KENYA MARINE & FISHERIES RESEARCH INSTITUIE
FRESHWATER SYSTEMS

A technical report on the ecological status of cage-culture in relation to wild fisheries in Lake Victoria and the dissemination of the findings

Technical Report

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DOCUMENT CERTIFICATION

Certification by Assistant Director

I hereby certify that this report has been done under my supervision and submitted to the Director.

Name: Dr. Christopher Mulanda Aura (PhD)

Signature:  Date: **16th, June, 2021**

Certification by Director KMFRI

I hereby acknowledge receipt of this Report

Name: Prof. James M. Njiru (PhD)

Signature:  Date: **18th June 2021**

Produced by:

Kenya Marine and Fisheries Research Institute
P.O. Box 81651 – 80100
Mombasa
KENYA
Tel. +254 (041)475151/4
Website: www.kmfri.co.ke
Email: director@kmfri.co.ke

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Abstract

The Catch Per Unit Effort (CPUE) has drastically reduced with many fishermen now reverting to fish cage culture practices for alternative livelihood, without good husbandry practices. Cage culture practice is on the rise within the Kenyan waters with majority of cages sited within inshore areas of bays, where farmers believe the cages and attendants are safe from strong waves and currents. Water nutrients were within recommendable ranges except for NH_4^+ and total nitrogen (TN) which are believed to be generated from decomposition of excess feeds. Results of this study showed temporal changes of phytoplankton community structure which is an important tool in diagnosis of environmental conditions influenced by anthropogenic inputs of nutrient from the cages and from the catchment. Fluctuations in abundance and composition are reflections of prevailing environmental conditions in the different ecological niches. The low diversities of the zooplankton within the study sites were attributed to predation to predation by organisms higher in the food chain and not environmental degradation. The water quality as indicated by HBI from macro-invertebrate studies shows levels of pollution are within recommendable ranges.

Key words: *Ecology, cage culture, Kadimo bay, fisheries.*

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1. Introduction

Growing of fish in cages has become a common practice in many parts of the world due to drastic decline in capture fisheries. It has notably become a popular fish farming practice in Africa specifically, Ghana, Kenya, Malawi, Uganda, Zambia, and Zimbabwe (Blow and Leonard, 2007). In comparison to pond culture system, cage fish culture technology has earned an advantage of the possibility of growing a larger amount of fish in a relatively small volume or area of water (Mwebaza-Ndawula et al., 2013). Fish culture in cages also provides greater production rates in comparison to yield in ponds or aquaponics systems. In the East African region, cage fish farming has not been widely embraced despite a large market and preference for fish, and the potentiality of practicing it in the region. Although the cage culture practice has not been fully embraced in Kenya, Victory cage fish farm in Southern part of Lake Victoria has shown great potential in improving national food security.

The greatest challenge in cage fish culture practice is its impact on ecological sustainability (Mangaliso *et al*., 2011; Dias *et al.*, 2011). The practice has a negative impact on the water quality and biological structure and abundances. Phytoplankton, zooplankton and macro-invertebrates structure and abundance have been impacted by the cage culture practices. Phytoplankton are vital and important organisms as they act as primary producers and direct food source for tertiary aquatic animals. They provide a base in the aquatic food web which is the most important factor for production of organic matter in aquatic ecosystem. Phytoplankton structure can be used as bio-indicator of environmental perturbations for better management practices and policy making.

Zooplankton are secondary producers and thus affects higher trophic levels by providing nutritional bases for macro-invertebrates. They consist of diverse assemblage of major taxonomic groups. Many of these forms have different environmental and physiological assemblage. The number, type and distribution of these organisms present in cages provide a clue on the environmental condition prevailing in that particular habitat.

Macro-invertebrates are tertiary benthic dwelling organisms. They feed on plankton and are food to fish in higher food chain. There structure and abundances can also be used as bio-indicators of environmental integrity.

The overall objective of this study was therefore to assess and evaluate the possible impacts of cage fish culture on water quality and biological communities within Kadimo-Bay in northern side of Lake Victoria, Kenya. The specific research questions were: “Do cage fish operation influence key physical-chemical parameters of the water?”, “Do fish cages have impacts on algal, zooplankton and macro-benthos communities within and around the cage operation areas?”

2. Materials and Methods

2.1 Study site

The study was conducted at Kadimo Bay with varying intensities of cage culture practices. At Kadimo Bay there are Anyanga, Uwaria (Usigu), and Oele sites that have varying cage culture practices (Figure 1). Anyanga consisted of intensive culture practice, Uwaria had medium practice while Oele had less intensive practice. Cage practices were compared only for sites within Kadimo Bay in order to limit influences from exogenous sources. Duplicate sampling of both water and sediments were conducted at three points within each site for chemical, phytoplankton, zooplankton and macro-invertebrate analyses. In some analyses, the samples were composited to minimize sample loads while in others they were analyzed in isolation.

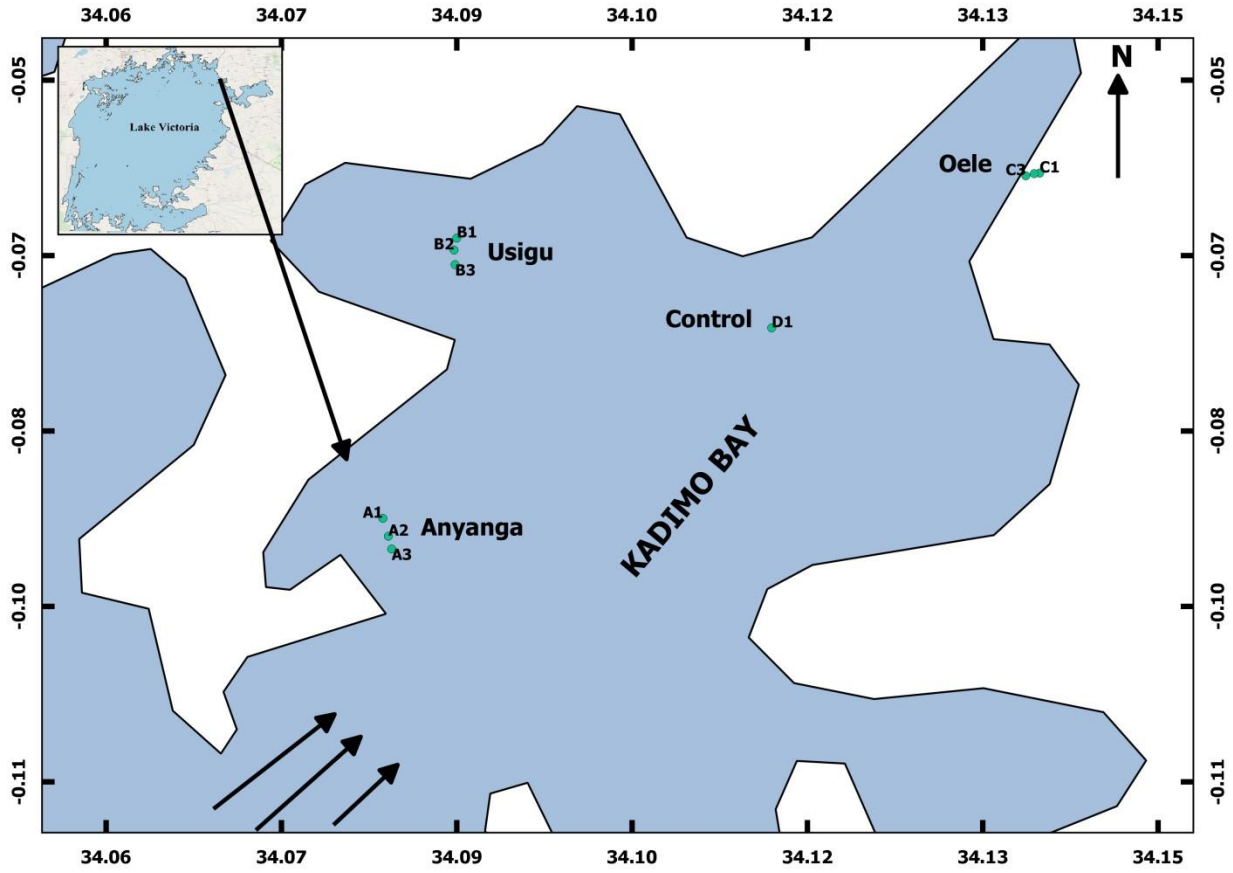

Figure 1. Map of Kadimo Bay in Lake Victoria showing sampled sites.

2.2 Ecological assessments

2.2.1 Chemical analyses

Scoop water samples were collected and preserved for onward laboratory analyses. Chemical analyses of nutrients were carried out in the laboratory using photometric methods. The analysed nutrient compounds were reactive phosphorus (soluble reactive phosphorus (SRP); PO_4^--P), total phosphorus (TP), nitrate-N (NO_3^-), nitrite-N (NO_2^-), total ammonia-N and total nitrogen (TN). Samples for SRP, Nitrate and Nitrites were filtered using 0.45-µm membrane filters. The filtrate for SRP was subsequently analysed using the ascorbic acid method. TP concentrations were analysed by hydrolysing the unfiltered samples with potassium persulphate, under heat and pressure, to orthophosphate, which was subsequently analysed using the ascorbic acid method. Nitrite was analysed by diazotising the samples with sulphanilamide and N-(1-naphthyl)

ethylenediamine as a coupling reagent. The coloured azo compound was then measured photometrically. Nitrate was reduced to nitrite using cadmium filings treated with copper sulphate. The resultant nitrite solution was analysed photometrically, using the method outlined above for nitrite. TN was measured by first hydrolysing all forms of nitrogen to nitrate, using potassium persulphate, before adopting the cadmium reduction method. Ammonium and silica were analysed using phenate and heteropoly blue methods, respectively. All these methods were adopted from American Public Health Association (APHA, 2005).

2.2.2 Phytoplankton analyses

Samples for phytoplankton analyses were collected using a Van-dorn water sampler. A portion of the sample (25 mls) was preserved using acidic Lugol's solution. A 2 ml phytoplankton sub-sample was placed in an Utermöhl sedimentation chamber and left to settle for at least three hours. Phytoplankton species identification and enumeration were done using a Zeiss Axioinvert 35 Inverted Microscope at 400x magnification. At least, ten fields of view were counted for the very abundant coccoid cyanobacteria and a 12.42 mm^2 transect was counted for the abundant and large algae. The whole bottom area of the chamber was examined for the big and rare taxa under low (100x) magnification. Phytoplankton taxa were identified using the methods of Huber –Pestalozzi (1968) as well as some publications on East African lakes (Cocquyt *et al*., 1993). Phytoplankton was estimated by counting all the individuals whether these organisms were single cells, colonies or filaments.

2.2.3 Zooplankton analyses

Samples were collected in triplicates with a 1 m long conical-Nansen plankton net with mesh size of 60 µm, mouth diameter 0.30 m towed vertically through the water column (Mwabeza-Ndaula 1994). In the laboratory, each sample was made to a known volume, thoroughly shaken for uniform distribution and a sub-sample taken, placed in a counting chamber and examined under inverted microscope at X100 magnification for taxonomic determination, and at X40 for counting. Zooplankton was identified to possible taxonomic level using published identification keys (Pennak, 1991). The group copepod was only identified to group level as nauplii, cyclopoda and calanoida while the other two groups were identified to species level. The number of individuals per litre of lake water was calculated from the count data, taking into account, the volume of the

sample, number of organisms in the sub-sample, volume of the lake water filtered by the vertical haul derived from the depth of the haul (Mwabeza-Ndaula 1994).

2.2.4 Macro-invertebrate analyses

Macro-invertebrates sediment samples were collected using an Ekman grab, at each station triplicate samples were collected then composed. The composited samples were washed with sieve of 500um, sorted live in a white tray and preserved in ethanol (70%). The samples were then transported to the laboratory, sorted, observed and counted under dissecting microscope and identified to genus level with the aid of different keys (Merritt and Cummins, 2006) Gerber and Gabriel, 2002; Samways, 2008; and http://extension.usu.edu/water quality).Macro invertebrate community structure and functional composition was described in terms of number of genera per station, relative abundance, numerical abundance, evenness, dominance, diversity, species richness, and functional feeding guilds of all taxa. The ratios of the various FFGs were calculated based on numerical abundance. The results were represented in tables and graphs.

Data collected from various aspects of the study were subjected to descriptive statistics. Biotic indices were used to characterize the sites based on their status.

3. Results

3.1 Water quality

Soluble Reactive Phosphorus (SRP) and Total Phosphorus (TP) were high within the cage culture sites (A, B, and C) as compared to the control site (D) (Figure, 2). The concentrations were low at Site A (Anyanga) which had the highest number of cages, moderately high at site B (Uwaria) with moderate cages and highest in site C (Oele) with the least number of cages. Site A was closest to the channel connecting Kadimo Bay to the open lake (Figure, 1). Stations on the offshore side of the cages exhibited the least concentration of phosphorus nutrients. The trophic status of the water was eutrophic (TP almost equal to 50 µg/l).

