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Full Length Research

Phytoplankton distribution, abundance and diversity along a salinity gradient between Lake Naivasha and Lake Oloiden

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ABSTRACT: A study was conducted with an objective of determing the spatial and temporal distribution, abundance and diversity of plankton along a salinity gradient in the Lakes Naivasha and Oloiden. The phytoplankton and some physico-chemical parameters were sampled monthly for one year (August, 2020 to July, 2021). Identification and counting of phytoplankton were done under a compound microscope and the diversity was studied using indices. Salinity was higher in Lake Oloiden sites and it associated negatively with the phytoplankton abundance. Thirty-two species were identified and they belonged to the families: *Bacillariophycea*, *Chlorophycea*, *Dinophycea*, *Euglenophycea, Cyanophycea* and *Rhodophycea*. The most abundant families were *Bacillariophycea and Cyanophycea* (Lake Naivasha), and *Chlorophycea* and *Dinophycea* (Lake Oloiden). The diversity index was low: 0.97 and 0.67 for Oseria and Oloiden (ST1, ST2) respectively. The Margalef's index was highest for Oseria (4.62) and lowest for Oloiden ST1 and ST2 (2.86). The dominance index (D) was highest in Korongo (0.16) and lowest in Oloiden ST1 (0.1) while Korongo had the lowest evenness (0.77) and Oseria's was the highest (0.86). The species richness decreased with an increase in salinity. The phytoplankton diversity was low in the lakes and it could be attributed to the salinity. Further research should be done along the salinity gradient since conditions may change and, thus the phytoplankton diversity.

Keywords: *Bacillariophycea*, *Chlorophycea*, *Cyanophycea*, salinity gradient.

INTRODUCTION

The water level in Lake Naivasha increased leading to its merging with Lake Oloiden (Nyangau, 2021). Mixing of fresh water with saline water created an estuary (Telesh and Khelebivich, 2010). A brackish water ecosystem is formed at the meeting of saline and fresh water and thus creating a salinity gradient. Definitive physical, chemical and biological features characterize it. There are major biotic and abiotic processes that illustrate nonlinear change of aspects in abiotic and biotic processes. Estuaries act as sink for organic matter and nutrients. There are varying modes of sedimentation on either side of the critical salinity barrier due to an increase in flocculation that influences the transparency (Telesh and Khelebivich, 2010). Flocculation of colloids removes trace elements and nutrients; making them less readily available (Nielsen *et al*., 2003).

Stressors in an aquatic environment may include; salinization, acidification of water, eutrophication e.t.c. Thus, changes in the pH, nutrients, temperature and salinity can cause stress to flora and fauna (Valsco *et al*., 2019). However, salinity is a major factor which defines the ecosystem and its aquatic biota (Telesh and Khelebivich, 2010). It is an important stressor that governs distribution, variations affect phytoplankton community structure (Flöder *et al*., 2010). Aquatic organisms may vary with the changing salinity (Velasco *et al*., 2019). Phytoplankton may exhibit fluctuations due to environmental conditions e.g., salinity gradient; families that dominate change with salinity (Olofsson *et al*., 2020). Salinity is a main environmental factor; its range plays a definitive role on characteristics of an aquatic ecosystem and structure of aquatic biota (Telesh and Khelebivich, 2010).

Variation in the salinity (seasonal fluctuations by fresh water inputs) was caused due to Rockfill railroad causeway that was constructed and it divided Great Salt Lake into two. Its salinity previously was 20-27% (annual precipitation variation) but has been fluctuating between 16-29% and the south arm ranged 6-28% (majority of fresh water enters the arm). In an inoculum experiment from Great Salt Lake Utah with different salinity samples: results indicated salinity as a strong determinant of phytoplankton diversity. Species richness decreased with an increase in salinity (Larson and Belovsky, 2013). There has been an increase in the water level in the Rift valley lakes; and thus, the Lake Oloiden and Naivasha have merged into one ecosystem. The merging of these two lakes may have an effect on the aquatic organisms due to their salinity differences (Ballot *et al*., 2009). The study objective was to determine the spatial and temporal distribution, abundance and diversity of plankton along a salinity gradient in the Lakes Naivasha and Oloiden.

