Journal of Technology & Socio-Economic Development
https://zenodo.org/deposit/new?c=ciris
ISSN Print: 2223-9227
ISSN Online: 2616-9614
DOI: 10.5281/zenodo.8122290

Spatial and temporal distribution and diversity of zooplankton along a salinity gradient between the Lake Naivasha and the Lake Oloiden

Guto Kerubo Carolyne[1]*, Njiru Murithi James[2], Getabu Albert[1], Gichana Moraa Zipporah[1]

[1]Department of Aquatic and Fishery Sciences, Kisii University, P.O. BOX 408-40200, Kisii, Kenya.
[2]Kenya Marine and Fisheries Research Institute, P.O. BOX 81651-80100, Mombasa, Kenya.

*Corresponding author email: carolynekerry09@gmail.com

Published online: 7th July 2023

Abstract
There has been an increase in the water level in the Lake Naivasha (fresh water) which led to its merging with Lake Oloiden (saline). This was due to the increase in rainfall: associated with climate change. This may have an impact on the zooplankton community (biodiversity) due to the salinity gradient that resulted. A study was conducted to investigate the spatial and temporal distribution and diversity of zooplankton along a salinity gradient between the Lake Naivasha and the Lake Oloiden. The salinity was measured insitu using a YSI Multiparameter meter and zooplankton were sampled twice by towing a zooplankton net with a flow meter for 10 minutes (monthly, per site for one year). The zooplankton were identified and analyzed under a compound microscope (×100). The species diversity, evenness and species richness index were computed. The salinity was higher in Oloiden ST1 and ST2 as compared to the rest of the sites while the correlation showed a slight positive association between salinity and zooplankton numbers. A total of 17 species were identified and they belonged to the following families: *Branchionidae*, *Lecanidae*, *Trichocercidae*, *Sisidae*, *Daphnidae* and C*yclopoidae*. The density (Ind/l) was highest for *daphnidae*, *cyclopoidae* and *sisidae*; however, Lake Oloiden had a lower density as compared to the rest of the sites. The diversity index was low; H'= 0.87 for Oloiden ST2 and H'=0.64 for Crescent. Species richness (d) was highest (2.84) for Oloiden ST2 and lowest in Crescent (1.24). Species evenness was highest in Crescent (0.83) and lowest in Oseria (0.71). The diversity index, evenness and Margalef's index was higher in Lake Oloiden as compared to Lake Naivasha. The salinity gradient had an impact on the distribution and diversity of zooplankton; species diversity, evenness and species richness increased with increase in salinity.

Key words: *Cyclopoidae*, *Daphnidae*, Diversity index, Evenness, Species richness

1.0 INTRODUCTION

The Lake Naivasha is a shallow water body with a gentle gradient whose basin fills at a slight rise in the level of water. The lake consists of 4-physico-chemically distinct basins: Crescent Island; main lake; Lake Oloiden and Lake Sonachi. The 3rd basin is Lake Oloiden; shallow crater lake that was disconnected from the main lake since 1962 (possibly by naturally drawing down) (Nyangau, 2021). The Lake Oloiden (saline) and Lake Naivasha (fresh water) united post water level rise and this may have an impact on the zooplankton community due to the salinity gradient (Valsco *et al*., 2019). A characteristic that is definitive is the mixing of water fresh and saline water (Telesh and Khelebivich, 2010).

Salinity is an important environmental factor that may shape the biodiversity and richness of zooplankton. An investigation was done on pearl River estuary on the distribution and structure of zooplankton community for one year. Identified were 68 species of zooplankton. The number and diversity decreased with the increase in the salinity. Salinity had a negative effect on the abundance of *rotifer, cladocerans* and total zooplankton. However, it had little effect on the abundance of *copepods* (Yuan *et al*., 2020).

