

**NATIONAL FISHERIES RESOURCES RESEARCH
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**Report on Environmental Monitoring of Cage Fish Farms at
Mwena, Kalangala on Lake Victoria**

Technical Report for Quarter Three (January-March, 2016)

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Table of Contents

EXECUTIVE SUMMARY	ii
1.0 INTRODUCTION	1
2.0 MATERIALS AND METHODS.....	2
2.1 Study site	2
2.2 Sample collection and analysis	3
2.2.1 Physico-chemical parameters	3
2.2.2 Nutrients and phytoplankton	4
3.0 RESULTS	5
3.1 Physico-chemical parameters.....	5
3.2 Nutrients.....	5
3.3 Phytoplankton composition and abundance	6
4.0 DISCUSSION	10
5.0 CONCLUSIONS AND RECOMMENDATIONS	12
REFERENCES	13

List of tables

Table 1. Mean dissolved oxygen, pH, conductivity, temperature and Secchi depth (mean $\pm$ standard deviation).....	5
Table 2 Concentrations of nutrients ($\mu\text{g/L}$) around the cages and reference site	6
Table 3. Algal bio-volume (mm^3L^{-1}) of the sampled cage sites (A1-A7) and the reference site (A8).....	7
Table 4. Phytoplankton species composition and distribution recorded around cages and reference site	8

List of figures

Figure 1. Map showing location of cage fish farms at Mwena, Kalangala- L. Victoria.....	3
Figure 2. Species richness of different algal groups at different sampling points	7

EXECUTIVE SUMMARY

Fish farming in cages generates considerable amounts of nutrient wastes (e.g., faeces, uneaten feed and metabolic excretions from fish) that are released into the water column, which may cause undesirable environmental effects. To ensure that cage fish farming develops in a more sustainable way, monitoring of water quality around cages is essential for generation of data from which decisions on environmental management may be reached. As part of the monitoring process, a survey was carried out on four cage fish farms at Mwena, Kalangala on Lake Victoria. Nutrient and phytoplankton samples as well as data on physico-chemical parameters were collected on 19th and 20th April 2016. The pH, DO, temperature and conductivity were measured in situ with a submersible multiprobe, CTD-90M (Sea and Sun, Germany). Water transparency and Total depth were measured using a standard Secchi disk and a hand held sonar respectively. Water samples for nutrients and phytoplankton were collected using a 3L Van Dorn water sampler, and analysed using standard methods.

Physico-chemical parameters: pH (7.23 to 8.86), DO (6.99 to 8.92 mg/L), conductivity (100 to 102.4 μ S/cm), temperature (24.18 to 24.83^oC) and Secchi depth (2.0 to 2.6m), around cages and the reference site were within the range for good water quality. The concentrations of ammonia nitrogen (5.02 to 11.18 μ g/L), nitrite nitrogen (0.14 to 7.46 μ g/L), nitrate nitrogen (75.68 to 189.36 μ g/L) and soluble reactive phosphorus (10.92 to 20.62 μ g/L) were within acceptable levels for fish farming. However, high levels of TN (>1mg/L), TP (>0.1mg/L) and SRSi (>1mg/L) were recorded both at the reference site and cage areas. The Chla concentration, indicative of algal biomass was relatively low, and ranged from 2.78 to 9.73 μ g/L both around cage fish farms and the reference site. Phytoplankton groups: Blue-green algae, Green algae, Diatoms, Dinoflagellates and Cryptophytes were encountered. Blue-green algae dominated at all sites both in terms of bio-volume and species richness, with dinoflagellates showing the least number. Generally, the bio-volume was relatively low, although that within the cage fish farms was higher than away from the cages.

These results suggest that there was negligible contribution of nutrients from cage fish farms; presence of other anthropogenic sources of nutrients in this part of the lake; and that other factors besides nutrients control phytoplankton biomass, abundance and species composition. There is need to collect more data over seasons in this part of the lake to capture nutrient variability of the system. Investigations on the direct or indirect effect of activities in the catchment, on this part of Lake Victoria are recommended.