MATERIALS AND METHODS

Study site

The study was done in the Lake Naivasha (00°46'S, 36°22'E) and Lake Oloiden (00°50'S, 36°17'E) (Ballot *et al*., 2009). The first station (ST1) was Oloiden ST1 which was at the Lake Oloiden (southern part of Lake Naivasha). Station two (ST2) was Oloiden, a shallow site that borders Oseria (ST3). The sites usually disconnected and connected during low and high-water level in the Lake Naivasha respectively: The fresh water mixes with saline water resulting in an estuarine environment. Station four (ST4) was Crescent; a crater lake on the eastern part of Lake Naivasha that connects to the main lake during high water levels. The station 5 (ST5) was Korongo: a lagoon situated at the North-West that is connected to the main lake. Midlake was the sixth station (ST6); an open water site. Its the most extensive proportion of the Lake Naivasha's surface area. Malewa was the seventh sampling site (ST7); a swampy area in the north that was covered at the edge with floating *Eichhornia crassipes* and *Cyperus papyrus*. The study was done along a transect (Oloiden ST1- Malewa ST7) with an addition of two sites in the Lake Naivasha.

Sampling and analysis

The sampling of some physico-chemical parameters and phytoplankton were done once per month, consistently for one year (August, 2020 to July, 2021).

Physical and chemical parameters

The physico-chemical parameters were measured *insitu* using a YSI Multiparameter probe (Nyangau, 2021).

Phytoplankton

Phytoplankton sample was picked by a van don sampler in duplicate: sieved through a phytoplankton net (30 µm) and preserved by drops of Lugol iodine solution. Identification and counting were done in Sedgewick Rafter cell, under a compound microscope (×100) and keys were utilized (Suthers and Rissik, 2008; Bellinger, 2015). In the calculation of the density (individuals per litre): the average number of individuals counted in the sample was divided by the water volume of the sample obtained.

Phytoplankton diversity

The Shannon-Wiener index, evenness and Margalef's index were utilized in studying the phytoplankton diversity (Ogbeigbu, 2005; Eyo *et al*., 2013). Below is the Shannon-Weiner index formula:

$$H' = \Sigma iPiLniPi$$

Where; Pi = n/N of phytoplankton belonging to the i^{th} species; Ln = natural logarithm and **Σ** = sum of the calculated values.

Assuming all species are represented in a sample and randomly selected. Evenness (E) formula:

$$E = \frac{H}{LnS}$$

In the case: Ln = natural logarithm (S) and S = sum of species.

Margalef's index (d) formula:

$$d = \frac{S-1}{LnN}$$

Where; N = total number of species.

Data analysis

One-way Analysis of Variance (ANOVA) was calculated (α= 0.05) in the Statistical Package for Social Scientist (SPSS) and a post hoc of Tukey pairwise comparison for the respective physico-chemical parameters. phytoplankton species. The Pearson's correlation was done for the salinity and the phytoplankton abundance in SPSS. Microsoft excel (2019) was used in the calculation of the indices (Rayori *et al*., 2021).

RESULTS

Physicochemical parameters

The temperature was significantly different between the stations and lakes ($p<0.05$) and the Midlake's was