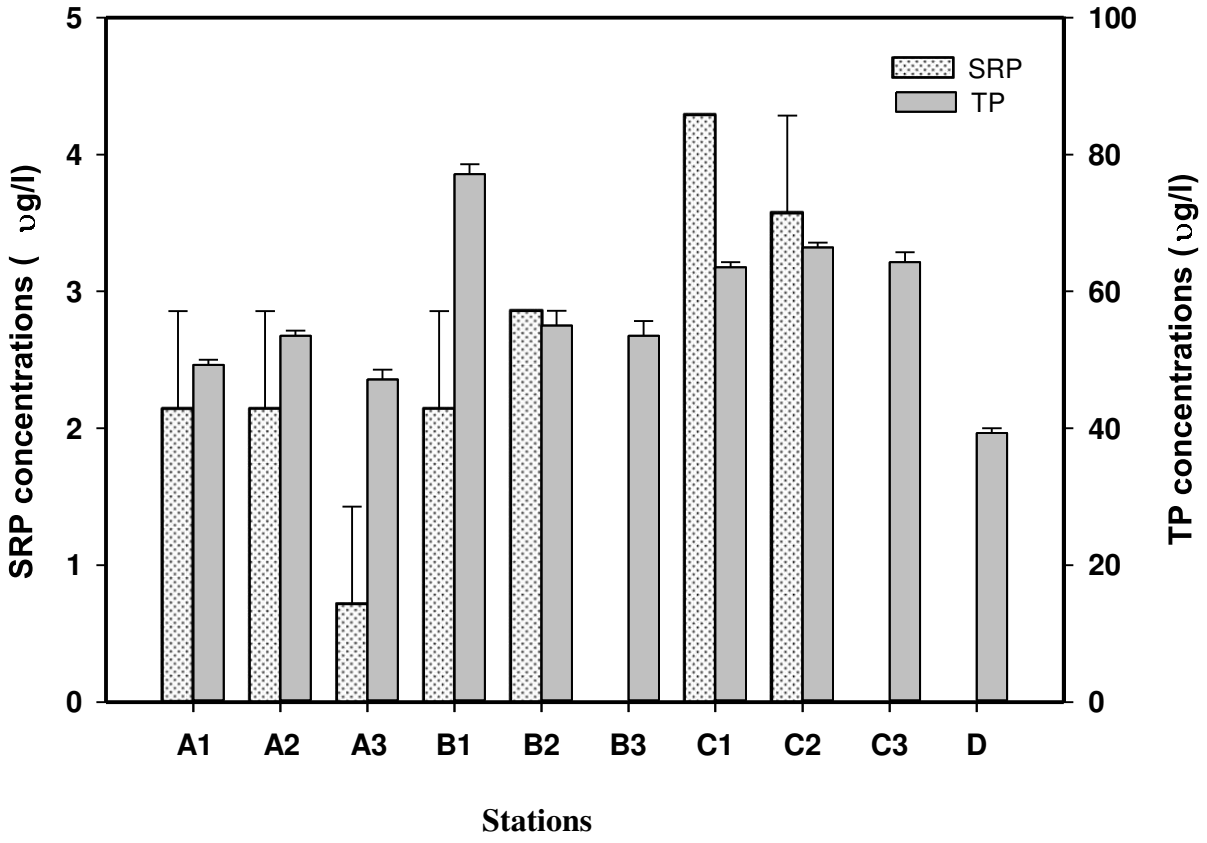

Figure 2. Graph showing the concentrations of Soluble Reactive Phosphorus (SRP) and Total Phosphorus (TP) across the sampled stations.

Ammonium (NH_4^+) species of nitrogen and Total Nitrogen (TN) were higher in the cage sites than within the control site (Figure, 3). Site B (Uwaria) had the least concentration of NH_4^+ followed by site A (Anyanga) while Oele (Site C) exhibited the highest concentration. TN was highest at site C, followed by site A. Site B had the least concentration of TN among the cage culture sites

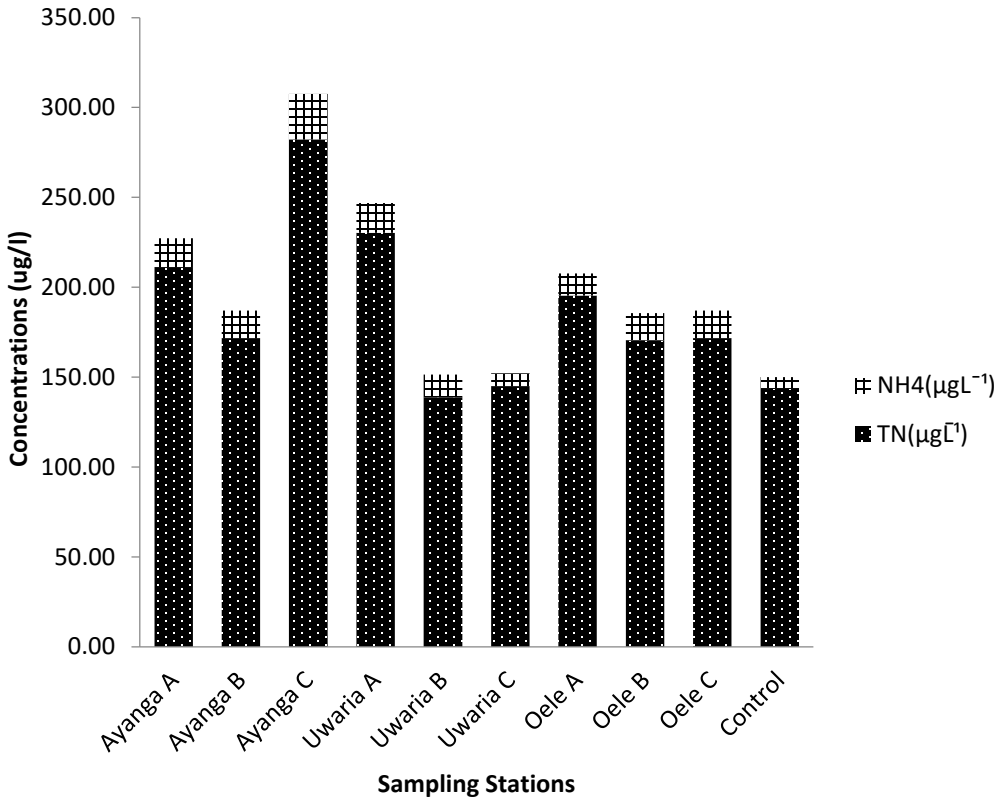

Figure 3. Graph showing concentrations of ammonium (NH_4^+) and Total Nitrogen (TN).

The high TN concentrations in site B were concomitant with the high chlorophyll-a concentrations at the same site (Figure, 4). The high chlorophyll-a at site A like in the TN, was followed by site C. Site B had the least concentration among cage culture sites. Control site exhibited the least concentration.

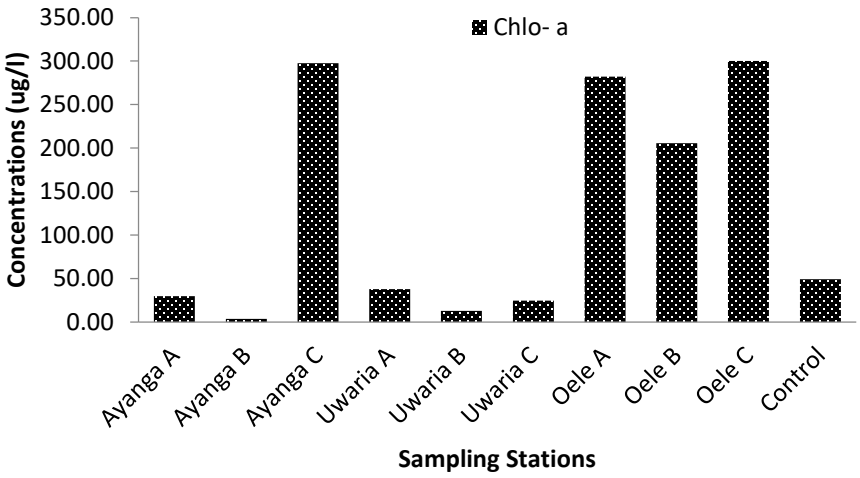

Figure 4. Chlorophyll-a concentrations across the sampled stations.

Water Quality variables (20/Apr./2021).

The Dissolved Oxygen (DO) levels varied between 4.4 and 7.4 mg/l (Figure 5). The oxygen levels increased from Anyanga cage site near the bay mouth to Oele cage site at the extreme end of the bay. The increase was concomitant with a similar increase in algal productivity as seen in chlorophyll-*a* concentrations (Figure 5). This implies that the DO concentrations are majorly driven by algal photosynthetic processes. The chlorophyll-a concentrations ranged between 18.1 and 35.2 µg/l. The averaged depth profile temperature data ranged between 26.5 and 28.3^{0}C. The temperatures were lowest at Anyanga cage sites and increased monotonically to the NE corner at Oele cage culture sites. The pH also increased from SW part at Anyanga to the NE corner at Oele cage culture sites and the readings ranged between 7.9 and 9.0. Conductivity varied between 135.3 and 158.0 µS/cm. Conductivity were lowest at Uwaria cage culture sites and highest at Oele cage culture sites. Turbidity, like chlorophyll-a measurements increased monotonically from the SW end of the bay at Anyanga sites to the NE end at Oele sites. Turbidity ranged between 3.4 and 8.6 NTU.

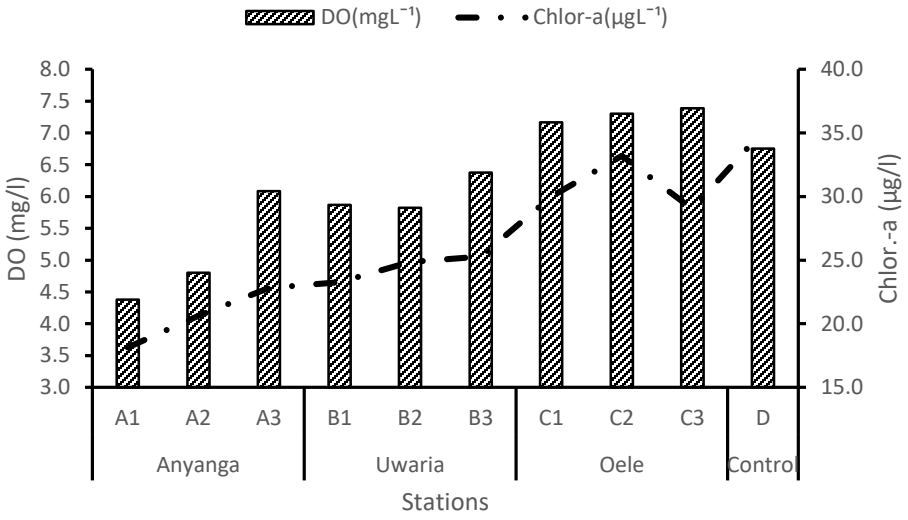

Figure 5. Variation in dissolved oxygen (DO) and chlorophyll-a concentrations across the study area.

Kadimo waters range between eutrophic to hypertrophic with Soluble Reactive Phosphorus (SRP) varying between 23.4 and 82.4 µg/l and Total Phosphorus (TP) ranging between 124.2 and 232.5 µg/l (Figure 6). Uwaria cage sites exhibited the lowest concentrations of SRP but with nearly the highest concentration of TP. Cage culture sites exhibited higher concentrationsin both SRP and TP concentrations as compared to Control site with no cages which manifested the lowest concentrations (Figure 6).

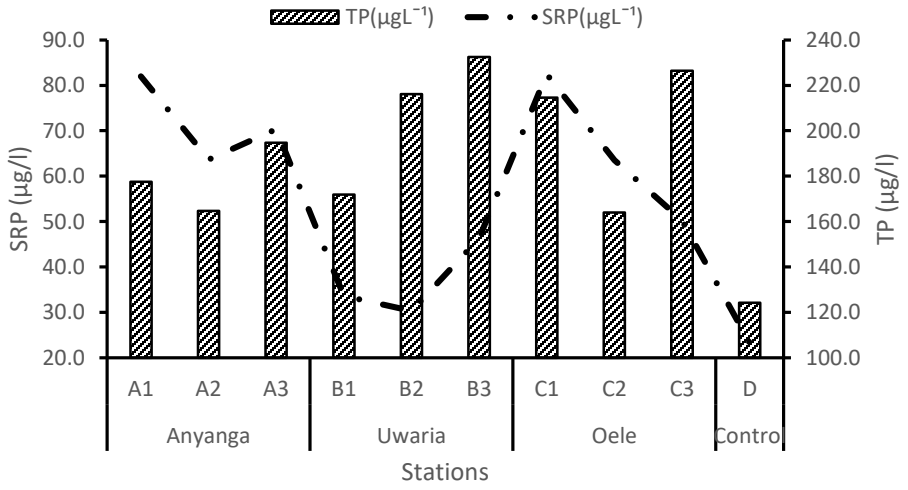

Figure 6. Concentrations of soluble reactive phosphorus (SRP) and total phosphorus (TP) within the study area.