1.0 INTRODUCTION

Fish farming in cages is growing rapidly on Lake Victoria and offering opportunities to contribute to poverty alleviation, employment, community development, reduction of exploitation of natural fish stocks, and food security. The practice (cage fish farming) grows many fish in a confined area and this generates considerable amounts of nutrient wastes in the form of particulate matter (e.g., faeces and uneaten feed) that typically settles to the benthic environment beneath the cage arrays, or they may be in the form of dissolved wastes that are released directly into the water column from feed, faeces and metabolic excretions of fish such as ammonia (Fernandes et al., 2001). High concentrations of nutrients, especially phosphorus and nitrogen, stimulate primary production and can lead to phytoplankton blooming. The degradation of excessive phytoplankton biomass can lead to decreased dissolved oxygen and increase in nutrients concentration in water (Mrcelic and Sliskovic, 2010). These environmental impacts must be maintained at a minimum and within acceptable limits.

Most of the negative impacts on the environment due to fish farm operations can be avoided through initial planning, proper site selection and during the undertaking of the practices (Kashindye et al., 2015). It is therefore important for the public, private sector and the community to invest in cage fish farming and adhere to environmentally, socially and economically sustainable practices. To ensure proper cage fish farming practice that conserves the environment while increasing fish production, fish farms operations need to be checked for possible negative impact on the environment. To achieve this, monitoring of water quality around cage fish farms is essential for generation of data from which decisions on the environmental management may be reached. This report presents detailed results and scientific interpretation and discussion of results from an environmental monitoring survey carried out on four fish cage farms at Mwena, Kalangala on Lake Victoria, to check for possible negative impact of the fish farms on water quality. The survey was undertaken in April, 2016 and generated data on physical and chemical parameters, nutrient status, and phytoplankton composition and biomass around the fish cages.

2.0 MATERIALS AND METHODS

2.1 Study site

Nutrient and phytoplankton samples as well as data on physico-chemical parameters were collected on 19th and 20th April 2016 around four cage fish farms (P, Q, R and S) at Mwena, Kalangala waters, Lake Victoria (Figure 1). Three of the cage groups or farms (P, Q and R) each with 8 cages, were separated by a distance of <50m from each other while a fourth cage fish farm (labelled S) with 16 cages is located 440m away from farm Q (Figure 1). Eight sampling locations labelled A1-8 (Figure 1) were selected and marked using GARMIN Global Positioning System (GPS). Once marked, latitude and longitude coordinates were recorded. Of the 8 sampling locations, two: A1 and A6 were at the edges of cage groups P and S respectively. Three sampling locations: A3, A4 and A5 were marked at the middle of the distance between cage groups P and R, P and Q, and Q and S respectively. Two other sampling locations: A2 and A6 were at a distance of 50m from farm P and S respectively while sampling location A8 served as a reference site located 500m off the edge of cage group S (Figure 1).