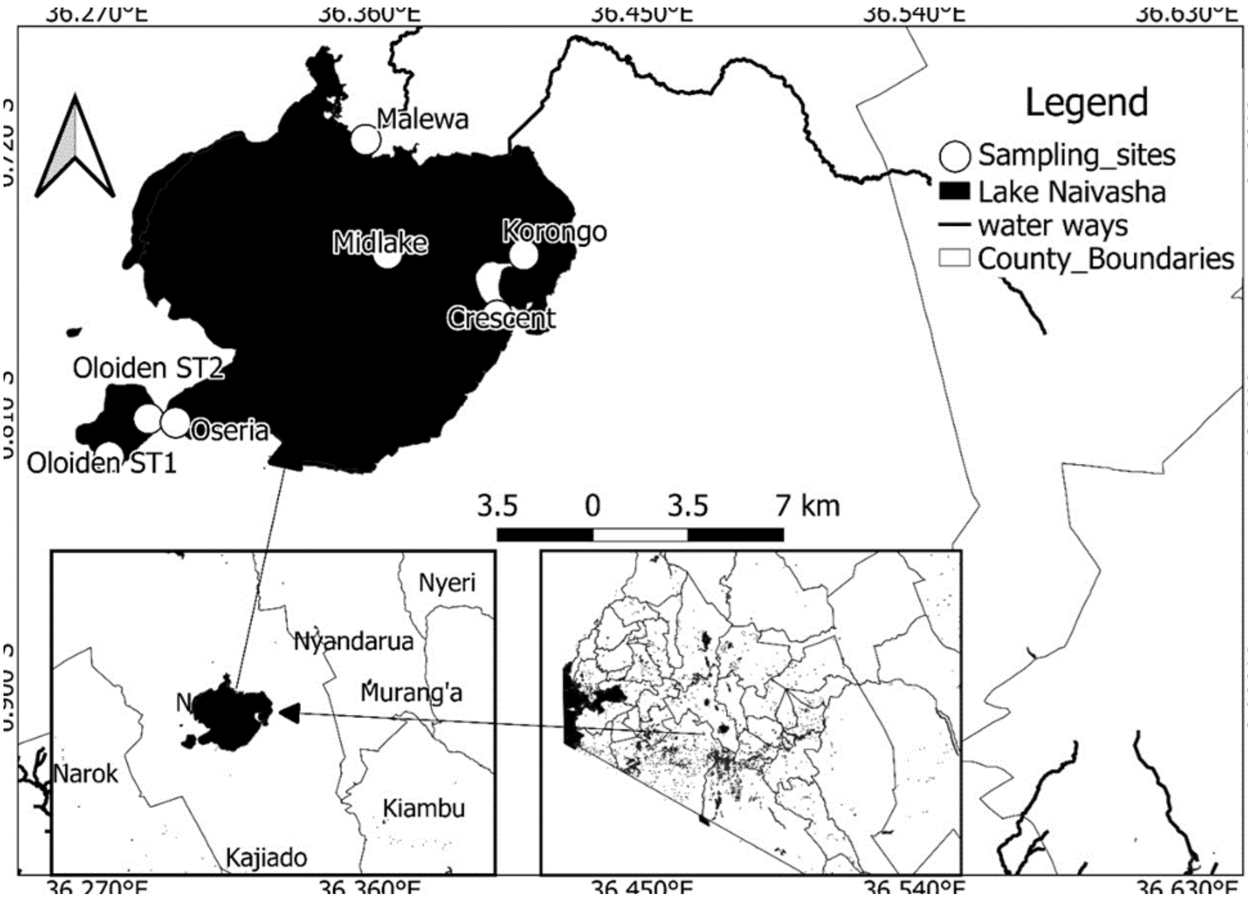

Figure 1. A map of the study sites in the Lake Naivasha and Lake Oloiden (Openstreetmap.org, 2021).

Table 1. Means of the physio-chemical parameters in the various sites in Lake Oloiden and Lake Naivasha (DO= dissolved oxygen and TDS= Total dissolved solids).

Variable	**Oloiden ST1**	**Oloiden ST2**	**Oseria**	**Midlake**	**Malewa**	**Crescent**	**Korongo**
Temperature º C	21.96±1.12	21.12±3.25	20.8±2.8	20.08±3.84	21.97±1.23	21.39±0.67	21.74±1
DO (mg l^{-1})	6.29±2.2	6.57±1.3	5.95±1	6.73±1.3	6.54±0.8	5.87±0.9	5.88±0.7
Conductivity (µS m^{-1})	0.58±0.1	0.58±0.1	0.19±0.04	0.18±0.04	0.18±0.04	0.17±0.04	0.19±0.4
Salinity (ppm)	310±70	310±0.06	98±20	96±20	93±20	96±20	98±20
pH	8.56±0.2	8.46±0.4	7.68±0.4	7.65±0.2	7.52±0.2	7.45±0.3	7.62±0.2
TDS (mg l^{-1})	0.41±0.09	0.41±0.08	0.13±0.02	0.12±0.02	0.15±0.1	0.12±0.02	0.13±0.02

distinctly high. The dissolved oxygen was significantly different within the stations (p<0.05) with Korongo and Midlake being outstanding, although, the lakes were similar. Each of the sites' conductivity had their distinction (p<0.05). The highest was in the Oloiden ST1 (0.57±0.13 µS/ m) and Oloiden ST2 (0.59±011 µS/ m). The rest of the sites mean range was: 0.17-0.185 µS/ m (Lake Naivasha) (Table 1).

