp qnd *Chlorella* were both 2.0 x 10^5 cells/mm^3 and *Syunura sp.* was 1.8 x 10^5 cells/mm^3 , *Surirella sp* was 1.1 x 10^5 cells/mm^3 *Lemnanea* and *Techlemonas* species recorded 1.6 x 10^6 cells/mm^3 and 1.5 x 10^5 cells/mm^3 respectively. Phytoplankton abundance ranged from 1.0 x 10^5 to 9.4 x 10^6 cells/mm^3, with *Aphizomenon* being the highest with 9.49 x 10^6 cells/mm^3, followed by *Zygnema sp , Ceratium* sp (Majority in lentic) with 7.5 x 10^6 and 6.7 x 10^6 cells/mm^3 respectively. *Pediastrum sp* recorded 4.74 x 10^6 cells/mm^3 and *Urothrix sp* recorded 1.9 x 10^6 cells/mm^3, *Meridion, Anabeana* and *Cymbella sp* abundance ranged between 5.0 x 10^5 to 5.4 x 10^5 cells/mm^3, while *Tabellaria, Flagilaria and Diatoma* recorded 4.1 x 10^5, 4.6 x 10^5 and 4.8 x10^5 cells/mm^3, respectively. *Uroglena sp, Cocconeis, Gompomenon* recorded 3.9 x 10^5, 3.0 x 10^5 and 2.8 x 10^5 cells/mm^3, respectively. *Akistriodesmus sp and Navicula* both recorded 2.9 x 10^5 cells/mm^3.

Phytoplankton relative abundance

Tabellaria had a relative abundance of 15.6 and 15.9% in RM5 and RM4, 13.1 and 12.6% in RM3 and RM1 and the rest of the stations were between 1.8 to 10.15%. *Anabeana* had a relative abundance of 14.7% in RM7, RM5 15.2%, 13.2% in RM8, RM6 12.9% and the rest varied between 2.2 to 9.9%. *Meridion* showed a relative abundance of 15.9% in RM7 and 12.7% in RM5 and RM4. Relative abundance of *Chrocoocus* in RM3 was 21.8%, RM5 20% and 16.3% at RM2, RM4 had a relative abundance of 13.3%, and the rest were below 12%. *Nitzschia* had a relative abundance of 19.14% in RM4, RM3 was 15.7% .RM5 was 17.02%, RM7 was 18.3% while the rest was below 15%. *Melosira* had a relative abundance of 38.48% in RM10 while 33.3% in RM9, 17.1% in RM8, and the rest of the stations recorded below 10%. *Aphizomenon* recorded a relative abundance of 76.5% in RM10, RM9 22.03%; the rest was below 2%.*Chlorella* showed relative abundance of 25.4%, RM4 21.11%, RM8 and RM1 18% each. *Flagilaria* had a relative