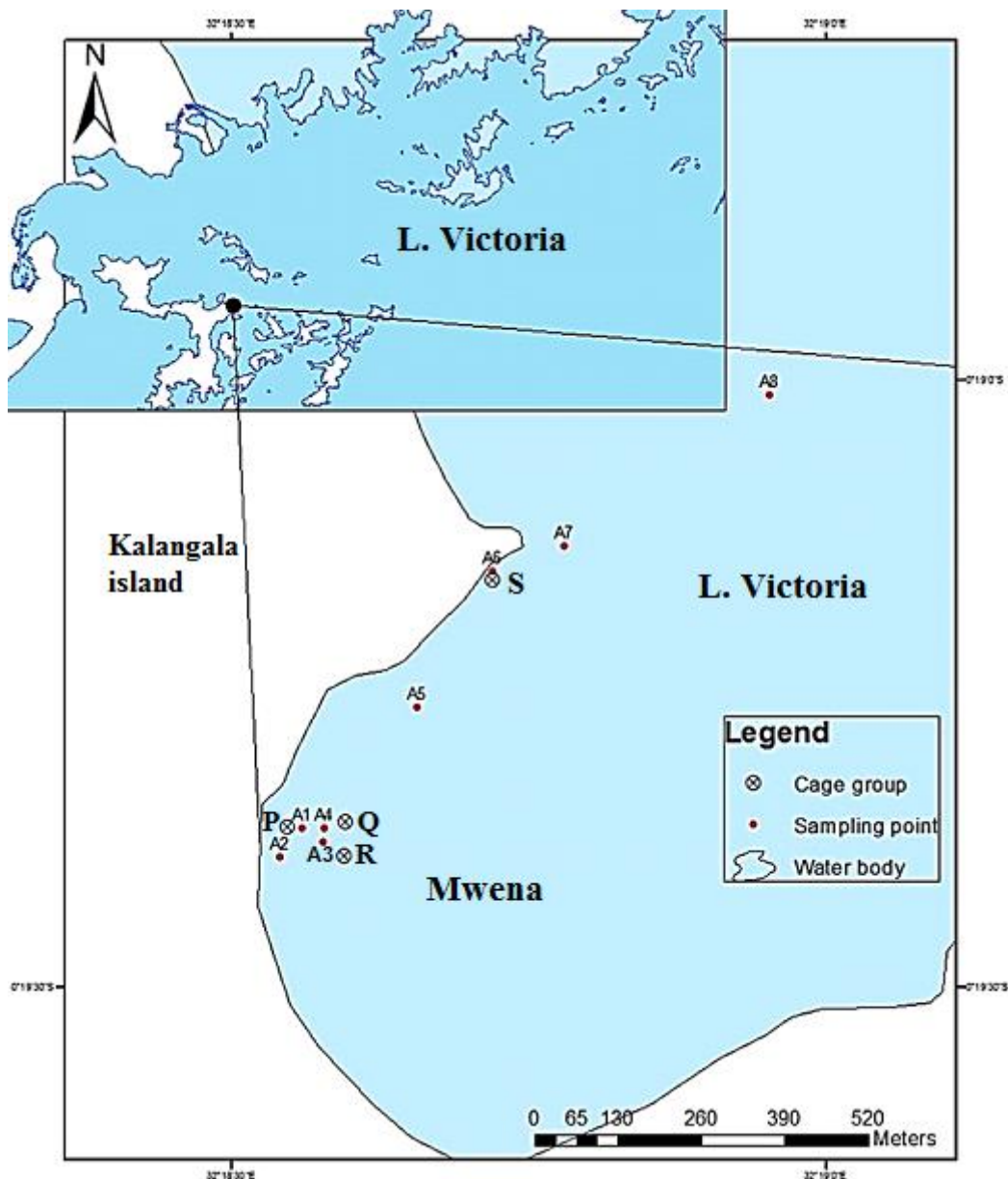


Figure 1. Map showing location of cage fish farms at Mwena, Kalangala- L. Victoria

2.2 Sample collection and analysis

2.2.1 Physico-chemical parameters

Physico-chemical parameters such as pH, Dissolved oxygen (DO), water temperature, conductivity, Secchi depth and total depth were measured. In-situ measurements of water temperature, conductivity, Oxygen and pH were made with a submersible multiparameter probe, CTD-90M (Sea and Sun technology, Germany). These variables were recorded every 2 seconds as the CTD was lowered from approximately 0.4 m (subsurface) to 0.4 m above the sediment (bottom). Water transparency (m) was measured by a standard Secchi disk of 20 cm diameter, with quadrants painted in black and white, by taking the average of the depths

at the disappearance and reappearance of the disk. Total depth (m) was measured using a hand held sonar (LCD portable sounder, Vexillar inc.).

2.2.2 Nutrients and phytoplankton

Water samples for the analysis of nutrients and phytoplankton status were collected using a 3L Van Dorn water sampler. Nutrient samples were collected from surface, mid, and bottom (about 0.4 m above the lake bottom and below the surface water) and mixed over the water column to make a composite sample per each sampling location. Samples were then preserved on ice pending analysis in the laboratory. Phytoplankton samples were collected at 0.5m below the water surface and preserved in Lugol's solution for laboratory analysis.

In the laboratory, standard methods were used to analyze key nutrients: Total phosphorus (TP) and Total nitrogen (TN) were analyzed by Persulfate digestion method; Soluble reactive phosphorous (SRP) by Ascorbic acid method; nitrate nitrogen ($\text{NO}_3\text{-N}$) by Cadmium reduction method, nitrite nitrogen ($\text{NO}_2\text{-N}$) by Colorimetric methods; ammonia nitrogen ($\text{NH}_4\text{-N}$) by Indophenol blue method; soluble reactive silicon (SRSi) was determined as yellow molybdate-silicic acid (Wetzel & Likens 2000); and Chlorophyll *a* concentrations by cold methanol extraction method. Concentrations of these nutrients and Chlorophyll *a* were determined by spectrophotometry. For phytoplankton analysis, a sub-sample of 2 ml was placed in an Utermöhl sedimentation chamber and left to settle for at least three hours. Phytoplankton species were identified and counted at 400X magnification using an inverted microscope, following the method of John et al. (2002). For each taxon, cell length and width were measured and algal bio-volume calculated using geometric approximations (Wetzel & Likens, 2000).