The soluble fractions of nitrogen species of ammonium (NH_4^+), Nitrites (NO_2^-) and Nitrates (NO_3^-) exhibited the lowest concentrations within Uwaria cage culture sites (Figure 7). The concentrations were highest at Oele cage culture sites. Ammonium concentrations ranged between 8.8 and 50.3 µg/l. Nitrite concentrations ranged between 4.5 and 36.8 µg/l while Nitrate concentrations ranged between 13.2 and 42.9 µg/l. Control site with no cage culture practice exhibited equally low concentrations of nitrogen nutrient species. Total Nitrogen (TN) were highest within Uwaria cage culture sites. Cage culture sites were relatively high in nitrogen species of nutrients as compared to Control site.

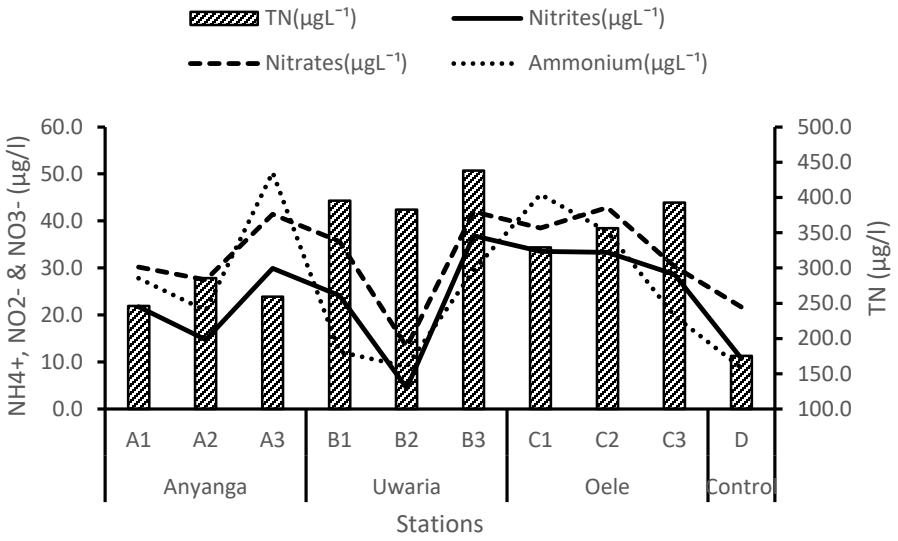

Figure 7. Concentrations of nitrogen species of nutrients across the study sites.

3.2 Phytoplankton

There were differences in phytoplankton taxa in the sampled sites (Figure, 8). Diatoms were the most dominant group, contributing an average 35 % of the total phytoplankton biovolume followed by Cyanophytes with 23%. There were fewer Chlorolophytes with all stations recording 4% biovolumes. A few other species like *Scenedesmus* sp., *coelomoron and monoraphidium* taxa were clearly the most dominant in most sampling stations especially Anyanga A and Oele C and Control. Diatom populations were represented by *Nitzschia palea, Synedra cunningtonii, Surillella* sp and *Fragillaria* spp and were most abundant taxa in the littoral zones and towards to the open lake. Within the Cyanobacteria, *Aphanocapsa* spp, *Chroococcus* spp and *Anabaena* species were the most abundant in Anyanga A, B, C, Oele A, B, C and Control stations. Cyanobacteria was never recorded at Uwaria A but there was a general low diversity observed across the study sites and this may be attributed to reduced mineral turbidity and phosphorus enrichment from the littoral zones.

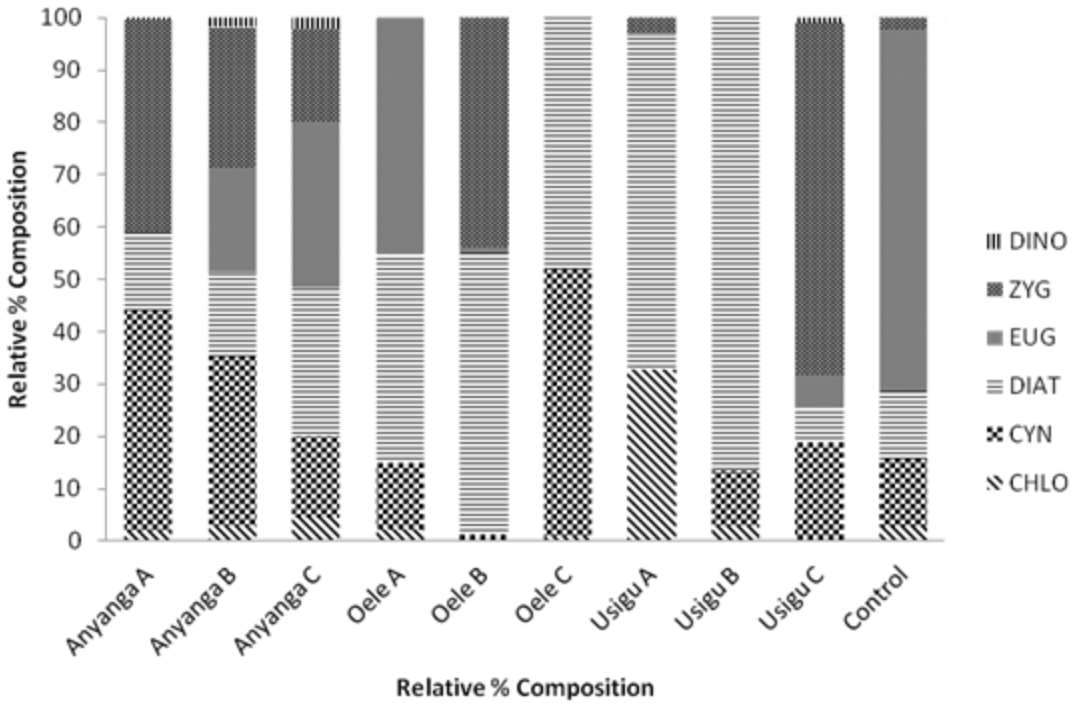

Figure 8. Percentage phytoplankton composition ($mm^3\ l^{-1}$) assigned to phytoplankton classes or families as recorded at different sites of the cages in Victoria, Kenya.

Species richness recorded a total of 73 phytoplanton species identified. They were represented by Diatoms, Cyanophytes, Euglenophytes, Zygnematophyceae, Chlorophytes during the study. Of the 20 different species of diatom were encountered, *Nitzschia palea, Synedra cunningtonii*, *Fragillaria* spp, and *Surillela* spp were the most common genera. Similarly, there were 19 species of Chlorophytes encountered of which, *Tetraedron arthromisforme,Tetraedron inflatum Ankistrodesmus* spp, *Tetraedron and Scenedesmus* spp were the most frequently encountered genera. The Zygnematophyceae family was represented by 7 taxa represented by *Cosmarium* spp and *crucigenia* spp. Euglenophytes which were represented by 8 genera and were represented by Euglena acus, Phacus *longicauda ,Euglena Virids, Strombomonous* spp*,Trachelemous* spp. Cyanobacteria were represented *Planktolyngbya taringii, Anabaena flos-Aquae, Anabaena limnetica, Cylindrospermopsis* sp *and Romeria elegans.*

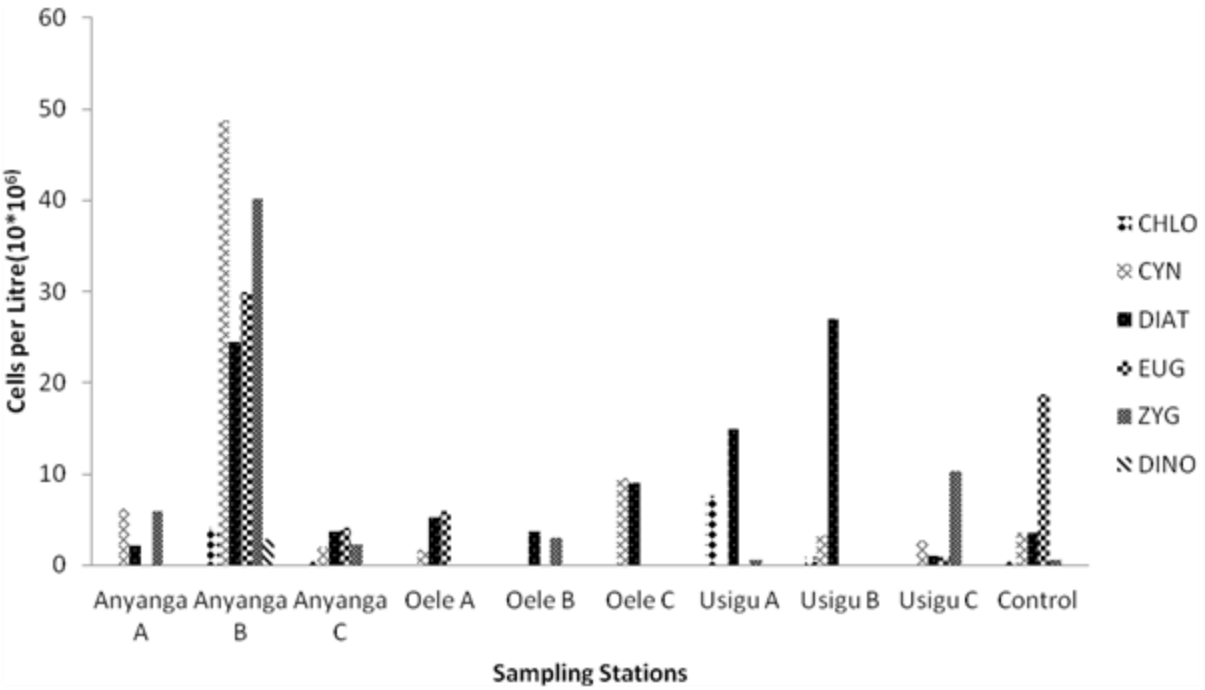

Figure 9. Percentage phytoplankton composition ($mm^3\ l^{-1}$) assigned to phytoplankton classes or families as recorded at different sites of the cages in Victoria, Kenya.

Phytoplankton biovolume showed its maxima at Anyanga B with >30 $mm^3\ l^{-1}$, whereas, Anyanga A, Anyanga C, Oele A, Oele B, Oele C recorded the lowest (< 10 $mm^3\ l^{-1}$). In addition, there were moderate high values generally recorded in Uwaria B and Control (< 20 $mm^3\ l^{-1}$) towards mid cages. Similarity to biovolume measurements exhibited higher phytoplankton cells in the mid cages than in the littoral, in particular Oele, Anyanga and Uwaria, all the sites had > 100 x 10^6 cells per litre (Figure 9).

Phytoplankton (20/April/2021).

In all the sampled fish cage sites, Microcystis species was the most dominant and evenly distributed while Merismopedia, Tetraedon, and Scenedesmus spp were only in Anyanga A2, Oele C1 and Anyanga A1 respectively. In both sampled fish cages, Microcystis was the most abundant, contributing between 40% to 97% of total phytoplankton abundance (Figure 11). Ankistrodesmus species were present in both cage sites but occurred in higher composition in Anyanga A1.

Generally, phytoplankton abundance was higher in Oele C3 and Anyanga A1, while the highest diverse site was Anyanga A1 (Figure 10).