The zooplankton are an essential component of the aquatic food web and indicators of ecosystem health (Koushik *et al*., 2016). Monitoring and assessment of an aquatic ecosystem can be done by looking at specific aquatic organisms (zooplankton). The abundance of zooplankton in the floating mass was investigated in Lake Naivasha (10 sampling sites). A total number of 15 and 9 species were identified in the open water and the water hyacinth infested areas respectively. The Margalefs richness index was low (d= 1.53) while Shannon-Weiner diversity Index was also low (H'= 0.65) in water hyacinth infested areas. The low abundance of zooplankton in the water hyacinth infested areas could be attributed to the dense mat that reduces dissolved oxygen level (Mironga *et al*., 2014).

There has been an increased in the water level in the Rift valley lakes. Thus, leading to the merging of the Lake Oloiden with the Lake Naivasha. Salinity may have a negative effect on distribution of organisms in an aquatic ecosystem. It shapes the distribution and diversity; study of zooplankton will provide an insight of the ecosystem health (Koushik *et al*., 2016). Little is known about the effect of increasing salinity on the zooplankton community in the Lakes Naivasha and Oloiden. Thus, study objective to investigate the spatial and temporal distribution and diversity of zooplankton along a salinity gradient between the Lake Naivasha and the Lake Oloiden.

2.0 MATERIAL AND METHODS

The study was done in the Lake Naivasha (00°46'S, 36°22'E, an altitude of 1890m) and Lake Oloiden (00°50'S, 36°17'E, an altitude of 1900m) (Ballot *et al*., 2009). Seven sampling points were chosen namely: Oloiden ST1, Oloiden ST2, Oseria, Korongo, Crescent, Midlake, Malewa, Crescent and Korongo (**Figure 1**).