There was a significant difference in the salinity for the respective study sites and lakes (p<0.05) and the Oloiden ST1 (0.31±71 ppt) and Oloiden ST2 (310 ppm) were distinctly higher than the rest (Tukey test). The pH difference between the study sites and lakes was significant (p<0.05). Korongo and Malewa were similar while the rest were distinct and the highest being: Oloiden ST1 (8.5±3.12) and Oloiden ST2 (8.46± 0.53). The TDS

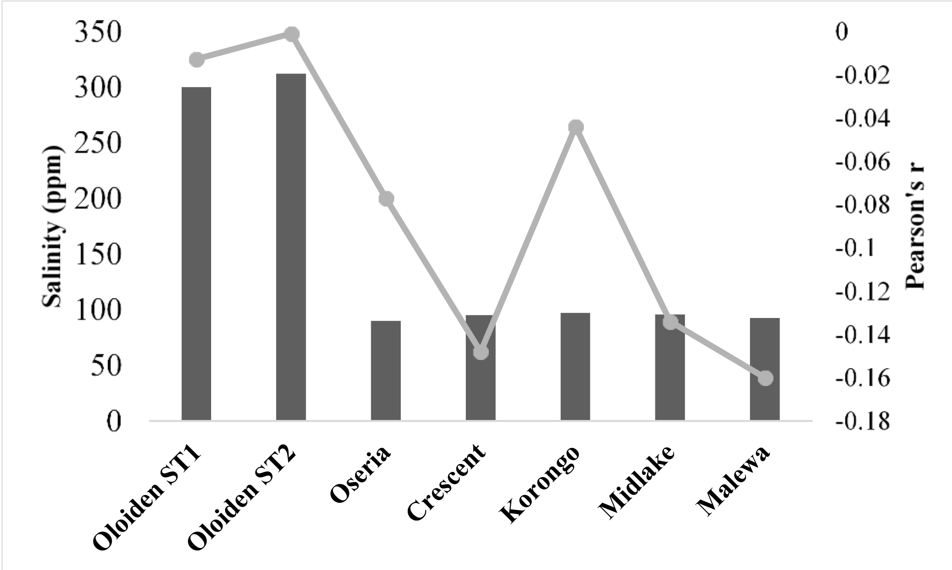

Figure 2. The Pearson's correlation (r) (between the phytoplankton numbers and the salinity) and the salinity in the respective study sites.

was significantly different in the respective sites and lakes and lakes ($p<0.05$).

Correlation

The Pearson's coefficient shows that the salinity had a slight negative association with the phytoplankton abundance in all sites with variations (Figure 2). The association was significant in Crescent and the Midlake ($p<0.05$).

Phytoplankton

The species were significantly different ($p<0.05$) with respect to the different sites. The family *Chlorophycea* had the highest number of species, followed by *Bacillariophycea* and C*yanophycea*. *Rhodophycea* had only one species (Table 2). There was no variation in the phytoplankton species and their counts in the different times of the day ($p>0.05$) (Table 3).

Oseria had the highest while Oloiden ST2 had the lowest number of species (Table 4). The diversity index was: 0.72±0.11 (overall) and it was highest in Oseria. The dominance index (D) was: 0.16 (Korongo) and 0.1 for Oloiden ST1. Lake Oloiden and Lake Naivasha had a species evenness of 0.73±0.06 which was highest in Oloiden ST2 and Oseria while it was lowest in Korongo. Species richness was 3.72±0.67 and Oseria was the highest while Oloiden ST1 and ST2 were the lowest.

The Lakes Naivasha and Oloiden had many species from *Chlorophycea* and the earlier had a high species number of *Cyanophycea* and *Bacillariophycea* (Table 5). Lake Oloiden study sites had the highest abundance of *Chlorophycea*, *Dinophycea* and E*uglenophycea* (low abundance in Lake Naivasha) (Table 6). The Lake Naivasha had the highest abundance of *Bacillariophycea*, *Cyanophycea*, D*inophycea*, *Chlorophycea*. Oseria had a high abundance of C*hlorophycea*, *Bacillariophycea*, *Rhodophycea* and *Cyanophycea* while Oloiden ST2 had the highest as *Dinophycea*, *Chlorophycea* and *Euglenophycea*.