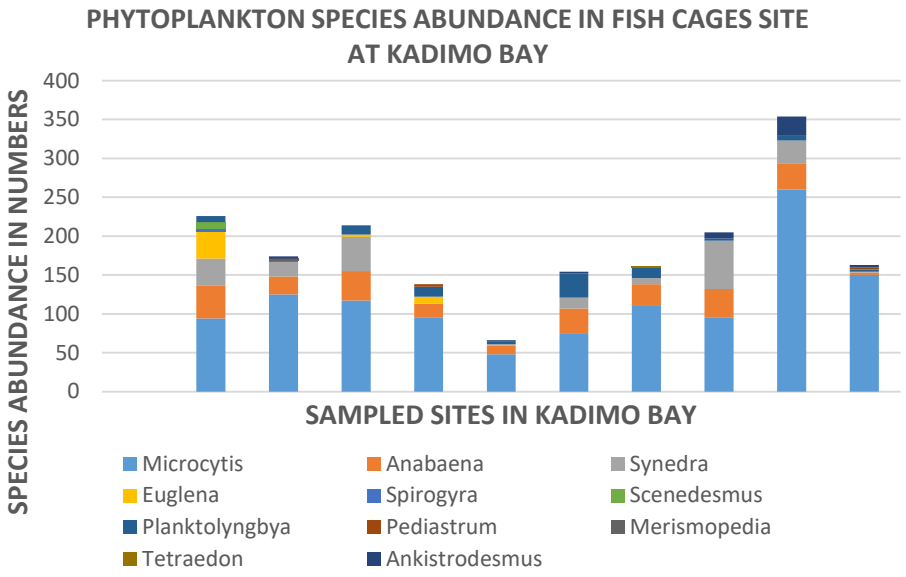

Figure 10. Sampled phytoplankton species by sites

Anyanga A1 accounted for the majority of Euglena species (35) and anabaena species (35) abundance among the sampled fish cage sites. Uwaria B3 had noticeably higher Planktolyngbya species (31) . Oele C3 accounted for the highest number of Microcystis species (260), while Oele C2 had Synedra species being the highest (62) amongst the sampled fish cage site (Figure 10).

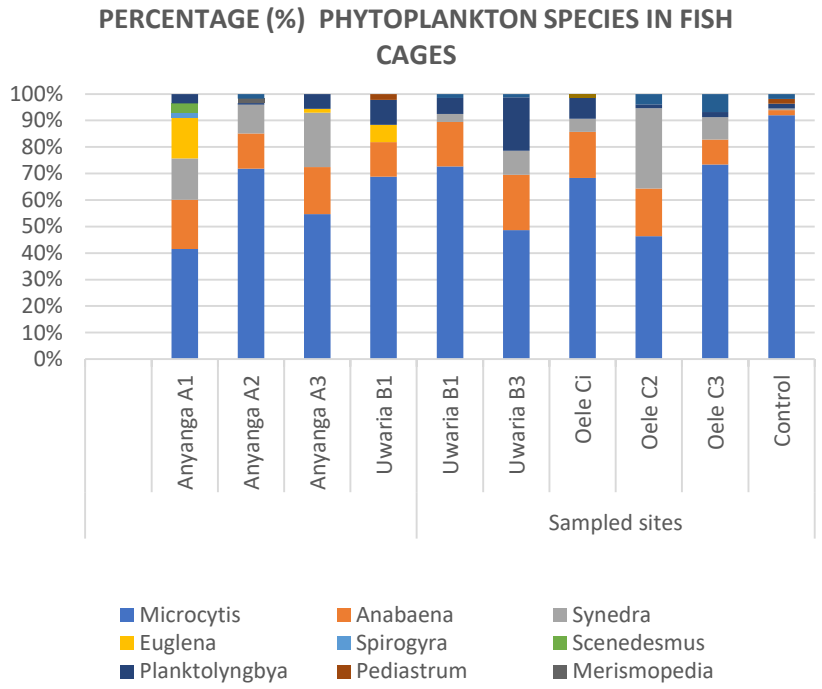

Figure 11. Sampled percentage phytoplankton species by sites

Control and Oele C3 accounted for the highest percentage (97% and 78% respectively) of Microcystis from all the sampled sites. Oele C2 had notably higher Synedra percentage (38%). While Anyanga A1 had higher percentages from Euglena (20%) and Anabaena (18%) (Figure 11).

3.3 Zooplankton

Total zooplankton densities recorded at the 10 stations sampled are presented below (Figure 12). There were spatial variations in abundance, distribution and composition. Zooplankton abundance (individuals/Lit.) were recorded in the 10 stations as follows Anyanga C 293.7, Control 288.9, Anyanga B 256, Uwaria B 247.5, Oele C 248.6;. Comparatively low abundance was recorded at Anyanga A which is toward the littoral sampling stations than in the once like Anyanga C which had high abundance and is toward the open Lake.

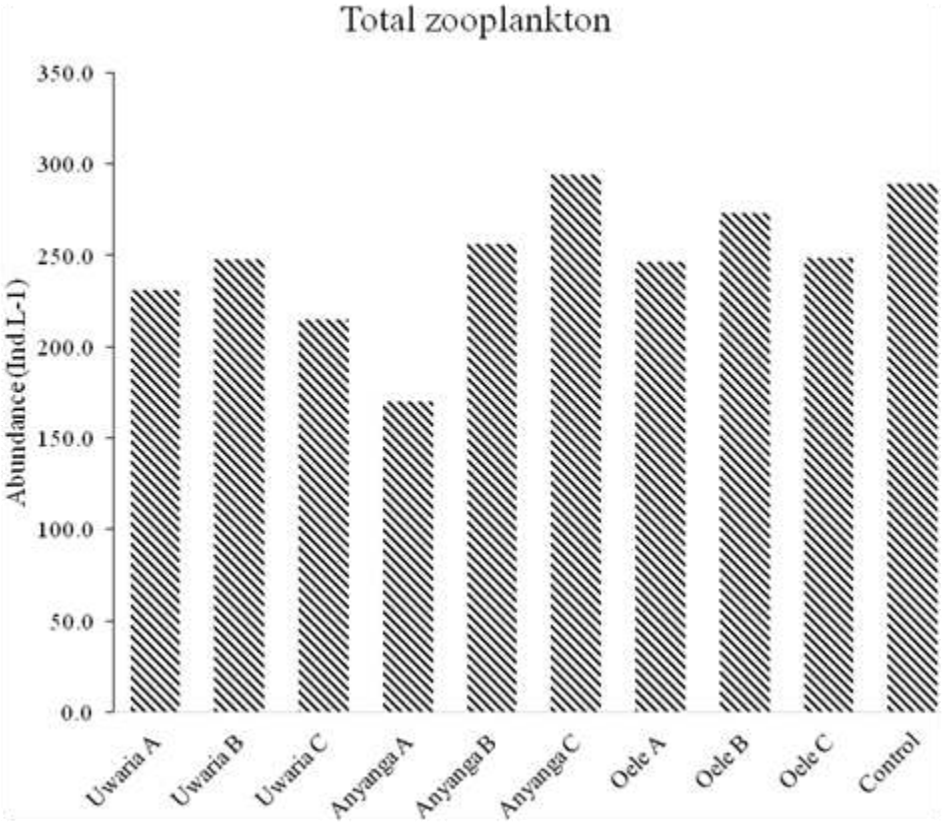

Figure 12. Total zooplankton abundance at the 10 stations in Lake Victoria

The three main groups of Zooplankton: Copepods, Cladocera and Rotifera were represented in the samples collected from the 10 stations (Figure 13). Copepods were grouped into naupii, Cyclopoida and calonoida. Cladocera were represented by seven species, *Diaphanosoma excisum, Moina micrura*, *Ceriodaphnia cornuta, Daphnia barbata, Daphnia lumhortzi, Daphnia longispina,* and *Bosmina longirostris*. Some 13 species of Rotifers were identified which included; *Brachionus calyciflorus, Brachionus angularis, Brachionus falcatus, Brachionus caudatus, Kerattela tropica, Filinia sp, Asplanchna* spp*, Lecane* spp., Polyarthra and Euclanis spp. Ostracoida *Hexarthra* sp. Copepods dominated all the sampling stations as follows; Copepods dominated at uwaria with (68.95%). The least found were *Rotifers* which were found at Anyanga C (6.8%).

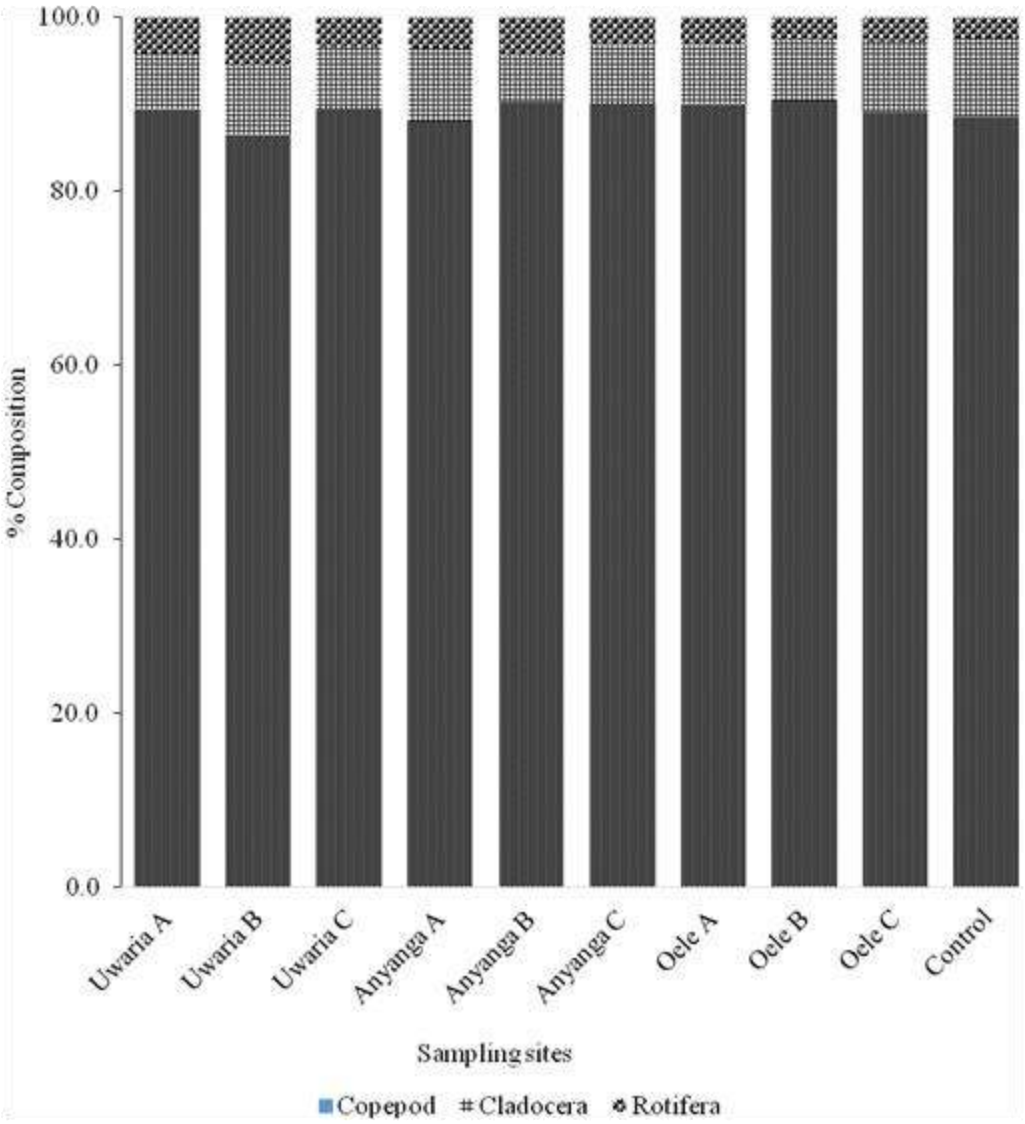

Figure 13. Percentage compositions of different groups of zooplanktons

The zooplankton group, *Copepoda* was dominated by *Cyclopoid nauplii* in all the10 sampling stations. This was followed respectively by *Cyclopoida* and *Calanoida* in that order (Figure 13). The highest abundance of Cyclopoid nauplii was recorded in Oele C sampling station whereas the lowest was noted within control sampling station. Calanoida and Cyclopoida recorded the least percentage below 10% in all sampling the stations.

Zooplankton (20th/April/2021)

Total zooplankton densities recorded at the 10 stations sampled are presented below (Figure 14). There were spatial variations in abundance, distribution and composition. Figure 14 shows the zooplankton abundances (Ind. L^{-1}) compared across the 10 sampled stations. Uharia recorded the lowest counts of zooplankton compared with the other sites.