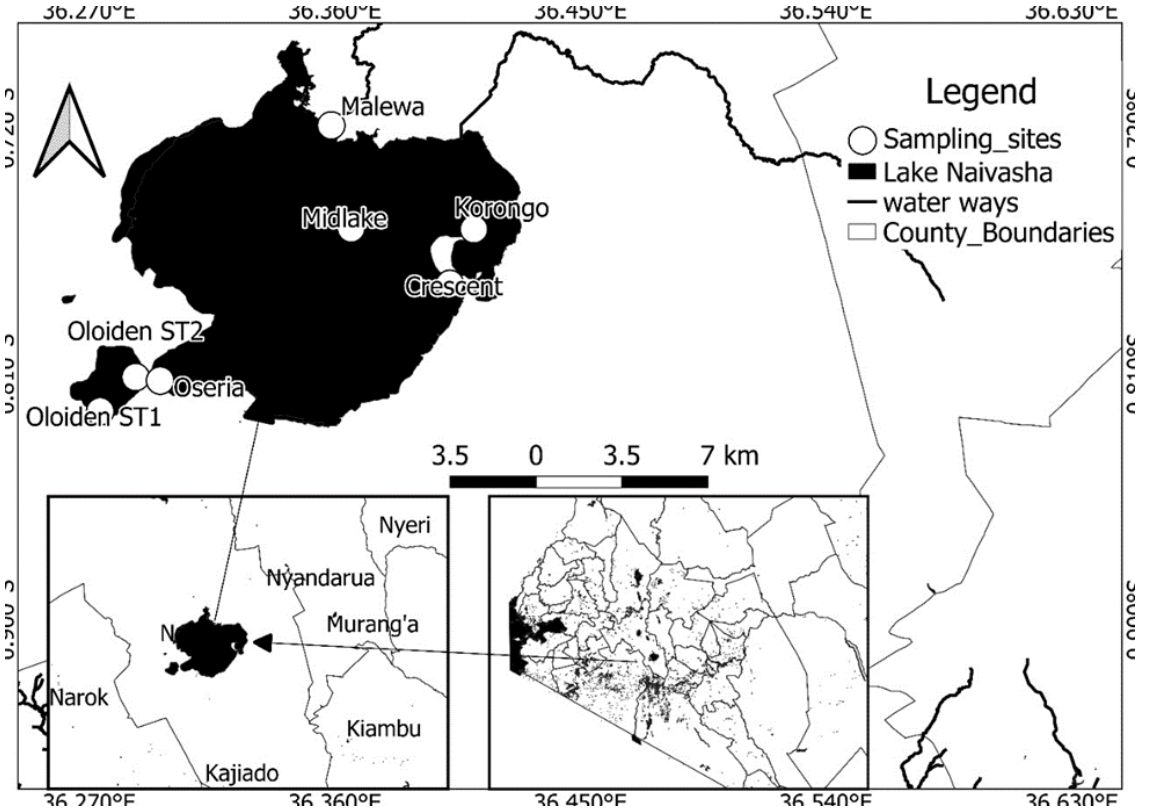

Figure 1. A study area map, showing the Lakes Naivasha (Oseria, Crescent, Korongo, Midlake and Malewa) and Oloiden (Oloiden ST1 and ST2) (Openstreetmap.org, 2021)

2.2 Sampling procedure and analysis

The salinity was measured and zooplankton samples (in duplicates) were collected monthly in each site.

2.2.1 Salinity

The salinity was measured insitu using a YSI Multiparameter meter, monthly during the sampling period of one year (August, 2020 to July, 2021).

2.2.2 Zooplankton

Zooplankton sample was obtained by towing a zooplankton net (60µm) at the speed of 1-2m/s for 10 minutes in two trips). The flow meter reading was taken prior and after towing. Zooplankton samples were also collected at different times of the day at Oseria in the Lake Naivasha. The sample obtained was preserved by adding 4 % formalin. Once in the laboratory, subsampling was done using a pipette: 1ml was diluted in 10ml distilled water. They were counted using a Sedgwick Rafter cell, under a compound microscope (×100) by

parallel scanning the whole cell (Suther and Rissik, 2008). Identification was done using keys according to: Sarma and Gutierrez, 1999; Suther and Rissik, 2008; Dang *et al*., 2015. The volume of water that was sieved through zooplankton net was calculated using the standard formulae as stated in EPA GLNPO, 2016.

2.2.2.1 Zooplankton indices

In the determination of the distribution and diversity in the different sites sampled: three diversity indices were computed according to the formular by Ogbeigbu, 2005; Eyo *et al*., 2013.

The species diversity was calculated using the Shannon-Weiner index.

$$H' = \boldsymbol{\Sigma iPiLniPi}$$

In the case: Pi= proportion of n/N of all zooplankton species that belong to the i^{th} species; Ln is the natural logarithm and **Σ**= sum of the calculation. Under an assumption that all the species were represented in a sample and there is random selection.

The species evenness (E) was estimated using the formulae:

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

Where; LnS is the natural logarithm of S; S is the total number of species and H is the Shannon-Wiener index (Rayori *et al*., 2021).

Margalef's index (d) was determined by:

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

Where; S= total number (species), Ln is the natural logarithm and N is number of individuals (total).

2.2.3 Data analysis

One-way Analysis of Variance (ANOVA) at α= 0.05) was done using Statistical Package for Social Scientists (SPSS) for spatial variation in salinity, a post hoc analysis was done using Tukey pairwise comparison. A correlation of the zooplankton numbers with the salinity was done in SPSS. The diversity indices: Shannon-Wiener index, evenness and Margalef's index were calculated in excel version 2019.

3.0 RESULTS

3.1 Salinity

There was a significant difference in the salinity of the study sites in the Lake Naivasha and the Lake Oloiden (P<0.05). The Oloiden ST1 (300±71 ppm) and Oloiden ST2 (312±59 ppm) were distinctly higher than the rest (**Figure 2**). The results show that the salinity had a slight

positive correlation with the zooplankton numbers. The sites of Lake Naivasha had slightly higher positive correlation (with exception of Crescent and Malewa) values as compared to Lake Oloiden's (Oloiden ST1 and ST2).