DISCUSSION

The temperature range was between 20.08-21.97°C which was within the range of previous findings in Lake Naivasha (Ndungu *et al*., 2014). There was significant variation in the temperature with respect to the study sites; Korongo had a high temperature. This was similar to Malewa, Oloiden ST1 and Oloiden ST2. The Lake Oloiden had a significantly higher temperature as compared to the Lake Naivasha. Dissolved oxygen range was 5.87-6.73 mg l^{-1} and it was lower than the previous findings in Lake Naivasha (7-9 mg l^{-1}). Significant variation was noted with respect to the study sites (Ndungu *et al*., 2014).

The conductivity varied with respect to the study sites and Lake Oloiden's was higher. However, the conductivity of Lake Naivasha was much lower than its previous (251-421 µS cm^{-1}), an indicator that the increase in water has caused a dilution (Ndungu *et al.,* 2014). The PH mean range was 7.45-8.56 it tallied with previous findings in Lake Naivasha and it was slightly lower in Lake Oloiden (previously, 9.3-9.9) (Ballot *et al*., 2009; Obegi *et al*., 2021). The Lake Oloiden's pH was significantly higher compared to the Lake Naivasha's. Lake Oloiden's total

Table 2. Phytoplankton species of the respective sites in the Lakes Naivasha and Oloiden, X= species present and – = species absent.

Phytoplankton species	Oseria	Crescent	Korongo	Midlake	Malewa	Oloiden ST1	Oloiden ST2
Bacillariophycea							
Aulacoseira granulate	X	X	X	X	X	X	X
Nitzschia sp.	X	X	X	X	X	X	X
Navicula subtilissima	X	-	X	X	X	-	-
Tetracyclus sp.	X	X	X	X	X	X	X
Surirella elegans	X	X	X	X	X	X	X
Surirella linearis	X	X	-	X	-	X	-
Surirella minuta	X	-	X	X	-	-	-
Chlorophycea							
Chlorella sp.	X	X	X	X	X	X	-
Crucigenia tetrapedia	X	-	X	-	-	-	-
Scenedesmus communis	X	X	X	X	X	X	X
Scenedesmus opoliensis	X	X	X	X	X	X	-
Scenedesmus accuminatus	X	X	X	X	X	X	X
Spirogyra prolecta	-	X	-	-	-	X	-
Pediastrum v. boryanum	X	-	X	X	X	X	X
Pediastrum boryanum	X	X	X	X	X	-	X
Pediastrum duplex	-	-	X	X	X	X	X
Pediastrum simplex	-	-	X	-	-	X	-
Tetraedron sp.	-	-	X	-	-	-	-
Tetmemorus sp.	X	X	-	-	-	-	-
Ankistrodesmus falcatus	X	X	X	-	-	-	-
Oocystis sp.	-	-	X	-	-	-	-
Coelastrum sp.	-	-	-	-	-	X	-
Westella sp.	-	X	-	-	-	X	-
Actinastrum sp.	X	-	-	-	-	-	-
Cyanophycea							
Anabaena circunalis	X	X	X	X	X	X	X
Athrospira sp.	X	X	-	X	-	X	X
Cylindrospermum sp.	X	X	X	X	X	X	X
Chroococcus turgidus	X	X	-	X	-	X	X
Microsistis sp.	X	X	X	X	X	X	X
Dinophyceae							
Ceratium hirundinella	X	-	X	X	X	X	X
Ceratium cornutum	-	-	-	X	X	X	X
Lepocinclis sp.	X	X	X	X	X	X	X
Euglenophycea							
Euglena mutabilis	-	-	X	X	X	X	X
Phacus helicoides	-	X	X	-	X	-	-
Peridinium cinctum	X	X	X	X	X	X	X
Rhodophycea							
Hildenbrandia sp.	X	X	X	X	X	X	X

dissolved solids were higher as compared to Lake Naivasha's. This could be due to surface runoff from an agricultural rich catchment and its shallowness that allows mixing (Ndungu *et al*., 2014).

The salinity was significant different with respect to the sites and lakes. Oloiden ST1 and ST2 had a higher salinity and thus a salinity gradient at point of confluence with Oseria (Telesh and Khelebivich, 2010). There was a weak

Table 3. Phytoplankton species in the Lakes Naivasha (Oseria) at the respective times of the day, X and – illustrates presence and absence respectively of specie.