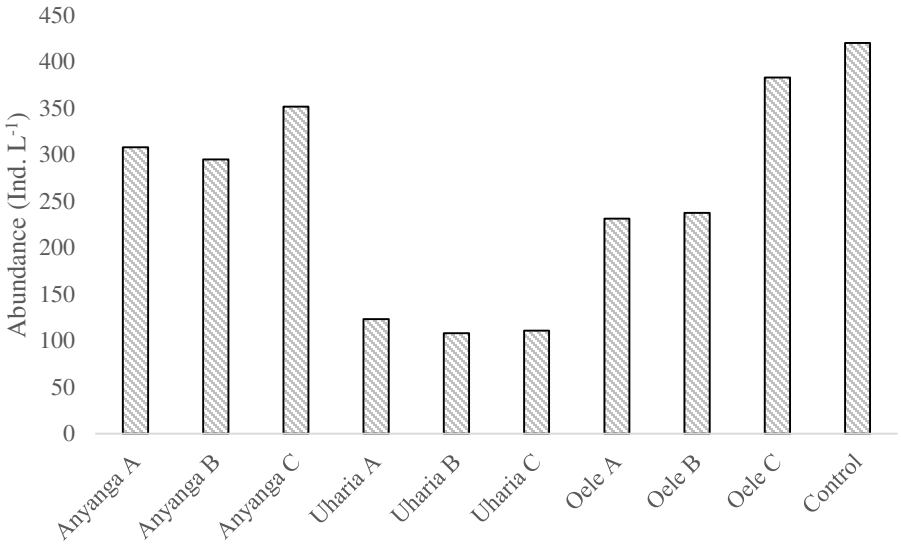

Figure 14. Total zooplankton abundance at the 10 stations in Lake Victoria

The three main groups of Zooplankton: Copepods, Cladocera and Rotifera were represented in the samples collected from the 10 stations (Figure 15). Copepods were grouped into naupii, Cyclopoida and calonoida. Cladocera were represented by four species, *Diaphanosoma excisum, Moina micrura*, *Daphnia lumhortzi,* and *Bosmina longirostris*. Some 8 species of Rotifers were identified which included; *Brachionus calyciflorus, Brachionus angularis, Brachionus falcatus, Brachionus caudatus, Kerattela tropica, Filinia sp, Asplanchna* spp*,* and Euclanis spp. Copepods dominated all the sampling stations at percentages above 79%.

The least found were *Rotifers* with the highest recorded percent abundance of 5 at Uharia C.

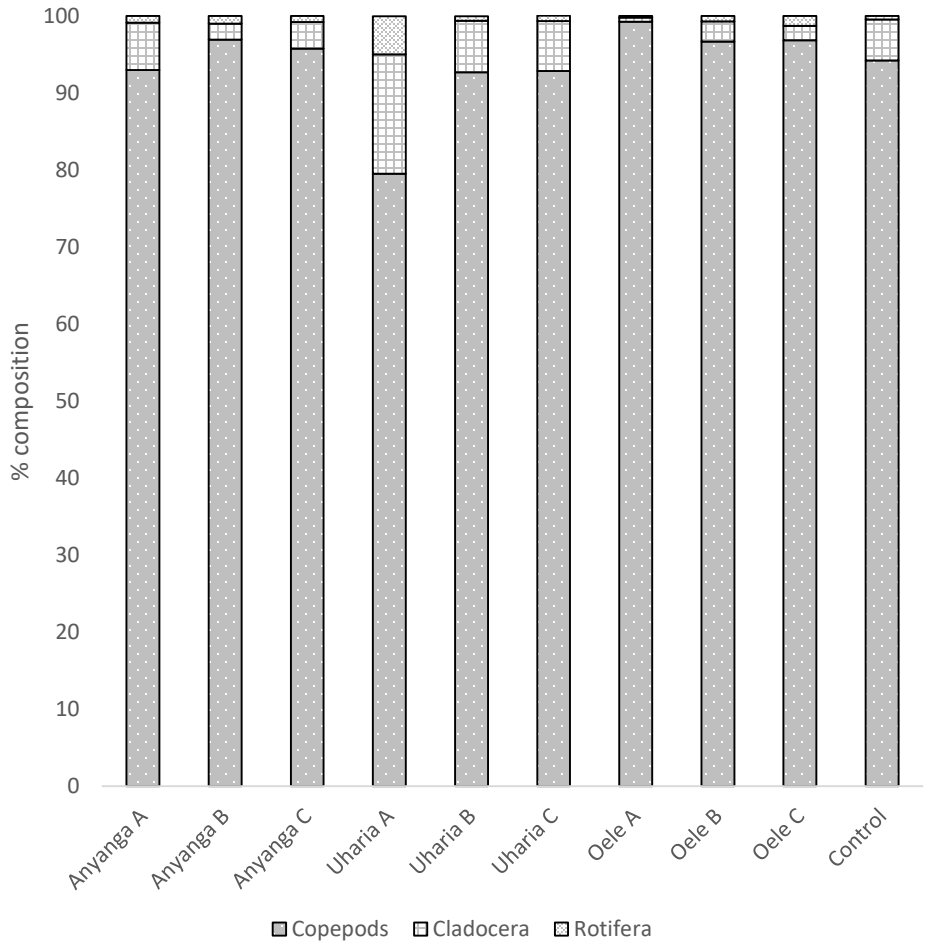

Figure 15 Percentage compositions of different groups of zooplankton

The zooplankton group, *Copepoda* dominated by *Cyclopoid nauplii* and Cyclopoida recorded the highest abundances in all the10 sampling stations. While *Cyclopoid nauplii* dominated in Anyanga A, Anyanga B, Oele A and Olele B at 53.1, 53.6, 57.8 and 57.0, respectively, Cyclopoida dominated in Anyanga C, Uharia A, Uharia B, Uharia C, Oele C and the Control (Figure 15). Calanoida and Cyclopoida recorded the least percentage below 10% in all sampling the stations.

3.4 Macro-invertebrates

A total of (5) orders representing (7) families and (8) genera (Table 1) were found in the study sites, the highest number of genera were recorded at all Anyanga sample stations and Uwaria (A) with total collection (5) each. During the study period, the orders Haplotaxida had the highest

number of genus while Trichoptera had the least number of genus. The family tubificid dominated with (126 Individuals).

Table 1, Shows the Orders, families and genera of the macro-invertebrates studied.

Order	Family	Genus	Species
Prosobranchiata	Hydrobidae	Cillias	Cillia altilis
	Thairidae	Melanoides	Melanoides tuberculata
Unionoida	Unionoidae	Anadonta	Anadouta cygneae
		Unio	Uniopictorum
Trichoptera	Leptoceridae	Antripsodes	Antripsodes sp
Haplotaxidae	Tubificidae	Tubifex	Tubifex tubifex
	Naididae	Naids	Naids sp
	Lumbriculidae	Lumbliculus	Lumbriculus vanagalus

Table 2, Calculation of the Hilsenhoff Biotic Indices (HBI)

	Anyanga A	Antyanga	Anyanga c	Uwaria A	Uwaria B	Uwaria C	Oele A	Oele B	Oele C	Control
Sum	10	38	21	38	3	7	23	54	36	3
Taxa	4	5	5	5	2	2	3	2	1	3
% scr	90	68.42105	66.66667	81.57895	0	0	30.43478	3.703704	0	33.33333
% prd	10	2.631579	4.761905	13.15789	33.33333	71.42857	0	0	0	0
%dpt	10	18.42105	33.33333	18.42105	100	100	69.56522	96.2963	100	66.66667
%shr	40	10.52632	14.28571	23.68421	0	0	0	0		0
%mode	75	40	40	60	0	0	66.66667	50	0	66.66667
%tole	25	60	60	40	100	100	33.33333	50	100	33.33333
%dominant	50	68.42105	47.61905	65.78947	66.66667	71.42857	69.56522	96.2963	100	0
(H)	1.16828245	1.046988	1.279177	1.089248	0.636514	0.59827	0.739321	0.184083	0	1.098612
1-D	0.36	0.465398	0.333333	0.466759	0.555556	0.591837	0.553875	0.927984	0	0.333333
HBI	0.37704918	0.157895	0.241611	0.140351	0.76385	0.278689	0.112903	0.0434	0	0.15

Water quality ratings for HBI values (from Hilsenhoff 1987)

HB1 value	Water quality rating	Degree of organic pollution
≤ 3.30	Excellent	Non apparent
3.51-4.50	Very good	Possible slight

4.51-5.50	Good	Some
6.51-7.50	Fairly poor	Significant
7.51-8,50	Poor	Very significant
8.51-10.00	Very Poor	Severe

According to the Hilsenhoff's Index, the water quality within the study sites were below 3.3 HBI indicating excellent water quality.

Richness measures

Taxa richness was high in Anyanga C (1.279) and the lowest diversity was at Oele C (0) in which only tubificids were present.

Diversity measures

Diversity measurement was high in Oele B (0.93) tubificids were dominant (52) organisms, and lowest in Oele C (0) with only tubificids (36) organisms respectively.

Functional feeding classes

Shredders were highest in Anyanga A. Collectors were highest in Uwaria B, C and Oele C (100) lowest in Anyanga (10), Predators were highest in Uwaria C (71.4) and lowest in Oele A, B, C and control (0) Respectively. Scrabbers were highest in Anyanga (90) and lowest at Uwaria B, C Oele C (0) all were measured in percentages.

Dominance measures

Percentage dominance was highest in Naya (1.20%) and lowest at the pier (0.21). The percentage of a dominant organism (irrespective of the identity) increases with increasing perturbation (Barbour et, al. 1996). Chironomids are useful in documenting water and habitat quality in many aquatic ecosystems because of their high diversity and variable pollution tolerance levels (Ferrington L.C. et,al. 2008)

4. Discussion

Measured ranges of physical chemical variables in selected cage sites were generally within acceptable levels of NEMA. There was no tangible evidence of impact of fish cages on any of the

measured parameters. Results exhibited higher NH_4^+ and TN in the cage sites than within the control sites especially in Anyanga and Uwaria. This could be probably due to increased number of cages in the two sites. Guo and Li (2003) working in Njushanhu Lake, China observed that most environmental impacts in cage fish farm areas are associated with increased number of cages.

The results from the study demonstrated the important role of physical conditions in influencing phytoplankton productivity and assemblage in the cages. The phytoplankton community in the littoral and towards the open lake were physically active. This was attributed to dominance of diatoms which are relatively photosynthetic and have capacity to thrive towards the main lake. Similar conditions were observed in Lake Victoria in the early 1960s (Talling, 1965; Sitoki 2012) reported on the increased water column stability in Lake Victoria and the possible effects of higher TP concentration. Light limitation of phytoplankton growth occurs when there is mixing in depth which becomes greater than the photic depth hence phytoplankton are forced to spend more time in the photic zone or can occur under high light attenuation conditions in the upper water column, hence is caused by mineral or biogenic turbidity. Some phytoplankton species have photo physiological adaptation to low light availability by adjusting their capacity to capture and use the ability to adjust their position in low turbulence water columns through production of gas vesicles or mobility, and therefore giving them an advantage over other species when light availability is low (Walsby et al 1997; Brookes et al 1999). The present study observed along the transect are partly attributed to morphological differences between the wide and shallow littoral zones to the cages which is associated with physical processes thus influences nutrient cycling. This is correlated with the high physio-chemical parameters recorded in the present study and can be explained by high washing effect of the diatoms from the upper catchment but also input of nutrients especially Soluble reactive silicates (SRSi) for their growth. Species like *Synedra* spp and *Aulacoseira nyassensis* are also indicators of cultural eutrophication in lake ecosystem which are known to prevail in nutrient rich environment as observed by Wetzel (2000). The colonial *Microcystis*, with their capacity to control buoyancy, dominate phytoplankton assemblages in the cages is a clear indication of trophic status of the Lake. This finding is important for the management of the cage water quality since an increase in P loading will translate to high algal biomass, mainly bloom forming and potentially toxic blue greens such as *Microcystis* sp, which

are palatable to fish and other organisms in the cages. There is need to protect and minimize the number of cages hence may lead to deterioration of water quality.

Zooplankton studies revealed low species diversity which is attributed to changes of plankton community structure. Changes in the water quality variables bring about changes in plankton communities and consequently affect the quantity and quality of food items available for invertebrates which in turn determine the abundance and composition of the plankton communities in the environment. It is believed that the recent upsurge of cages would trigger the dynamics of nutrient especially with feeding regimes and bring a visible change in the species diversity and species abundance in the bay. The present data as well as the historical data accrued does not show any visible change since the traditional species that have been present in the Lake are still the ones present in the previous pattern of abundance and diversity. However, the low diversity may be attributed predation pressure from Zooplanktvorous fish as well as the carnivorous Zooplankton which feeds *Merismopedia* sp. The dominant algae like Microcystis which were abundant are palatable and not easily digested by Zooplankton due to its fibrous nature and colonial formations. This impacts the Zooplankton community species especially rotifers found at Uwaria and control. *Branchionus spp* conditions only favour predation species on the large bodied Zooplankters. Occurrence of lecane genus is known to inhabit littoral areas but appeared in Uwaria A, and could have a risen from sweeping effect of water through adjacent macrophytes and algal bloom which is reported in this survey. The latter is a new finding in the lake cages, there is need to focus on the same in future sampling activities for temporal and spatial scales of the physico-chemical environment that determine levels of primary production and plankton dynamics in aquatic ecosystems.

The observed results indicates there is no pollution as indicated by the HBI results although tubificid, which is highly tolerant to pollution and occasionally used as bio-indicator of pollution were highly present. In relation to the 2019 study, there is reduction in the number of orders and families across the study sites, a probable indication of enhanced pollution loads from cage activities. The taxa richness that was high at Anyanga and lowest at Oele may not depict environmental integrity or perturbation since even physical disturbance of a water column may shift the ecological structure (Townsend et, al. 1997).