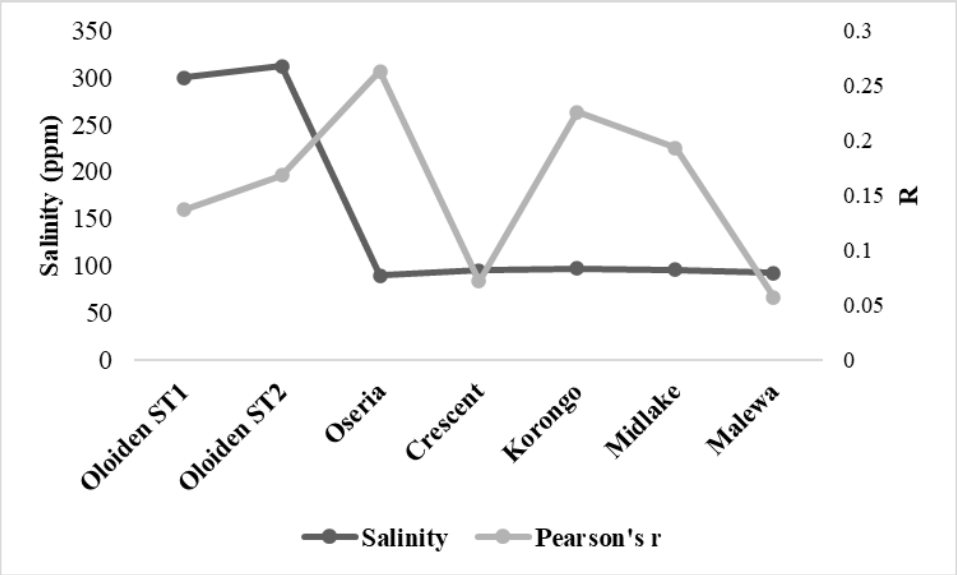

Figure 2. The salinity and Pearson's r (correlation between the zooplankton numbers and salinity) in the respective study sites in the Lakes Naivasha and Oloiden

3.2 Zooplankton

The zooplankton species (17) were significantly different with respect to the study sites ($P<0.05$) (**Table 1**). Oloiden ST1 and ST2 had more *Branchionidae* species (6) as compared to other sites; and they were absent in Crescent. *Cyclopoidae* was the most abundant in species numbers after *Branchionidae*. Oseria was the only site with *Lecanidae* species.

Table 1. The list of zooplankton species in Lakes Naivasha and Oloiden study sites.

Zooplankton species	Oseria	Crescent	Korongo	Midlake	Malewa	Oloiden ST1	Oloiden ST2
Branchionidae							
Branchionus caudata	X	-	X	-	X	X	X
Branchionus angularis angularis	-	-	-	X		X	X
Branchionus calyciflorus	-	-	X	-	-	X	X
Branchionus diversicornis	X	-	X	X	X	X	X
Branchionus forficula	-	-	-	-	X	-	-
Branchionus plicatilis	-	-	-	-	-	X	X
Branchionus falcatus	X	-	X	-	X	X	X
Branchionus quadridentatus quadridemtus	X	-	-	X	-	-	-
Plationus patulus patulus	-	-	-	X	-	-	-
Trichocercidae							
Trichocerca similis	X	-	-	X	X	X	X
Sididae							
Diaphanosoma Sarsi	X	X	X	X	X	-X	X
Daphnidae							
Moinamacropa	X	X	X	X	X	X	X
Lecanidae							
Lecane lunaris	X	-	-	-	-	-	-
Cyclopoidae							
Microcyclops varicans varicans	X	X	X	X	X	-	-
Tropocyclops prasinus prasinus	X	X	X	X	X	X	X
Mesocyclop leuckarti leuckarti	X	X	X	X	X	X	X
Thermocyclops crassus	X	X	X	X	X	X	X

The zooplankton species and their counts at Lake Naivasha did not vary with respect to time ($P>0.05$) (**Table 2**).

Table 2. The list of zooplankton species in the Lakes Naivasha (Oseria) with respect to time (a cross (X) indicates presence while a dash (-) shows an absence).