Phytoplankton species	4 am	10am	2pm	2pm	10pm
Pediastrum v. boryanum	-	X	X	-	-
Pediastrum boryanum	X	-	-	-	-
Microsistis sp.	X	X	X	X	X
Ceratium hirundinella	X	X	X	X	X
Peridinium cinctum	X	X	-	-	-
Anabaena circunalis	X	X	X	X	-
Tetracyclus sp.	X	-	X	X	X
Cylindrospermum sp.	X	X	X	X	X
Tetraedron sp.	X	-	-	X	-
Nitzschia sp.	X	X	X	X	X
Spirogyra prolecta	X	X	X	-	-
Lepocinclis sp.	-	-	-	X	-
Navicula subtilissima	-	X	X	-	-
Aulacoseira granulata	X	X	X	X	-

Table 4. The phytoplankton diversity indices in the Lake Naivasha and Lake Oloiden.

Parameters	Oseria	Crescent	Korongo	Midlake	Malewa	Oloiden ST1	Oloiden ST2
Taxa	26	25	22	24	23	14	13
Individuals	10,597	14,700	9,366	9,861	10,800	6,993	5,573
Dominance index	0.14	0.14	0.16	0.15	0.15	0.1	0.14
Shannon- Weiner index (H)	0.97	0.66	0.66	0.71	0.68	0.68	0.67
Evenness	0.81	0.74	0.67	0.69	0.64	0.68	0.81
Margalefs index	4.62	3.97	3.54	4	4.2	2.86	2.86

Table 5. The species number of the various phytoplankton families in the Lakes Naivasha and Oloiden study sites.

Phytoplankton family	Oseria	Crescent	Korongo	Midlake	Malewa	Oloiden ST1	Oloiden ST2
Bacillariophycea	4	4	4	4	4	1	1
Chlorophycea	12	12	10	9	8	8	8
Cyanophycea	5	5	5	5	5	2	1
Dinophycea	2	2	2	2	2	1	1
Euglenophycea	2	1	2	2	2	2	2
Rhodophycea	1	1	1	1	1	-	-
Total	26	25	24	23	22	14	13

Table 6. Spatial variation in the phytoplankton density (Ind/l) of various families in the Lakes Oloiden and Naivasha.

Taxonomic group	Oseria	Crescent	Korongo	Midlake	Malewa	Oloiden ST1	Oloiden ST2
Bacillariophycea	3,245,867	3,251,173	4,013,509	3,860,778	4,299,992	416,463	653,218
Chlorophycea	5,394,381	455,980	341,083	514,282	489,727	1,884,898	1,517,161
Cyanophycea	1,493,768	1,383,710	1,030,666	1,063,182	1,183,777	388,031	362,670
Dinophycea	577,148	1,237,199	1,078,119	1,316,635	1,360,719	1,670,948	1,674,205
Euglenophycea	389,312	346,185	755,432	362,670	237,384	1,424,140	1,353,752
Rhodophycea	1,827,480	362,670	593,460	437,286	395,640	-	-

negative correlation of salinity with phytoplankton abundance. Oloiden ST2's phytoplankton abundance had a very weak negative association with salinity. The correlation was also low in Korongo and Oseria study sites. The phytoplankton numbers decreased with the increase in salinity (Flöder *et al*., 2010). This was displayed in the phytoplankton density which was low in Oloiden ST2 and ST1, salinity may be a strong determinant (Larson and Belovsky, 2013).

A total of 32 phytoplankton species were identified which was similar to previous findings (Omondi *et al*., 2019). They belonged to 6 families namely: C*hlorophycea*, *Bacillariophycea*, *Cyanophycea*, *Rhodophycea* (had 1 species), E*uglenophycea* and *Dinophycea* (Koushik *et al*., 2016; Rayori *et al*., 2021). A high number of species was noted in Oseria while Oloiden ST1 and ST2 had a low number of species. The species composition and number differed with salinity: Oseria was estuarine and it's salinity was lower as compared to Oloiden ST1 and ST2 whose was higher. An estuarine environment is characterized by higher productivity and a saline environment may have a low number of species (Larson and Belovsky, 2013).