3.0 RESULTS

3.1 Physico-chemical parameters

Total depth (TD) at sampling locations (A1-7) around cage fish farms ranged from 3.60 to 7.20m while that at the reference site was 14.9m. The pH ranged from 7.23 ± 0.02 to 8.86 ± 0.02 and was highest at sampling locations between the cage groups. The concentration of DO ranged from 6.99 ± 0.02 to 8.92 ± 0.44 mg/l while secchi depth (SD) ranged from 2.0m to 2.6m, with higher values for both DO and secchi depth recorded at reference site (A8) than at the cage sites. Conductivity values were uniform at most of the sampled locations except site A1 where a higher value was recorded. There was small variation in temperature (range; 24.18 ± 0.01 to $24.83 \pm 0.01^\circ\text{C}$) among sampling points within and away from cage group areas (Table 1).

Table 1. Mean dissolved oxygen, pH, conductivity, temperature and Secchi depth (mean $\pm$ standard deviation)

Sampling Location		TD	SD (m)	Temp ($^\circ\text{C}$)	Cond. ($\mu\text{S cm}^{-1}$)	pH	DO (mg/L)
Edge of cages	A1	5.10	2.25	24.31 ± 0.01	102.40 ± 4.36	8.00 ± 0.02	7.11 ± 0.04
	A6	3.60	2.50	24.34 ± 0.17	100.00 ± 0.00	7.23 ± 0.02	8.25 ± 0.26
Between cage groups	A3	6.00	2.50	24.83 ± 0.01	100.00 ± 0.00	8.41 ± 0.03	7.32 ± 0.14
	A4	5.60	2.30	24.18 ± 0.01	100.00 ± 0.00	8.86 ± 0.02	8.39 ± 0.05
	A5	7.20	2.50	24.20 ± 0.14	100.00 ± 0.00	8.00 ± 0.13	7.88 ± 0.09
50m away from cages	A2	3.80	2.00	24.28 ± 0.18	100.00 ± 0.00	8.16 ± 0.02	7.42 ± 0.01
	A7	4.30	2.50	24.80 ± 0.17	100.00 ± 0.00	7.67 ± 0.28	6.99 ± 0.02
Reference site	A8	14.90	2.60	24.50 ± 0.01	100.00 ± 0.00	7.45 ± 0.01	8.92 ± 0.44

3.2 Nutrients

Ammonia nitrogen was detected within the cage areas especially at the edge of cage groups and not the reference site whereas nitrate nitrogen was highly concentrated at the reference site compared to the cage areas. High levels of TN ($>1\text{mg/L}$) and TP ($>0.1\text{mg/L}$) were recorded both at the reference and cage areas with highest levels recorded around cage groups compared to the reference site. Low concentrations of soluble reactive phosphorus (SRP) ranging from 10.92 to 20.62 $\mu\text{g/L}$ were recorded around cages and reference site. Soluble reactive silicon (SRSi) concentrations ranged from 1375.38 to 1697.77 $\mu\text{g/L}$ at all sites. The

Chla concentration, indicative of algal biomass was relatively low, and was lowest at site A1 and highest at site A4 (Table 2). The Chla concentration at the reference site (i.e. 4.17 µg/L) was within the range (2.78 to 9.73 µg/L) of that recorded around the cage fish farms.

Table 2 Concentrations of nutrients (µg/L) around the cages and reference site

Location		NO ₂ -N	NO ₃ -N	NH ₄ -N	TN	SRP	TP	SRSi	Chla
Edge of cages	A1	6.24	75.68	9.90	5924.36	17.85	163.35	1556.16	2.78
	A6	0.14	78.55	5.02	2240.54	19.23	372.52	1501.93	6.95
Between cage groups	A3	1.36	77.11	6.29	1864.64	13.69	230.51	1697.77	8.34
	A4	0.75	78.55	ND*	4721.48	19.23	172.94	1616.42	9.73
	A5	3.19	78.55	ND*	3217.88	20.62	1479.78	1510.97	4.17
50m away from cages	A2	1.36	79.99	11.18	4571.12	10.92	174.86	1375.38	6.95
	A7	7.46	97.26	ND*	3217.88	20.62	328.38	1610.39	5.56
Control site	A8	6.24	189.36	ND*	4270.40	24.78	334.14	1447.69	4.17