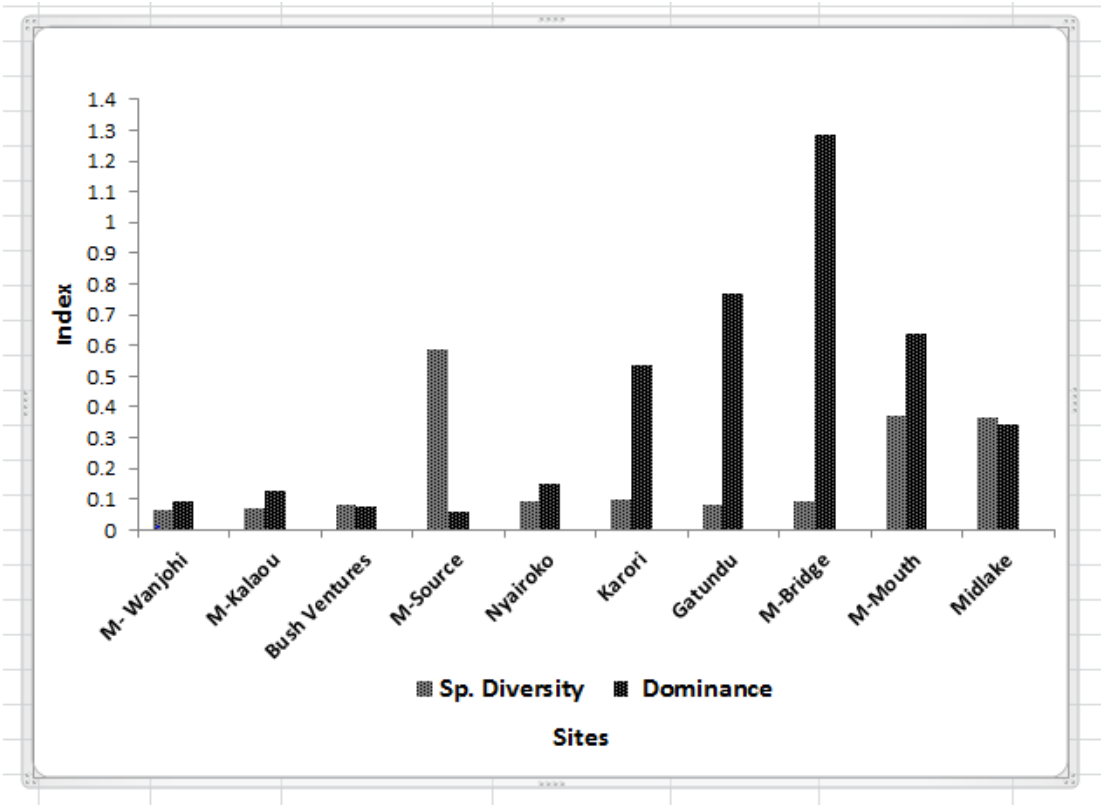

Figure 8. Showing diversity and dominance index.

abundance of 67.85% in RM6, 15.17% in RM7, 11.65% in RM5 while the rest of remaining percentage was represented by other stations. *Melosira* had a relative abundance of 38.48% in RM10 while 33.3% in RM9 and 17.1% in RM8, the rest of the stations recorded below 10%.

Phytoplankton diversity and dominance index

The analysis of phytoplankton diversity index in River Malewa showed high value of Shannon-Wiener's index (H ') was recorded in RM6 (1.556), followed by RM4 (1.521), RM7 (1.504), and lowest was RM10 1.141, RM5 1.299, RM1 1.398, 1.403 in RM3, 1.474 in RM2 and 1.473 in RM8 (Figure 8).

The diversity in RM6, RM4 and RM7 were stable while RM8 was unstable. The Simpson (dominance) index varies between 0.2807 and 0.7119. The highest value was at RM6 0.7119, followed 0.6997 in RM4 and 0.6799 in RM2. The highest value was at RM6 0.7119, followed by RM8 0.6997, RM4 6797, RM2 0.6719, RM3 0.6671, RM1 0.6607, RM7 0.6527, RM10 0.6341, RM5 0.6154 and RM9 0.2807. High value of Shannon-Wiener's (H) was recorded at Karori RM6 (0.10), followed by Malewa bridge RM8 (0.095), RM5 (0.093), RM7 (0.084), then RM3 (0.083), RM 2 (0.074) then least in the river ecosystem was RM1 and RM3 with 0.067 and 0.059, respectively. Further, the Lake sites recorded highest than the river. River mouth RM9 had 0.373 and Midlake was (0.365). Sites RM9 and RM10 are more stable but the river sites are less stable. The Simpson (Dominance) index varied between 0.060 and 1.284. The highest value was at RM8 (1.284) followed by RM7 (0.770), RM9 (0.640), then followed by RM6 (0.538), RM 5 (0.151), RM2 (0.126), RM 1(0.097), RM3 (0.077) and the least was RM4 (0.060).

Multivariate PCA analysis

The study on to groups of phytoplankton and sites was done using PCA analysis (Figure 9). PCA performed on the correlation matrix of phytoplankton species on studied stations showed that the four principal components represented 99.79% of the total variation in the entire dataset. The actual eigenvalue and the percentage cumulative variability are shown in Figure 9. The first PC accounted for 75.75% of total of the variations between sites and comprised of the following parameters: Euglenophyceae, Rhodophyceae, cyptohyceae, myxanthophyceae, Dinophyceae and Bacillariophyceae. The second PC comprised of 13.27% of the total variations