Conclusions

- Although other physico-chemical variables were within acceptable ranges, the elevated concentration of NH_4^+ and TN are believed to emanate from decomposition of excess feeds from cage practices.
- The phytoplankton community structure in the littoral zones towards to the open lake were physically active and is attributed to dominance of diatoms which are relatively photosynthetic and have capacity to thrive towards the main lake hence high washing effect of diatoms from the upper catchment but also input of nutrients especially Soluble reactive silicates (SRSi) for their growth. Species like *Synedra* spp and *Aulacoseira nyassensis* are also indicators of cultural eutrophication in lake ecosystem which are known to prevail in nutrient rich environment in the cages.
- The low diversities of the zooplankton within the study sites were attributed to predation to predation by organisms higher in the food chain and not environmental degradation.
- The water quality as indicated by HBI from macro-invertebrate studies shows levels of pollution are within recommendable ranges.

Recommendations

- Since the ecological state is dynamic depending on the integrity of fish husbandry, there is need for continuous monitoring for prompt intervention.
- There is need to undertake further studies to establish the causative factors influencing low diversities of plankton communities.
- The farmers needs further sensitization on proper husbandry techniques i.e. quality, quantity and frequency of feeds and feeding regimes.
- Relevant implementing institutions should enforce existing policies that are in place to guide the industry.

Challenges

- The level of finding needs to be up-scaled so that a greater majority of cage culture sites along the Lake needs to be covered.

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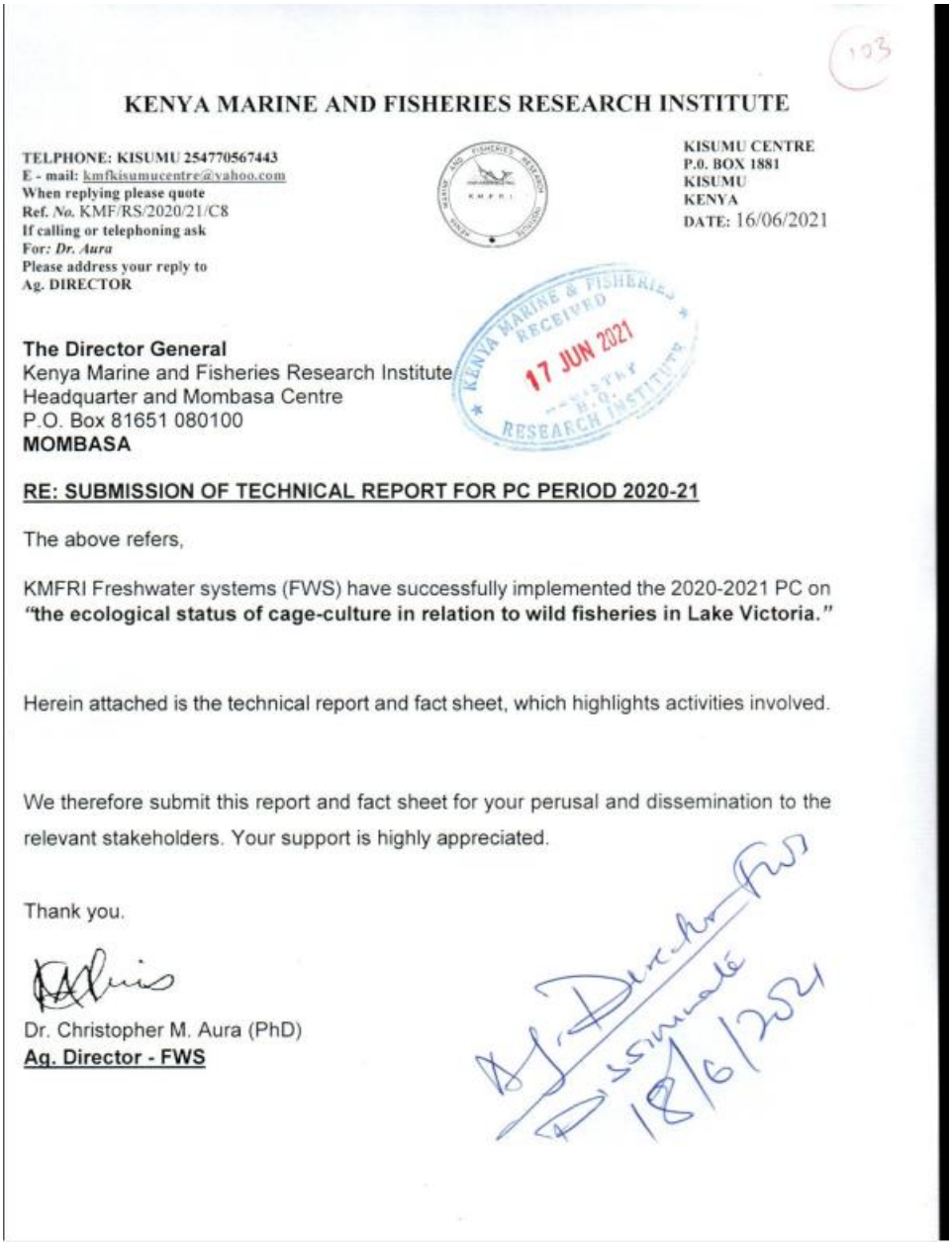
Appendix 1. Submission letter of the technical report to the Director KMFRI



KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

TELPHONE: KISUMU 254770567443
E - mail: kmfkisumucentre@yahoo.com
When replying please quote
Ref. No. KMF/RS/2020/21/C8
If calling or telephoning ask
For: Dr. Aura
Please address your reply to
Ag. DIRECTOR

KISUMU CENTRE
P.0. BOX 1881
KISUMU
KENYA
DATE: 16/06/2021

KENYA MARINE & FISHERIES RESEARCH INSTITUTE RECEIVED 17 JUN 2021 P.O. BOX

The Director General
Kenya Marine and Fisheries Research Institute
Headquarter and Mombasa Centre
P.O. Box 81651 080100
MOMBASA

RE: SUBMISSION OF TECHNICAL REPORT FOR PC PERIOD 2020-21

The above refers,

KMFRI Freshwater systems (FWS) have successfully implemented the 2020-2021 PC on **"the ecological status of cage-culture in relation to wild fisheries in Lake Victoria."**

Herein attached is the technical report and fact sheet, which highlights activities involved.

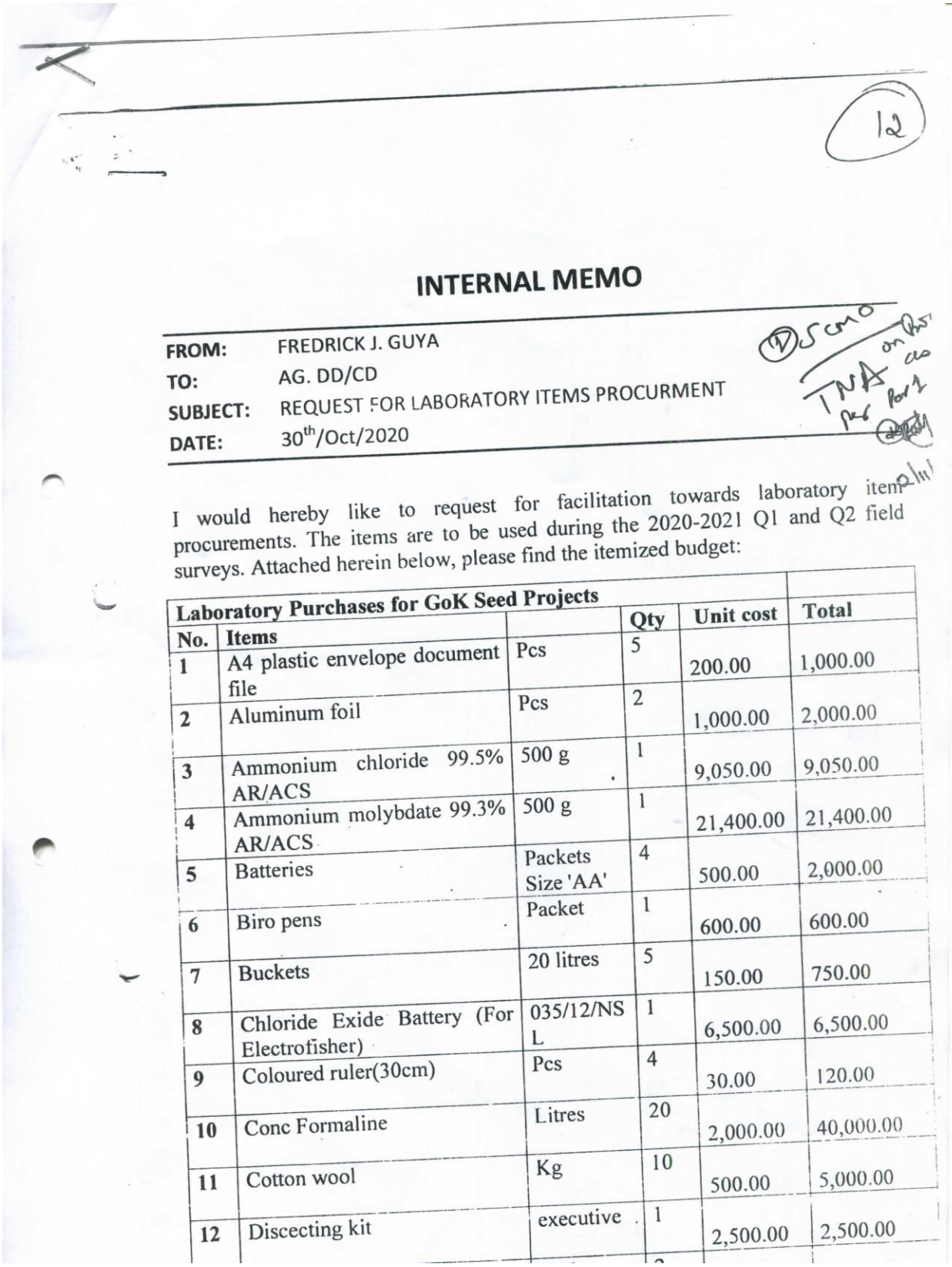
We therefore submit this report and fact sheet for your perusal and dissemination to the relevant stakeholders. Your support is highly appreciated.

Thank you.

Dr. Christopher M. Aura (PhD)
Ag. Director - FWS

Ag. Director FWS
Dissemination
18/6/2021

Appendix 2. Field requisition approval letter



INTERNAL MEMO

FROM: FREDRICK J. GUYA
TO: AG. DD/CD
SUBJECT: REQUEST FOR LABORATORY ITEMS PROCURMENT
DATE: 30th/Oct/2020

I would hereby like to request for facilitation towards laboratory items procurements. The items are to be used during the 2020-2021 Q1 and Q2 field surveys. Attached herein below, please find the itemized budget:

Laboratory Purchases for GoK Seed Projects					
No.	**Items**		**Qty**	**Unit cost**	**Total**
1	A4 plastic envelope document file	Pcs	5	200.00	1,000.00
2	Aluminum foil	Pcs	2	1,000.00	2,000.00
3	Ammonium chloride 99.5% AR/ACS	500 g	1	9,050.00	9,050.00
4	Ammonium molybdate 99.3% AR/ACS	500 g	1	21,400.00	21,400.00
5	Batteries	Packets Size 'AA'	4	500.00	2,000.00
6	Biro pens	Packet	1	600.00	600.00
7	Buckets	20 litres	5	150.00	750.00
8	Chloride Exide Battery (For Electrofisher)	035/12/NSL	1	6,500.00	6,500.00
9	Coloured ruler(30cm)	Pcs	4	30.00	120.00
10	Conc Formaline	Litres	20	2,000.00	40,000.00
11	Cotton wool	Kg	10	500.00	5,000.00
12	Discecting kit	executive	1	2,500.00	2,500.00

				600.00	1,200.00
14	Duracell size AA batteries	Quadruplet	3	520.00	1,560.00
15	Duracell size C batteries	Pairs	6	610.00	3,660.00
16	Ethylene Diamine Tetra Acetic Acid (EDTA)-Disodium salt AR/ACS	500 g	1	5,600.00	5,600.00
17	Gas Catridge	pcs	1	500.00	500.00
18	GFC Filters	Pcs	2	9,000.00	18,000.00
19	Guide facilitation		5	1,000.00	5,000.00
20	Hand Sanitizers	pkts	3	1,800.00	5,400.00
21	Hard cover 3quire A4 data book	In pcs	2	350.00	700.00
22	Hydrogen peroxide (AR) (250ml)	Lts	1	2,500.00	2,500.00
23	Liquid Soap (Lts)	Lts	1	650.00	650.00
24	Marker pens	Staedtler	4	200.00	800.00
25	Masking tape	2" in Pc	4	300.00	1,200.00
26	Mouth Masks	Pkts	2	1,800.00	3,600.00
27	Media pads	Pkt	1	12,500.00	12,500.00
28	Membrane Filters	Pcs	2	12,000.00	24,000.00
29	Pencils	Packet	1	600.00	600.00
30	Photocopy Papers	Reams	2	500.00	1,000.00
31	Plastic tit droppers	Pkt	2	500.00	1,000.00