*ND = Not Detected

3.3 Phytoplankton composition and abundance

Five broad taxonomic groups: Cyanophyta (Blue-green algae), Chlorophyta (Green algae), Bacillariophyta (Diatoms), Dinophyta (Dinoflagellates) and Cryptophyta (Cryptophytes) were encountered. With the exception of dinoflagellates and cryptophytes recorded at one site (Site A8) and three sites (sites: A3, A4 and A6) respectively, the rest of the groups were recorded at all sampling locations (Figure 2). Blue-green algae dominated at all sites both in terms of bio-volume and species richness, with dinoflagellates showing the least number. For most sites except A7, blue-green algae bio-volume was $> 20 \text{ mm}^3\text{L}^{-1}$ while other groups had $<10 \text{ mm}^3\text{L}^{-1}$ at all sites (Table 3). Blue-green were followed by diatoms and green algae while the other groups had $<2 \text{ mm}^3\text{L}^{-1}$ at all sites. Generally, the bio-volume was relatively low, although that within the cage farms (A1, A3, A4, A5 and A6) was higher than away from the cages (A7 and A8). In terms of species composition, blue-green algae: *Merismopedia tenuissima*, *Planktolyngbya circumcreta* and *Planktolyngbya limnetica*; green algae: *Ankistrodesmus falcatus* and diatoms such as *Nitzschia acicularis* were common to all sampling locations (Table 4).

Table 3. Algal bio-volume (mm^3L^{-1}) of the sampled cage sites (A1-A7) and the reference site (A8).

	Sampling location							
Phytoplankton group						50m away from cages		Reference site
	Edge of cages		Between cage groups					
	A1	A6	A3	A5	A4	A2	A7	A8
Blue green	55.392	56.160	172.721	114.720	192.540	75.113	2.617	22.080
Diatoms	9.242	0.182	9.000	1.680	8.760	2.460	0.540	0.361
Green	1.140	0.936	1.068	1.500	1.620	1.100	0.668	0.264
Cryptophytes	0.000	0.061	0.060	0.000	0.060	0.000	0.000	0.000
Dinoflagellates	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
	65.774	57.339	182.849	117.900	202.980	78.673	3.825	22.706