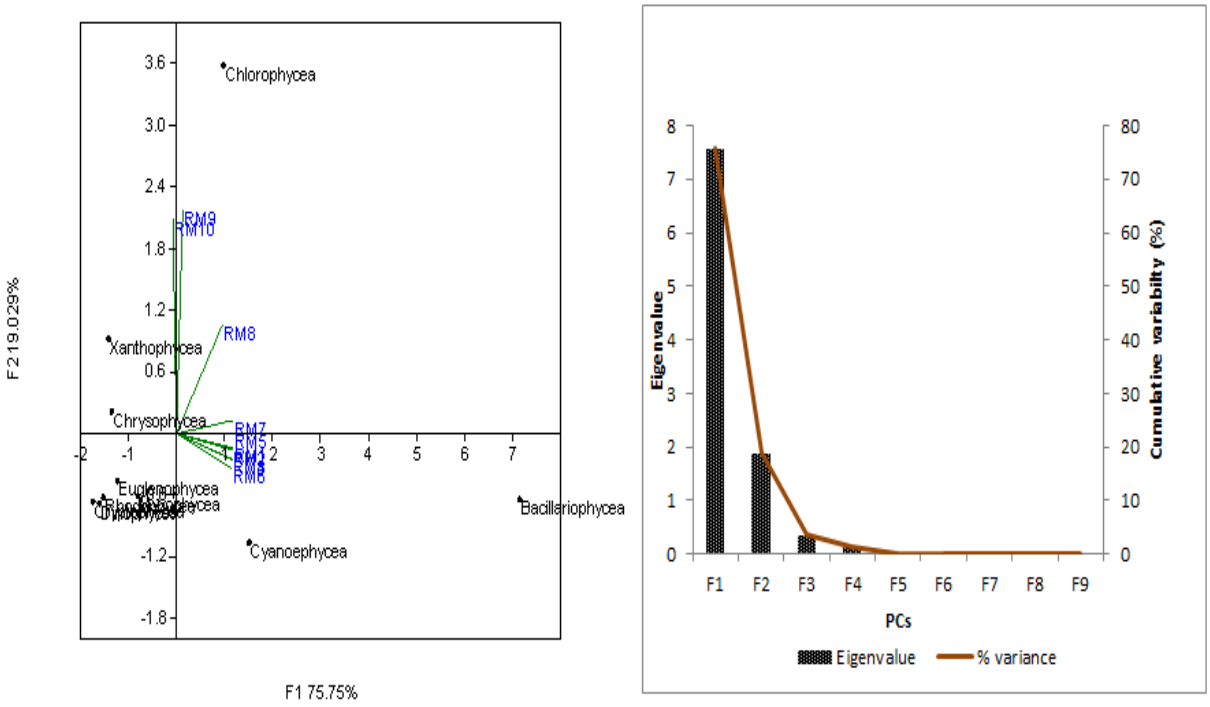

Figure 9. Shows the Multivariate analysis of the variables with the site stations.

and was associated with Chrysophyceae and Xanthophyceae. The third PC comprised of 4.25% which was associated with uglenophyceae, 4th and 5th PC comprised of 3.53% of the total variations which associated with Cyanophyceae and Bacillariophyce while the 6th and 7th PC comprised of 2.29 % of the variations and was associated with Chlorophycea.

DISCUSSION

Algal communities are major producers of organic carbon in larger rivers, and may represent the primary oxygen source in many low-gradient rivers. Excessive supplies of inorganic nutrients and may pose problems in long stretches of rivers with cultural eutrophication, but may also enhance water quality for humans in rivers affected by agricultural or industrial uses. Algal communities of river systems consists suspended algae, diverse benthic assemblage of macrophytic forms, epiphytes, and sediment-dwelling forms. The study appreciated more Chlorophytes, Cyanobacteria, and Uglenophytes which were the most common groups in the turbid lacustrine habitats, whereas diatoms (Bacillariophyceae) dominated along the salinity gradient of the River Malewa Belt. The long-term trends of algae provide information on change in the trophic status of the river and the lakes. These study is comparable with several studies which have shown that the density and distribution of phytoplankton in rivers not only depends on the availability of sunlight and nutrients but also relies on tides, salinity, turbidity, and river flows (Lodang and Kurnia, 2019; Lawler *et al*., 2006; Hampson *et al*., 2017; Norton *et al*., 1996). Phytoplankton growth are very essential in choosing better management options and strategies in maintaining a natural ecosystem (Norton *et al.*, 1996; Peden *et al*., 2016; Rojo *et al.*, 1994; Rosli *et al.*, 2020; Sitoki *et al.*, 2012)). Diatoms communities respond quickly to physical, chemical and biological changes and may develop harmful algal blooms (HABs) that may affect aquatic organisms. The study explained that diatoms are usually the common element of freshwaters and Chlorophycea were the most common in lacustrine ecosystem. It is well known that diatoms diversity are sensitive to a wide range of environmental variables, and that their community structure may quickly respond to changing physical, chemical and biological conditions in the environment. Distribution of Bacillariophyceae species are known to be able to develop harmful algae blooms that increasingly affect aquaculture and tourism in wide areas of the subtropical. Presence of so many cells may suffocate fish by clogging or irritating the gills. Differences in geographical location, season, and pollutant substances from urban, industrial, and agricultural sources have an effect on declining water quality and, therefore, influence species richness and the density of phytoplankton in estuaries. Many studies, such as those by Norton *et al*. (1996), Breuer *et al.* (2017) and Reavie *et al.* (2010), have investigated the effects of environmental determinants on