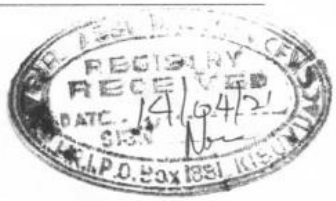
				1,500.00	1,500.00
33	Small Basins	In pcs	10	120.00	1,200.00
34	Sodium hydroxide	500g	1	4,200.00	4,200.00
35	Sorting trays	Pcs	4	200.00	800.00
36	Surgical blades	pkt	1	1,000.00	1,000.00
37	Table Clothe	pcs	3	50.00	150.00
38	Tape measure	Pcs	2	200.00	400.00
39	Tissue Rolls	Two in one	10	300.00	3,000.00
40	Tracing paper	Roll	1	7,000.00	7,000.00
41	Tri-Sodium citrate Dihydrate 99% AR/ACS	500 g	1	7,120.00	7,120.00
42	Vasseline Jelly	Gm	1	250.00	250.00
43	Wash bottle	Pcs	2	600.00	1,200.00
					208,210.00

Yours Sincerely

Fredrick Guya

25

INTERNAL MEMO



TO: Ag. Director (FWS)

FROM: Assistant Director (Limnology)

DATE: 13th April 2021

SUBJECT: PERFORMANCE CONTRACT (PC) FIELD WORKR

KMFRI Kisumu center is undertaking performance contracting (PC) activities for the 2020-2021 financial year. Most of the PC targets have already completed with technical reports under various stages of completion. However, two PC activities still need beefing up of data for the set-out deliverables to be achieved. Consequently, the field for the following targets is required:

i) Assessment of the ecological status of cage-culture in relation to wild fisheries in Lake Victoria, and;
ii) Mapping and monitoring major point sources of pollution and assess their effect on fish ecology in Lake Victoria.;

The activities will take three (3) days and are scheduled to begin on 19th April 2021. Participants in activities will observe socio-distancing, wear masks, regularly hand sanitize and strictly adhere with guidelines given by government to curb COVID-19.

The purpose of this memo is to request for facilitation (**KES 496,180**) to undertake the aforementioned activities as detailed in the attached budget.

Your support will be highly appreciated.

Yours Sincerely,
Dr. Chrispine Nyamweya (PhD)
AD Limnology.

Activity budget

PC TARGET Description

Assess the ecological status of cage-culture in relation to wild fisheries in Lake Victoria, prepare a technical report and share the findings by 30th June, 2021 (100%).				
Item description	**Qty**	**No.**	**Rate**	**Cost**
Dr. Christopher Aura		3	12,600	37,800
Fredrick Guya		3	8,400	25,200
Horace Owiti		3	8,400	25,200
Veronica Ombwa		3	8,400	25,200
Collins Ongore		3	8,400	25,200
John Ouko		3	8,400	25,200
Michael Onyango		3	8,400	25,200
Omwamba Basweti		3	8,400	25,200
Dismas Koscieny		3	4,900	14,700
Driver (Venzwa Wandera)		3	4,900	14,700
Fuel for vehicle	120	1	112	13,440
Boat hire		2	3,000	6,000
Subtotal				**263,040**

Map and monitor major point sources of pollution and assess their effect on fish ecology in Lake Victoria.				
Item description	**Qty**	**No.**	**Rate**	**Cost**
Dr. Chrisphine Nyamweya		3	10,500	31,500
George Basweti		3	8,400	25,200
Joyce Abaga		3	4,900	14,700
Fredrick Okello		3	8,400	25,200
Evans Akama		3	8,400	25,200
James Omollo		3	~~4,900~~	~~14,700~~
Pamela Olela		3	4,900	14,700
James Nyangute		3	4,900	14,700
Daudi Ndere		3	4,900	14,700
Driver (Paul Odhach)		3	4,900	14,700
Fuel for vehicle	120	1	112	13,440
Boat hire		2	3,000	6,000
Senior Accountant		1	8,400	8,400
Admistration costs		1	10,000	10,000
Subtotal				**233,140**
GRAND TOTAL				**496,180**

Appendix 3. Minutes for the field survey protocol meeting.

PROTOCOL MEETING HELD ON 05TH NOVEMBER 2020 AT THE CONFERENCE HALL FOR THE GoK 2020-2021 PC TARGETS

Agenda:

1. Protocol meeting for Performance Contracting Targets for FY: 2020-2021
2. A.O.B

Attendance:

- Attendance list attached. (Appendix 1)

Absent with an apology:

- Horace Owiti
- Megan Kinara

Meeting started at 0910hrs with opening remarks from Mr. Fred Guya and word of prayer from Mr. Zablon Awuonda. The chairman invited the DD-FWS, Dr Christopher Aura, to chair the meeting.

MIN 1/05/11/2020: PC TARGETS PROTOCOL MEETING

The chairman highlighted the limitations caused by Covid-19 pandemic on the budget allocation and called on all members to keep calm and be understanding of the situation. Members were called upon to keep time and the DD-FWS stressed on the need to observe time and always be punctual in meetings. The chair instructed that all absent members without an apology were to be excluded from undertaking on this activity unless they present a valid reason for absconding the meeting.

The chairman called upon the team-leaders to always ensure that all team members per group observed the laid-out Ministry of Health protocols in regards to Covid-19 spread control and personnel safety. Team leaders were called upon to make their protocol presentations:

i. PC Target 1: Monitoring of the point sources of pollution in Lake Victoria for protection of ecosystem services and use. This team will be led by Mr. George Basweti. The team will undertake sampling of water from major rivers, river mouths and other point sources and this data will be crucial as this are the same point sources monitored by KIWASCO.

ii. PC Target 2: Undertake continued bi-annual monitoring and mapping of water hyacinth and other macrophytes in Lake Victoria, Kenya for improved lake surveillance to inform lake users. This team will be led by Mr. Joseph Nyaundi. The team undertaking Target 1 and Target 2 will be undertaking their activities concurrently and thus had synchronized schedule and sampling places. The activity was pointed out to be a validation exercise and thus the team was tasked to come up with a correlation showing the water hyacinth locations as sampled vis a vis the macrophyte locations shown by the satellite imagery.

iii. PC Target 3: Assess the ecological status of cage culture in relation to wild fisheries in Lake Victoria. This team will be led by Mr. Fred Guya. The team will undertake sampling and plans to use a plankton net to collect the zooplankton which will be preserved under formalin. This team was also tasked to collect samples on macroinvertebrates.

iv. PC Target 4: Undertake mapping of Omena in comparison with Caridina fisheries for quality and safety assessment along the value chain in Lake Victoria to identify critical points for intervention. This team will be led by Monica Owili. The team will undertake the activity using a Focus Group Discussion protocol approach.

v. PC Target 5: Assessment of the socioeconomic effect of illegal fishing in Lake Victoria. The team will be led by Mr. Patrick Otuo with the proposed protocols to be used being: Key Informant Questionnaire and Focused Group Discussions. Both Target 4 & 5 deploy a socioeconomic approach, on the FGDs, and were called to observe social distancing during the discussions. The team will undertake on understanding the major illegal fishing gears and their percentage contribution towards fishing illegality. Also, the team will undertake on understanding the local names of the fishing gears and also new and upcoming illegal fishing ways.

vi. PC Target 6: Conducting an Economic and Financial Impact Assessment (EFIA) of Lake Victoria fisheries in Kenya and make recommendations for management. This will be a workshop held in Vihiga County, with the team already equipped with data collected from an LVFO sponsored project. The team will be led by Hilda Nyaboke. Part of the project data collection had already been done by July 2020 from funding by GIZ and the team will undertake to develop a report for the PC Target.

vii. PC Target 7: Roll-out the revamped EFMIS application for increased fisheries data dissemination for blue growth. The team will be led by Eric Odari under supervision from Horace Owiti. The chairman noted that this was a roll-out action for an application and thus the reporting should be able to show the roll-out success.

MIN 2/05/11/2020: A.O.B

- Time observation was called upon by the chairman whilst respecting colleagues and other personnel in the field. This was to apply to all members, whether going to the field or attending the workshop.
- Also, timely surrender after the field work was advocated for to ensure effective and timely accountability. All members were called upon to carry out splendid and outstanding research work that reflects the quality of the institute.
- All members were called upon to be very serious about the Balanced Score Card.

Having no any other business, the meeting was adjourned by the DD-FWS with a word of prayer from Mr. Joseph Nyaundi at 1110hrs.

Minutes confirmed by:

Secretary: ..... Chairman: .....

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE-KISUMU

PROTOCOL WORKSHOP IN PREPARATION FOR GOK 2020/2021 PC TARGETS FILED SURVEYS

DATE: 05 NOVEMBER 2020

ATTENDANCE LIST

NO	NAME	DEPARTMENT	E-MAIL	SIGN
1	Dr. Christopher Aura	Research	auramulen@yahoo.com	[signature]
2	ERICK OGARI	TECHNICAL	jimbomjaotke@gmail.com	[signature]
3	James Omolo	,,	oomolootieno@gmail.com	[signature]
4	Monica Owili	Research	owili@yahoo.co.uk	[signature]
5	Joseph Onyango	Technical	onyangojoseph098@gmail.com	[signature]
6	Caleb Ogwai	Research	ogwaic@yahoo.ca	[signature]
7	Wanguche Patrick	Research	partyotuo2009@gmail.com	[signature]
8	JULIA AKINYI	INTERN	juliapauls46@gmail.com	[signature]
9	Jane Oburu	Technical	janeochiengo5@gmail.com	[signature]
10	Pamela Olelo	Technical	olelapam1@gmail.com	[signature]
11	Zablon Awuondo	Technical	zawuondo@yahoo.com	[signature]
12	Hilda Nyaboke	Research	nyabokehilda@gmail.com	[signature]

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE-KISUMU

PROTOCOL WORKSHOP IN PREPARATION FOR GOK 2020/2021 PC TARGETS FILED SURVEYS

DATE: 05 NOVEMBER 202(

ATTENDANCE LIST

NO	NAME	DEPARTMENT	E-MAIL	SIGN
18	Christine Oyaro	Technical	christineoyaro02@gmail.com	
9.	James. O. Achiya	Technical	jachiya67@gmail.com	
10	Reuben Mairura	Technical	reubenmairura@gmail.com	
11	Joyce Abuga	Technical	joycebitenga076@gmail.com	
12.	Joseph K. Nyaundi	Scientist	nyaundjo@gmail.com	
13	George N. Onduso	Technical	georgenyonga0nduso@gmail.com	
14	Zebedee Moturi	Coxswain I	ZebeMoturi@gmail.com	
15	EVANS AKAMA	TECHNICIAN	evans_akama@yahoo.com	
16	Salima Oieno	Technical	ssalmawinotieno@yahoo.com	
17	VENNY MAPH	RESEARCH	vennyom2ini@yahoo.com	
18.	Michael G. Onyango	Technical	onyangom14@gmail.com	
19	Peter J. Wawiye	Scientist	pwawiye@yahoo.com	

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE-KISUMU

PROTOCOL WORKSHOP IN PREPARATION FOR GOK 2020/2021 PC TARGETS FILED SURVEYS

DATE: 05 NOVEMBER 2020

ATTENDANCE LIST

NO	NAME	DEPARTMENT	E-MAIL	SIGN
20	Omwamba Basweti	Technical	obasweti62@gmail.com	
21	Josephat Mwanchi	Technical	Jmwanchi71@gmail.com	
22	Nathan Lenjo Mrombo	Research	lenjomrombo@gmail.com	
23	Jared Minika	Research	jminika2018@yahoo.com	
34	James Kilonzi	LABORATORY	Jkakilonzi@yahoo.ca	
35	Veronica O. Ombwa	Research	vombwa@gmail.com	
36	GEOFFREY WAFULA	FINANCE	wageoffreywa@gmail.com	
37	FREDRICK RUMA	Research	fregwa@yahoo.com	
38	John Ouko	Technical	oukoogingaj@yahoo.com	
39	Naftaly Mwirigi	Research	naphtaleenavs@gmail.com	
40	GEORGE M. BASWETI	Research	mbasweti2013@gmail.com	
41	Priscilla N. Makindi	ICT	Scillamakindi@yahoo.com	

Appendix 4. Attendance register during the field survey.

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

K.M.F.R.I

Assessment of the ecological status of cage-culture in relation to wild fisheries in Lake Victoria.