Zooplankton	4am	9.30am	10am	2pm	2pm	2pm	4pm
Moinamacropa	X	X	X	X	X	X	X
Diaphanosoma Sarsi	X	X	-	X	X	X	X
Tropocyclop prasinus prasinus	-	-	X	X	X	X	-
Mesocyclop leuckarti leuckarti	-	-	X	X	X	X	X
Thermocyclops crassus	X	X	X	X	X	X	X
Branchionus diversicornis	X	X	X	-	X	-	-
Branchionus falcatus	-	-	X	X	X	-	-

Oloiden ST1, Oloiden ST2, Midlake and Oseria had 12 species each while Korongo and Malewa had 10 species (**Table 3**). Lake Oloiden (7,762) had a lower number of individuals as compared to Lake Naivasha (18,506). Shannon Wiener Index (H') was low: Oloiden ST1 had the highest (H'=0.87), Oseria was 0.77 while Crescent's was the lowest (0.64). Lake Naivasha had a diversity index of 0.75 while Lake Oloiden's was 0.85. Species evenness (E) was highest in Crescent (0.83) and lowest in Oseria (0.71). Lake Oloiden (0.80) had a higher evenness as compared to Lake Naivasha (0.77). Margalef's index had its highest in Oloiden ST2 (2.84) and the lowest was in Crescent (1.24). Overall, Margalef's index was higher in Lake Oloiden (2.83) as compared to that of Lake Naivasha (2.22).

Table 3. Indices and zooplankton count for Lakes Naivasha and Oloiden.

	Oseria	**Crescent**	**Korongo**	**Midlake**	**Malewa**	**Oloiden ST1**	**Oloiden ST2**
Taxa	12	6	10	12	11	12	12
Individuals	21561	31149	10430	15201	14188	8012	7512
Dominance index	0.16	0.16	0.16	0.16	0.16	0.16	0.15
Shannon-Weiner index (H')	0.77	0.64	0.75	0.84	0.77	0.87	0.84
Evenness	0.71	0.83	0.75	0.77	0.77	0.81	0.78
Margalefs index (d)	2.73	1.24	2.34	2.63	2.16	2.82	2.84

Trichocercidae, Lecanidae and *Branchionidae* had a low abundance as compared to the rest of the families (*Daphnidae, Sisidae* and *Cyclopoidae*) (**Table 4**). *Branchionidae* had a higher density in Oloiden ST1 and ST2 as compared to the rest of sites while *Trichocercidae, Daphnidae* and *Cyclopoidae* density was lower.

Table 4. The zooplankton density (Ind/l) of the respective families and sites in the Lakes Oloiden and Naivasha.

Taxonomic group	**Oseria**	**Crescent**	**Korongo**	**Midlake**	**Malewa**	**Oloiden ST1**	**Oloiden ST2**
Branchionidae	1,988	-	2,736	2,514	3,751	10,311	14,463
Lecanidae	2,976	-	-	-	-	-	-
Trichocercidae	-	7,439	3,394	3,601	-	2,026	1,759
Sisidae	57,205	64,436	117,000	3,116	53,544	36,212	32,691
Daphnidae	219,194	191,052	227,957	227,957	185,468	121,971	97,633
Cyclopoidae	57,476	50,015	80,839	80,839	61,897	30,011	24.420

4.0 DISCUSSION

Oloiden ST1 and ST2 had a higher salinity as compared to the rest of the sites and the association between salinity and zooplankton numbers was low. Salinity had an impact on the distribution of zooplankton. The salinity and zooplankton numbers had a low positive

association in Malewa and this could be because River Malewa enters Lake Naivasha at this point. The results show a slight positive association in Korongo, Oseria and Midlake. The union of saline water and fresh water occurred at Oloiden ST2 and Oseria thus creating a salinity gradient: biotic and abiotic processes that illustrate nonlinear change. There may be a division in the living conditions appropriate for saline water and freshwater organisms due to osmoregulation (Telesh and Khelebivich, 2010).

The zooplankton are diverse, many occupying intermediate trophic levels and are an important food source for the juveniles and adult fish. They are sensitive and thus utilized as indicators in monitoring and assessment of changes in the aquatic environment (Suther and Rissik, 2008). The zooplankton species were 17 and the findings were within the range of previous findings (15 species). Midlake (open water) had a high number of species and it tallied with Oseria, Oloiden ST1 and ST2 (Mironga *et al*., 2014).