phytoplankton abundance. Norton et al. (1996) and Huang *et al.* (2004) showed same findings in comparison with these study. Other useful studies include Effendi *et al.* (2016) and Lueangthuwapranit *et al*. (2011). Algal communities are major producers of organic carbon in larger rivers, are a food source for planktonic consumers, and may represent the primary oxygen source in many low-gradient rivers (Ndebele-Murisa *et al*., 2010; Santos and Ferreira, 2020; De Senerpont Domis *et al.*, 2013; Jerling and Wooldridge, 1995; Kozak et al., 2020; Everard *et al*., 2002; Liu *et al*., 2020; Breuer *et al*., 2017). Decomposition process may affect the chemistry of the water when the densely concentrated algal cells die off, the decay process, assisted by bacteria, can deplete the water of oxygen, which in turn can lead to the death of oxygen-dependent aquatic organisms. Some algal species produce deadly toxins which directly kill the animals that ingest the poisons. In conclusion, it was strongly observe that some species of Cyanophyceae group may release toxins that may kill mussels, and therefore recommend that this can form a foundation for further studies on the distributions of upper-level aquatic species in freshwater ecosystems. Further continued observations of phytoplankton density and composition are needed, emphasizing any unusual increases in density and determine the presence of HABs.

CONFLICT OF INTEREST

The authors have that they have no conflict of interest.

REFERENCES

Bellinger, E. G., & Sigee, D. C. (2010). *Freshwater algae: identification and use as bioindicators*. John Wiley & Sons, Ltd, New Jersey. Pp. 1-40.

Breuer, F., Janz, P., Farrelly, E., & Ebke, K. P. (2017). Environmental and structural factors influencing algal communities in small streams and ditches in central Germany. *Journal of Freshwater Ecology*, *32*(1), 65-83.

Cellamare, M., Rolland, A., & Jacquet, S. (2010). Flow cytometry sorting of freshwater phytoplankton. *Journal of Applied Phycology*, *22*(1), 87-100.

Cheruiyot, M., Gathuru, G., & Koske, J. (2018). Quantity and trends in streamflows of the Malewa River Basin, Kenya. *Journal of Environmental Science and Engineering B*, 7(1), 1-11.

De Senerpont Domis, L. N., Elser, J. J., Gsell, A. S., Huszar, V. L., Ibelings, B. W., Jeppesen, E., Kosten, S., Mooij, W. M., Roland, F., Sommer, U., & Lürling, M. (2013). Plankton dynamics under different climatic conditions in space and time. *Freshwater Biology*, *58*(3), 463-482.

Effendi, H., Kawaroe, M., Lestari, D. F., & Permadi, T. (2016). Distribution of phytoplankton diversity and abundance in Mahakam Delta, East Kalimantan. *Procedia Environmental Sciences*, *33*, 496-504.

Everard, M., Vale, J. A., Harper, D. M., & Tarras-Wahlberg, H. (2002). The physical attributes of the Lake Naivasha catchment rivers. In *Lake Naivasha, Kenya* (pp. 13-25). Springer, Dordrecht.

Hampson, D. I., Ferrini, S., Rigby, D., & Bateman, I. J. (2017). River water quality: who cares, how much and why?. *Water*, *9*(8), 621.

Hastuti, A. W., Pancawati, Y., & Surana, I. N. (2018, July). The abundance and spatial distribution of plankton communities in Perancak Estuary, Bali. In *IOP Conference Series: Earth and Environmental Science* (Vol. 176, No. 1, p. 012042). IOP Publishing.