The family *Chlorophycea* had the highest number of species, followed with *Cyanophycea*. Oseria had the highest abundance of *Bacillariophycea* and *Cyanophycea*. The shift in the dominance of *Bacillariophycea* and *Cyanophycea* indicated a moderate eutrophic environment (Omondi *et al*., 2019). The high abundance of the respective families and especially *Bacillariophycea* was an indicator to a eutrophic state. Presence of *dinophycea* showed that there was accumulation of organic matter (Hubble and Harper, 2002). The accumulation of organic matter was a sign of a moderately eutrophic condition (Rayori *et al*., 2021). Also, the prevailing site particular abiotic conditions may have an impact in the phytoplankton family that was abundant: biotic and abiotic aspects may undergo change with space and time along the salinity gradient (Larson and Belovsky, 2013) The finding that *Bacillariophycea* was the most abundant while *Dinophycea* was the 3rd abundant family (more salt tolerant) tallies with Nelson *et al*. (2021) and Olofsson *et al*. (2020).

The Lake Oloiden sites had the dominance of *Euglenophycea* and *Dinophycea* (salt tolerant families). The dominance of D*inophycea* (2nd) tallies with the findings of Nelson *et al*. (2021. The species that occurred in the Oloiden ST1 and Oloiden ST2 were tolerant to a higher salinity. The presence of *Dinophycea* was a sign of water column stability and low nutrient availability. The salinity may have an influence on the species composition and thus the family that occurred at particular sites (Larson and Belovsky, 2013).

Changes in the diversity pattern may exist due to the change in abiotic conditions along a salinity gradient: salinity is a strong determinant. Oseria was estuarine and had the highest species diversity while Oloiden ST1 and ST2 were saline and had the lower species diversity (Larson and Belovsky, 2013). The dominance index was similar in Oloiden ST2 and Oseria. The diversity index varied along the salinity gradient and it was low. The low diversity could be attributed to salinity. In contrast with the findings; phytoplankton diversity decreased with increase in the salinity (Hussan *et al*., 2020; Flöder *et al*., 2010).

The phytoplankton species evenness was low and it tallied with Kathiresa (2013). Although, high in Oloiden ST2 and Oseria. The points of confluence may have a higher productivity Hussan et al. (2020). Some of the sites e.g., Malewa (inlet of River Malewa) and Korongo had the lowest species evenness. The results were in contrast to Larson and Belovsky (20130), where the species evenness decreased with increase in salinity (Oloiden ST1) (Flöder *et al*., 2010).

Margalef's index for phytoplankton was high; results contrasted with Kathiresan (2013). The highest was in Oseria (estuarine), it was followed by Malewa then Midlake. Oloiden ST1 and ST2 had the lowest species richness. There may be a decrease in the species richness with increased salinity (Larson and Belovsky, 2013) and it contrasts with the findings of Flöder *et al*. (2010). Thus, the species richness was high in Lake Naivasha as compared to the Lake Oloiden. Phytoplankton may have diel migration although, in the study there was no difference in the phytoplankton species and their counts with respect to time (Suthers and Rissik, 2008).

Conclusion and Recommendation

The Lake Naivasha was moderately eutrophic (shown by the density of the respective families). Species diversity and evenness were low while species richness was high and it decreased with an increase in salinity. The phytoplankton diversity was low in the lakes. Further research should be done along the salinity gradient since conditions may change and thus the phytoplankton diversity.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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REFERENCES

Ballot, A., Kotut, K., Novelo, E., & Krienitz, L. (2009). Changes of phytoplankton communities in Lakes Naivasha and Oloidien, examples of degradation and salinization of lakes in the Kenyan Rift Valley. *Hydrobiologia*, *632*, 359-363.

Bellinger, E. (2015). *Fresh water algae: identification, enumeration and use as bioindicators*. In. Bellinger, E., & Sigee, D. (Eds.). *A key to the more frequently occurring fresh water algae*. John Wiley and Sons. Pp.141-251.