The species number was high in Oloiden ST2 and Oseria and this could be attributed to the salinity gradient where there was higher productivity. The sites further from Lake Oloiden had a lower salinity and lower number of species namely: Crescent, Korongo and Malewa. The species richness was high in the Lake Oloiden as compared to the Lake Naivasha. The Oloiden ST2 and Oseria had their species richness being higher than other sites and may be due to the salinity gradient (Telesh and Khelebivich, 2010; Larson and Belovsky, 2013).

The Lake Oloiden had a higher diversity index as compared the Lake Naivasha and this could be attributed to a higher salinity (Hussan *et al*., 2020). The diversity index was higher as compared to previous findings in the Lake Naivasha (Mironga *et al*., 2014).

Salinity is a limiting factor that influences the plankton community. Diversity index was high in Oloiden ST2 as compared to other sites of lower salinity, namely; Oseria, Crescent, Malewa and Korongo (Hussan *et al*., 2020). The following families: *Trichocercidae*, L*ecanidae* and *Branchionidae* had a lower abundance as compared to *Sisidae*, *Daphnidae* and *Cyclopoidae*. Although, the density was lower in the Lake Oloiden as compared to the Lake Naivasha. Salinity may have a negative effect on the abundance of rotifer (*Trichocercidae*) and thus, the low density in Lake Oloiden, missing in Oseria while *lecanidae* was missing in most sites except Oseria. However, it may have little effect on the abundance of *copepods*; since most species were present in all sites with exception of *Microcyclop varicans* that was missing in Oloiden ST1 and ST2. *Branchionidae* and *Cyclopoidae* had high number of species throughout the sites; although, Oloiden ST1 and ST2 had a higher species number (attributed to salinity) (Yuan *et al*., 2020).

The study site; Oseria, Crescent and Malewa had the highest abundance (density) of *Daphnidae* followed by *Cyclopoidae*, S*isidae*, *Lecanidae* and *Branchionidae*. Oloiden ST2 had the highest abundance of *Daphnidae, Sisidae, Cyclopoidae* and *Trichocercidae*. A high abundance of some families may be an indicator of eutrophication: there was an increase in the density (Suther and Rissik, 2008; Mironga *et al*., 2014). This may be coupled up with the mixing of saline and fresh water (Oloiden ST2 and Oseria): high productivity and high adjustment level for the species in the respective families that were present (Telesh and Khelebivich, 2010).

The species evenness was highest in Crescent and lowest in Oseria; all the other sites had an evenness greater than 0.75. Oloiden ST2 had a lower evenness as compared to Oloiden ST1. Lake Oloiden had higher zooplankton evenness as compared to Lake Naivasha. This could be attributed to the salinity gradient; where there was reduction at the confluence of fresh water and saline water (Telesh and Khelebivich, 2010). The Margalef's index was higher than previously findings with Midlake, Korongo being higher as compared to Malewa. The Lake Oloiden had the highest species richness while Lake Naivasha's sites varied and the highest was in Oseria and the least was in Crescent (Mironga *et al*., 2014). On the other hand, it was higher in Oloiden ST2 as compared to Oseria. This could be attributed to the mixing of saline and fresh water (Larson and Belovsky, 2013). The species richness was higher as compared to previous findings (Mironga *et al*., 2014). The species richness increased with increase in salinity, contrary to the findings of Yuan *et al*., 2020. A diel migratory behavior by zooplankton may be caused by the light intensity and the adaptation of avoidance of visual predators i.e., fish. Although, in the study was no difference in the species number with respect to time (Suther and Rissik, 2008).

5.0 CONCLUSION AND RECOMMENDATION

The change in the salinity may have an impact on the biological community that were present in the aquatic ecosystem. The salinity had an impact on the distribution and diversity of zooplankton: species diversity, evenness and species richness increased with increase in salinity. Further research should be done by increasing the number of study sites between the Oloiden ST2 and Oseria.