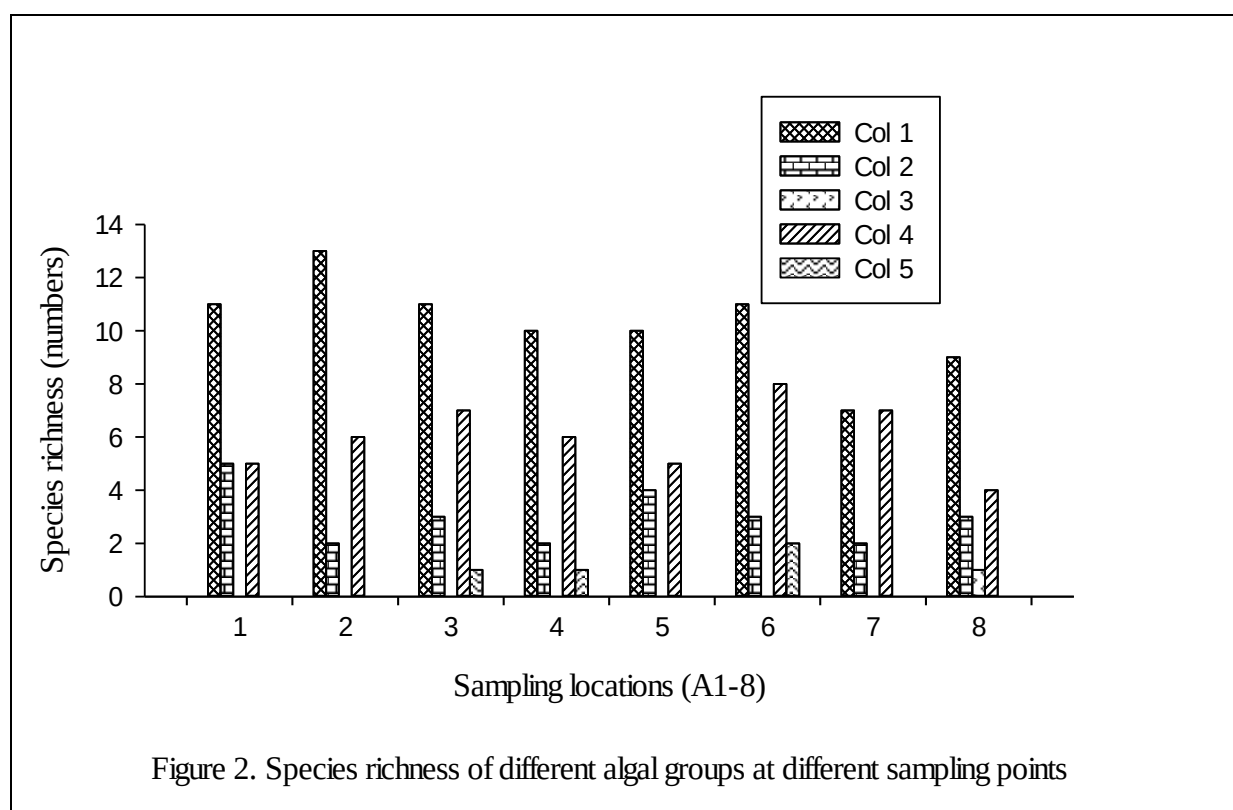


Figure 2. Species richness of different algal groups at different sampling points

Table 4. Phytoplankton species composition and distribution recorded around cages and reference site

Phytoplankton taxa	Edge of cages		Between cage groups			50m away from cages		Reference site
	A1	A6	A3	A4	A5	A2	A7	A8
Blue-Green algae								
<i>Anabaena circinalis</i>		✓	✓		✓	✓	✓	✓
<i>aphanocapsa delicatissima</i>	✓			✓	✓			✓
<i>Aphanocapsa incerta</i>			✓			✓	✓	
<i>Aphanocapsa incerta</i>				✓				
<i>Aphanocapsa sp</i>		✓	✓		✓	✓		
<i>Chroococcus dispersus</i>	✓	✓			✓	✓		
<i>Chroococcus limnetica</i>					✓			
<i>Chroococcus sp</i>	✓		✓	✓		✓	✓	✓
<i>Coelastrum cambrium</i>							✓	
<i>Cylindrospermopsis africana</i>	✓	✓	✓	✓		✓		✓
<i>Cylindrospermopsis cupsis</i>						✓		
<i>Merismopedia glauca</i>				✓				
<i>Merismopedia tenuissima</i>	✓	✓	✓	✓	✓	✓	✓	✓
<i>Microcystis flos-aquae</i>	✓	✓	✓			✓		
<i>Microcystis flos-aquae</i>	✓							
<i>Planktolyngbya circumcreta</i>	✓	✓	✓	✓	✓	✓	✓	✓
<i>Planktolyngbya contorta</i>		✓	✓		✓			
<i>Planktolyngbya limnetica</i>	✓	✓	✓	✓	✓	✓	✓	✓
<i>Planktolyngbya tallingii</i>	✓	✓		✓	✓	✓		✓
<i>Pseudoanabeana limnetica</i>	✓							
<i>Romeria gracile</i>	✓	✓	✓	✓		✓	✓	✓
Diatoms								
<i>Cyclotellaphanodiscus sp</i>	✓		✓		✓	✓	✓	✓
<i>Cyclotella sp</i>			✓		✓			
<i>Navicula gastrum</i>	✓							
<i>Navicula radiosa</i>	✓	✓						✓

Phytoplankton taxa	Edge of cages		Between cage groups			50m away from cages		Reference site
	A1	A6	A3	A4	A5	A2	A7	A8
<i>Nitzschia acicularis</i>	✓	✓	✓	✓	✓	✓	✓	✓
<i>Nitzschia fonticola</i>	✓	✓		✓	✓			
Dinoflagellates								
<i>Peridinium sp</i>								✓
Green algae								
<i>Ankistrodesmus falcatus</i>	✓	✓	✓	✓	✓	✓	✓	✓
<i>Ankistrodesmus fusiformis</i>		✓	✓			✓		
<i>Ankistrodesmus setigera</i>							✓	
<i>Closterium acicularis</i>			✓	✓			✓	
<i>Crucigenia sp</i>	✓							
<i>Crucigenia tetrapedia</i>				✓				
<i>Cyclostephanodiscus sp</i>								
<i>Monoraphidium contortum</i>	✓	✓		✓	✓	✓	✓	✓
<i>Oocystis solitaria</i>		✓				✓	✓	
<i>Pediastrum duplex</i>		✓	✓			✓		
<i>Pediastrum simplex</i>			✓					
<i>Pediastrum tetras</i>		✓						
<i>Scenedesmus acuminatus</i>	✓			✓	✓		✓	
<i>Scenedesmus arcuatus</i>		✓			✓	✓	✓	
<i>Scenedesmus quadricauda</i>			✓		✓			
<i>Scenedesmus sp</i>				✓				
<i>Staurastrum cuspidatum</i>			✓					✓
<i>Staurastrum sp</i>								✓
<i>Tetraedron trigonum</i>	✓	✓						
Cryptophytes								
<i>Cryptomonas sp</i>		✓						
<i>Rhodomonas sp</i>		✓	✓	✓				