Eyo, V. O., Ekyo, P. B., Andem, A. B., & Okorafor, K. A. (2013). Ecology and diversity of phytoplankton in the Great River Kwa,

Cross River State, Nigeria. *International Journal of Science and Research*, *1*(2), 1-7.
Flöder, S., Jaschinski, S., Wells, G., & Burns, C. W. (2010). Dominance and compensatory growth in phytoplankton communities under salinity stress. *Journal of Experimental Marine Biology and Ecology*, *395*(1-2), 223-231.
Hubble, D. S., & Harper, D. M. (2002). Phytoplankton community structure and succession in the water column of Lake Naivasha, Kenya: a shallow tropical lake. *Hydrobiologia*, *488*, 89-98.
Hussan, S., Uddin, N., Emma, S. N., Rahman, M, M., & Hussain, Z. (2020). Assessment of fish and plankton biodiversity in the Bay of Bengal, Cox's Bazar, Bangladesh. *World Applied Science Journal*, *38*(6), 471-478.
Kathiresan, M. (2013). *Composition and community structure of plankton from Muthupet coastal waters and application of marine copepods (oithuna rigida) for larval rearing of Pacific white shrimp (Litopevaeus vannamei)*. Doctoral dissertation. Bharathidasan University, Tiruchirappalli.
Koushik, R., Sandipan, G., & Saurav, K. M. (2016). Checklist of commonly occurring phytoplankton and zooplankton genera of urban and rural ponds of Raipur, Chhattisgarh. *International Journal of Research in Biological Sciences*, *6*(1), 1-6.
Larson, A. C., & Belovsky, E. G. (2013). Salinity and nutrients Influence richness and evenness of phytoplankton community in microcosm experiment from Great Salt Lake Utah, USA. *Journal of Plankton Research*, 35 (5), 1154-1166.
Ndungu, J., Augustijn, D. C., Hulscher, S. J., Fulanda, B., Kitaka, N., & Mathooko, J. M. (2014). A multivariate analysis of water quality in Lake Naivasha, Kenya. *Marine and Freshwater Research*, *66*(2), 177-186.
Nelson, T. R., Hightower, C. L., Coogan, J., Walther, B. D., & Powers, S. P. (2021). Patterns and consequences of life history diversity in salinity exposure of an estuarine dependent fish. *Environmental Biology of Fishes*, *104*, 419-436.
Nielsen, D. L., Brock, M. A., Rees, G. N., & Baldwin, D. S. (2003). Effects of increasing salinity on freshwater ecosystems in Australia. *Australian Journal of Botany*, *51*(6), 655-665.
Nyangau, G. (2021). *Assessment of fisheries changes in relation to water level fluctuations, Species introductions and management trend in the Lake Naivasha.* PhD thesis, Kisii University, Kenya.
Obegi, B. N., Ogendi, G. M., Omondi, R., Siriba, B. J., Morara, G. N., Rindoria, N. M., & Orina, P. (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*(01), 53-67.
Ogbeigbu, A. E. (2005). *A practical approach to research and data handling*. Minex publishing, Benin city, Nigeria. Pp. 153-155.
Olofsson, M., Hagan, J. G., Karlson, B., & Gamfeldt, L. (2020). Large seasonal and spatial variation in nano-and microphytoplankton diversity along a Baltic Sea—North Sea salinity gradient. *Scientific Reports*, *10*, Article number 17666.
Omondi, A. O., Balaka, S. O., Mokua, G. O., Mokua J. O & Omondi S. O. (2020). A review of the changes in phytoplankton community structure and ecology in Lake Naivasha, Kenya. *Journal of Ecology and the Natural Environment* (In Print)
OpenStreetMap.org (2021). *OpenStreetMap Nominatim*. Retrieved from https://nominatim.openstreetmap.org/ui/search.html.
Rayori, D., Getabu, A., Omondi, R., Orina, P., Babu, J., & Omondi, A. (2021). Plankton diversity in Gusii waste water treatment plant in Kisii county, Kenya. *International Journal of Fisheries and Aquatic Studies*, *9*(3), 299-306.
Suthers, M., & Rissik, D. (2009). *Plankton: A guide to their ecology and monitoring for water quality*. CSIRO publishing.
Telesh, I. V., & Khlebovich, V. V. (2010). Principal processes within the estuarine salinity gradient: a review. *Marine Pollution Bulletin*, *61*(4-6), 149-155.
Velasco, J., Gutiérrez-Cánovas, C., Botella-Cruz, M., Sánchez-Fernández, D., Arribas, P., Carbonell, J. A., Millán, A., & Pallarés, S. (2019). Effects of salinity changes on aquatic organisms in a multiple stressor context. *Philosophical Transactions of the Royal Society B*, *374*(1764), 20180011.