6.0 ACKNOWLEDGEMENT

This study was supported by Kenya Marine and Fisheries Research Institute (KMFRI), Naivasha station, to the staff that aided in the acquiring of the samples, laboratory space and equipment; our gratitude.

REFERENCE

Ballot, A., Kotut, K. Novelo, E. and Krienitz, L. (2009). Changes of phytoplankton communities in Lakes Naivasha and Oloiden, examples of degradation and salinization of lakes in the Kenyan Rift valley. *Hydrobiologia*, 632.

Dang, P., Khoi, N., Nga, T., Thanh, D. and Hai, T. (2015). *Identification Handbook of Freshwater Zooplankton of the Mekong River and its tributaries*. Mekong River Commission, Vientiane (pp. 207).

Exploring Project Examples, Great Lakes National Program Office (EPA, GLNPO). (2016). *Standard Operating Procedure for Zooplankton Analysis (LG 402)*. In: Standard Operating Procedure (SOP) for zooplankton sample collection and preservation.

Eyo, V. O., Ekyo, P. B., Andem, A. B. and 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.

Hubble D. and D. Harper. (2002). Phytoplankton community structure and succession in the water column of Lake Naivasha, Kenya: A shallow tropical lake. *Hydrobiologia*, 488, 89-98.

Larson A. C. and 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.

Koushik R., Sandipan G. and Saurav K. M. (2016). Checklist of the commonly occurring phytoplankton and zooplankton genera of urban and rural ponds of Raipur, Cchattisgar. *International Journal of research and Biological Sciences*, 6 (1), 1-6.

Mavuti, K. and D. Harper. (2005). *The ecological state of Lake Naivasha, Kenya, 2005: Turning 25 years research into an effective Ramsar monitoring Programme*. Proceeding of the 11th World Monitoring Programme, 2, 30-34.

Mironga, J. M., Mathooko J. M. and S. M. Onywere. (2014). Effects of spreading pattern of water hyacinth (*Eichhornia crassipies*) on zooplankton population in Lake Naivasha, Kenya. *International Journal of Development and sustainability*, 3 (10), 1971-1987.

Nyangau, G., 2021. *Assessment of fisheries changes in relation to water level fluctuations, Species introductions and management trend in the Lake Naivasha (Doctoral dissertation)*. Kisii University, Kenya.

Ndungu, J., Augustijn, D., Husscher, A., Fulanda, B., Kitaka, N. and Mathooko, J. (2014). A multivariate analysis of water quality in the Lake Naivasha, Kenya. *Marine and Fresh water Research*. http://dx.doi.org/10.1071/MF14031

Obegi, B., Ogendi, G., Omondi, R., Siriba, B., Morara, G., Rindoria, N. and Orina, P (2021). Characteristic relationship between phosphorus accrual ecosystem aspects and water level fluctuations in tropical lakes: Naivasha Ramsar site, Kenya. *The Journal of Geoscience and Environment protection*, 9.

OpenStreetMap.org, (2021). *OpenStreetMap Nominatim*. https://www.researchgate.net

Sarma, S. and Gutierrez, M. (1999). Rotifer (Rotifera) for four natural water bodies of central Mexico. *Limnologica*, 29, 475-483.

Suthers M. and Rissik D. (2009). *Plankton: A guide to their ecology and monitoring for water quality*. CSIRO publishing.

Telesh, I. V. and Khelebivich, V. V. (2010). Principal processes within the estuarine salinity gradient: A review. *Marine Pollution Bulletin*, 61, 145-155.

Valsco, J., Gutierrez-Canovas, C., Botella-Cruz, M., Sanchez-Fermandez, D., Arribas, P., Carbonell, J. A., Millan, A., and Pallare's S., (2019*). Effects of salinity on aquatic organisms in a multiple stressor context*. Royal Society.

Yuan, D., Chen, L., Luan, L., Wang, Q and Yang, Y. (2020). Effect of salinity on the zooplankton community in the pearl River estuary. *Journal of Ocean University of China*, 19, 1389-1398.