4.0 DISCUSSION

The dominant phytoplankton groups and species are consistent with reports from previous studies on Lake Victoria, comprising of blue-green algae and diatoms (Kling et al., 2001; Larsson et al., 2009). This as reported resulted from increases in subsistence agricultural, deforestation, municipal and industrial effluents, and human encroachment on the shoreline giving rise to historically unprecedented nutrient loadings (Hecky, 1993; Mugidde, 2001; Verschuren et al., 2002). The general conclusion from these studies was that eutrophication is a major problem which could detrimentally affect ecosystem functioning and fish production. No wonder, as for the rest of the lake, the study area is still dominated by blue-greens and diatoms. In addition, blue-greens have higher temperature optima for growth than other algal groups, and hence elevated temperatures are found to favor abundance of blue greens (Robarts and Zohary, 1987; Dokulil and Teubner, 2000).

The conductivity of the water was relatively low, typical of Lake Victoria which falls into category I, defined by Talling and Talling (1965) as lakes with conductivity $< 600 \mu\text{Scm}^{-1}$, which includes most African lakes. Notwithstanding, the variation in transparency (SD), pH and conductivity at all the sampled sites including the reference was almost negligible, and within the range for good water quality. Temperature is the most important physical variable affecting the metabolic rate of fish and is therefore one of the most important water quality attributes in aquaculture. Water temperature values (24.18 to 24.83) recorded were lower than the optimal range of 27-30°C (Bhatnagar and Devi, 2013), suitable for: maximal growth rate, efficient food conversion, resistance to disease and tolerance to toxins (Kane et al., 2015). But this low temperature recorded is not a concern if we consider that the water samples were collected during cold days characterised by cloud cover and rain.

The transparency values recorded were close to the mean value that was reported by Sitoki et al. (2010) for Lake Victoria inshore waters although the Chla concentration was comparable to that of offshore waters implying that the productivity of the area is still low. The nutrient concentrations for ammonia nitrogen, nitrite nitrogen, nitrate nitrogen and soluble reactive phosphorus were within acceptable levels for fish farming, suggested by Bhatnagar and Devi (2013). However, the concentrations of TN, TP and SRSi were much higher than expected, even higher than recorded previously for a eutrophic Murchison Bay (Haande et al., 2011). Moreover, even the nutrient concentration and algal abundance in the reference site (A8) was almost as high or even higher (for some sites) than in and around the cage fish farms. First,

these high TN and TP concentrations cannot be from cages alone. Secondly, the high concentrations in the sampled sites would imply a comparably high algal biomass, bio-volume and therefore lower transparency which was not the case. This information shows that there could be other factors limiting phytoplankton growth and abundance in this studied area such as food web-changes (Semyalo, 2009) or other local hydrographic and hydrologic factors.

5.0 CONCLUSIONS AND RECOMMENDATIONS

- High concentrations of TN and TP were recorded at the cage fish farms and the reference site, suggesting negligible contribution of nutrients from cage fish farm operations, and presence of other anthropogenic sources of nutrients in this part of the lake.
- The phytoplankton community was dominated by blue-green algae both in species richness and bio-volume at all sites. Generally, the bio-volume was relatively low, although that within the cage fish farms was higher than away from the cages.
- These results suggest that other factors besides nutrients control phytoplankton biomass, abundance and species composition.
- There is need to collect more data over seasons in this part of the lake to capture nutrient variability of the system. Investigations on the direct or indirect effect of activities in the catchment, on this part of Lake Victoria are recommended.

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