Huang, L., Jian, W., Song, X., Huang, X., Liu, S., Qian, P., Yin, K., & Wu, M. (2004). Species diversity and distribution for phytoplankton of the Pearl River estuary during rainy and dry seasons. *Marine Pollution Bulletin*, *49*(7-8), 588-596.

Indrayani, E., Dimara, L., Paiki, K., & Reba, F. (2018). The analysis of phytoplankton abundance using Weibull Distribution (A case study in the coastal area of East Yapen in the Regency of Yapen Islands, Papua). *Journal of Education and Learning*, *7*(3), 251-258.

Jerling, H. L., & Wooldridge, T. H. (1995). Plankton distribution and abundance in the Sundays River estuary, South Africa, with comments on potential feeding interactions. *South African Journal of Marine Science*, *15*(1), 169-184.

Kozak, A., Budzyńska, A., Dondajewska-Pielka, R., Kowalczewska-Madura, K., & Gołdyn, R. (2020). Functional groups of phytoplankton and their relationship with environmental factors in the restored Uzarzewskie Lake. *Water*, *12*(2), 313.

Lawler, D. M., Petts, G. E., Foster, I. D., & Harper, S. (2006). Turbidity dynamics during spring storm events in an urban headwater river system: The Upper Tame, West Midlands, UK. *Science of the Total Environment*, *360*(1-3), 109-126.

Leland, H. V. (2003). The influence of water depth and flow regime on phytoplankton biomass and community structure in a shallow, lowland river. *Hydrobiologia*, *506*(1), 247-255.

Liu, Y., Li, H., Cui, G., & Cao, Y. (2020). Water quality attribution and simulation of non-point source pollution load flux in the Hulan River basin. *Scientific Reports*, *10*(1), 1-15.

Lodang, H., & Kurnia, N. (2019, June). Distribution and abundance of plankton in the downstream of Jeneberang River. In *Journal of Physics: Conference Series* (Vol. 1244, No. 1, p. 012011). IOP Publishing.

Lueangthuwapranit, C., Sampantarak, U., & Wongsai, S. (2011). Distribution and abundance of phytoplankton: influence of salinity and turbidity gradients in the Na Thap River, Songkhla Province, Thailand. *Journal of Coastal Research*, *27*(3), 585-594.

Ndebele-Murisa, M. R., Musil, C. F., & Raitt, L. (2010). A review of phytoplankton dynamics in tropical African lakes. *South African Journal of Science*, *106*(1), 13-18.

Norton, T. A., Melkonian, M., & Andersen, R. A. (1996). Algal biodiversity. *Phycologia*, *35*(4), 308-326.

Omondi, R., Rindoria, N., Orina, P., Siriba, B., Morara, G., Obegi, B., & Ogendi, G. (2021). Characteristic relationships between phosphorous accrual, ecosystem aspects and water level fluctuations in tropical lakes: Naivasha Ramsar site, Kenya. *Journal of Geoscience and Environment Protection*, 9(1), 53-67

Peden, A. E., Franklin, R. C., & Leggat, P. A. (2016). Fatal river drowning: The identification of research gaps through a

systematic literature review. *Injury Prevention*, *22*(3), 202-209.
Reavie, E. D., Jicha, T. M., Angradi, T. R., Bolgrien, D. W., & Hill, B. H. (2010). Algal assemblages for large river monitoring: comparison among biovolume, absolute and relative abundance metrics. *Ecological Indicators*, *10*(2), 167-177.
Rojo, C., Cobelas, M. A., & Arauzo, M. (1994). An elementary, structural analysis of river phytoplankton. Hydrobiologia, 289(1), 43-55.
Rosli, N., Gandaseca, S., Gerusu, G. J., Heng, R. K. J., Ahmed, O. H., Idris, M. H., & Mohamad Pazi, A. M. (2020). Quality of tropical river water in different catchments of canopy cover. *The Malaysian Forester*, *83*(1), 128-148.
Santos, J. M., & Ferreira, M. T. (2020). Use of aquatic biota to detect ecological changes in freshwater: Current status and future directions. *Water*, *12*(6), 1611.
Sitoki, L., Kurmayer, R., & Rott, E. (2012). Spatial variation of phytoplankton composition, biovolume, and resulting microcystin concentrations in the Nyanza Gulf (Lake Victoria, Kenya). *Hydrobiologia*, *691*(1), 109-122.
Wehr, J. D., & Descy, J. P. (1998). Use of phytoplankton in large river management. *Journal of Phycology*, *34*(5), 741-749.