Dates 9th – 12th November 2020

ATTENDANCE REGISTER

No.	Names	Designation	Contacts Email/phone	9th Nov. 2020	10th Nov. 2020	11th Nov. 2020	12th Nov. 2020
1	FREDRICK GUYA	RS II	0733-891690	[signature]	[signature]	[signature]	[signature]
2	Caleb Ogwai	RSI	0720639796	[signature]	[signature]	[signature]	[signature]
3	Veronica O. Ombwa	ARS	0722408429	Obiero.	Obiero	Obiero.	Obiero.
4	Jared Miruka	ARS	0722935138	[signature]	[signature]	[signature]	[signature]
5	Mwanche' Josephat	Technician	07108[illegible]	[signature]	[signature]	[signature]	[signature]
6	EVANS AIKAMA	Technician	0725634131	[signature]	[signature]	[signature]	[signature]
7	Obadiah Onduso	Driver	0722867260	[signature]	[signature]	[signature]	[signature]
8	DAVID NYABUTO	DRIVER	0701744914	[signature]	[signature]	[signature]	[signature]
9	Joyce Abaga	Technician	072601747	[signature]	[signature]	[signature]	[signature]

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

Assessment of the ecological status of cage-culture in relation to wild fisheries in Lake Victoria.

Dates 9th – 12th November 2020

ATTENDANCE REGISTER

No.	Names	Designation	Contacts Email/phone	9th Nov. 2020	10th Nov. 2020	11th Nov. 2020	12th Nov. 2020
10	Meggan Kinara	ICT Officer II	kinaram@yahoo				

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE-KISUMU CENTRE

Assess the Ecological Status of Cage Culture in Relation to Wild Fisheries in Lake Victoria– 4TH QUARTER PC TARGET ACTIVITY

DATE: 19th-22rd April, 2021

Attendance Register

No.	Name	Designation	Sign 19/4/2021	Sign 20/4/2021	Sign 21/4/2021	Sign 22/4/2021
1.	Dr. Christopher M. Aura	Ag Director				
2.	FREDRICK OUMA	RESEARCH				
3.	COLLINS O. ONGORE	RESEARCH				
4.	HORACE OUITI ONYANGO	RS				
5.	VERONICA OMBWA OBIERO	RS	Obiero	Obiero	Obiero	Obiero
6.	John Ouko	Ag. PLT				
7.	MICHAEL GEORGE ONYANGO	TECHNOLOGIST II	MGO	MGO	MGO	MGO
8.	Kosiemy Dismus	TECHNOLOGIST III				
9.	Omwamba Baswet	S. L. Technician				
10.	VENZWA WANDERA	DRIVER				
11.	ABDI RIZACK HUSSEIN	DRIVER				

Appendix 5. Sensitization of cage fish farmers during the survey

(a) Oele Beach

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

K.M.F.R.I

Sensitization workshop on the impact of unsustainable fish cage culture practices to aquatic environment.

Dates 9th – 12th November 2020

ATTENDANCE REGISTER

No.	Names	Institution	Contacts Email/phone	9th Nov. 2020	10th Nov. 2020	11th Nov. 2020	12th Nov. 2020
1.	JOSHUA ONANI	B-M-U	0729023738	[illegible]			
2.	ELLY ODONGO	B.MU	0702648794	[illegible]			
3.	CALEB OGWAI	KMFRI	0720639796	[illegible]			
4.	VERONICA OMBWA	KMFRI	0722408429	[illegible]			
5	Josephat Mwanchi	KMFRI	0710884495	[illegible]			
6	Joyce Alogo	KMFRI	0726011747	[illegible]			
7.	FREDRICK GUYA	KMFRI	0733-891690	[illegible]			
8	EVANS AKAMA	KMFRI	0725634131	[illegible]			
9	DENNIS AYIMBA	FARMER	0719647122	[illegible]			

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

Sensitization workshop on the impact of unsustainable fish cage culture practices to aquatic environment.

Dates 9th – 12th November 2020

ATTENDANCE REGISTER

No.	Names	Institution	Contacts Email/phone	9th Nov. 2020	10th Nov. 2020	11th Nov. 2020	12th Nov. 2020
10	OBADIAH ONDUSO	KMFRI	0722867260				
11	DAVID NYABUTO	KMFRI	0701744714				
12	Jared Mirugi	KMFRI	0722935138				
13	Muggan Kinara	KMFRI	0714685399				

(b)Usenge Beach

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

K.M.F.R.I

Sensitization workshop on the impact of unsustainable fish cage culture practices to aquatic environment.

Dates 9th – 12th November 2020

ATTENDANCE REGISTER

No.	Names	Institution	Contacts Email/phone	9th Nov. 2020	10th Nov. 2020	11th Nov. 2020	12th Nov. 2020
1	MAURICE ODHIAMBO OKLA	FISHERG	0728227455		[signature]		
2	JOHN OGWEZA ODKO	FISHERMAN	0701739467		[signature]		
3	JECTONEACHIENG OBIGO	FISHERMAN	0725385587		[signature]		
4	Nwanchi Jozephat	KMFRI	0710884075		[signature]		
5	Caleb Ogwow	KMFRI	0720 639796		[signature]	[signature]	
6	EVANS AKAMA	KMFRI	0725634131		[signature]		
7	FREDRICK Guya	KMFRI	0733-891690		[signature]		
8	VERONICA O. OMBWA	KMFRI	0722408429		[signature]		
9	Joyce Abaga	KMFRI	0726011747		[signature]		

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

Sensitization workshop on the impact of unsustainable fish cage culture practices to aquatic environment.

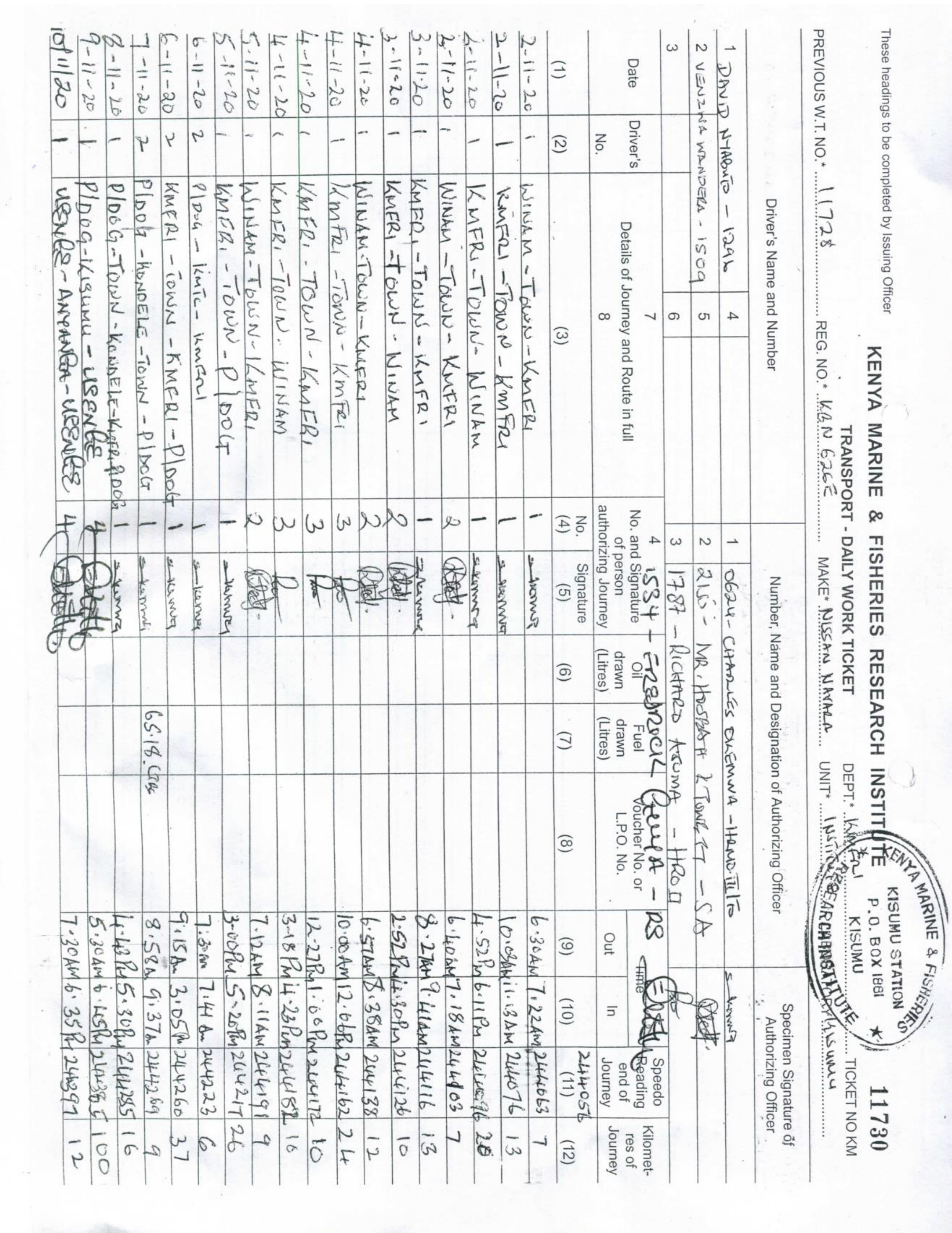
Dates 9th – 12th November 2020

ATTENDANCE REGISTER

No.	Names	Institution	Contacts Email/phone	9th Nov. 2020	10th Nov. 2020	11th Nov. 2020	12th Nov. 2020
10	Jared Mwikya	KMFRI	JMwikya2012@gmail.com				
11	DAVID NYABUTO	KMFRI	0701744714				
12	OBADIAH ONDUSO	KMFRI	0722867260				

Appendix 6. KMFRI Scientists working during the survey

Appendix 7. Work ticket



These headings to be completed by Issuing Officer

KENYA MARINE & FISHERIES RESEARCH INSTITUTE

TRANSPORT - DAILY WORK TICKET

11730

DEPT.* KMFRI ... TICKET NO KM

PREVIOUS W.T. NO.* 11728 REG. NO.* KBN 626E MAKE* NISSAN NAVARA UNIT* INSTITUTE RESEARCH LABORATORY KISUMU

KENYA MARINE & FISHERIES KISUMU STATION P.O. BOX 1881 KISUMU

Driver's Name and Number				Number, Name and Designation of Authorizing Officer		Specimen Signature of Authorizing Officer
1	DAVID NYABUTO - 1296	4		1	0624 - CHARLES OKEMWA - HRMO III/TO	[signature]
2	VENZINA WANDERA - 1509	5		2	2150 - MR. HOSBATH K TOWETT - SA	[signature]
3		6		3	1787 - RICHARD ASUMA - HRO II	[signature]
				4	1534 - FREDRICK GUYA - RS	[signature]

Date (1)	Driver's No. (2)	Details of Journey and Route in full (3)	No. and Signature of person authorizing Journey: No. (4)	Signature (5)	Oil drawn (Litres) (6)	Fuel drawn (Litres) (7)	Voucher No. or L.P.O. No. (8)	Time Out (9)	Time In (10)	Speedo Reading end of Journey (11)	Kilometres of Journey (12)
										244056	
2-11-20	1	WINAM - TOWN - KMFRI	1	[signature]				6.30AM	7.22AM	244063	7
2-11-20	1	KMFRI - TOWN - KMFRI	1	[signature]				10.03AM	11.13AM	244076	13
2-11-20	1	KMFRI - TOWN - WINAM	1	[signature]				4.52PM	6.11PM	244096	20
3-11-20	1	WINAM - TOWN - KMFRI	2	[signature]				6.40AM	7.18AM	244103	7
3-11-20	1	KMFRI - TOWN - KMFRI	1	[signature]				8.27AM	9.41AM	244116	13
3-11-20	1	KMFRI - TOWN - WINAM	2	[signature]				2.52PM	4.30PM	244126	10
4-11-20	1	WINAM - TOWN - KMFRI	2	[signature]				6.57AM	8.38AM	244138	12
4-11-20	1	KMFRI - TOWN - KMFRI	3	[signature]				10.00AM	12.06PM	244162	24
4-11-20	1	KMFRI - TOWN - KMFRI	3	[signature]				12.27PM	1.00PM	244172	10
4-11-20	1	KMFRI - TOWN - WINAM	3	[signature]				3.18PM	4.23PM	244182	10
5-11-20	1	WINAM - TOWN - KMFRI	2	[signature]				7.12AM	8.11AM	244191	9
5-11-20	1	KMFRI - TOWN - P/DOG	1	[signature]				3.00PM	5.20PM	244217	26
6-11-20	2	P/DOG - KMTC - KMFRI	1	[signature]				7:30AM	7.41AM	244223	6
6-11-20	2	KMFRI - TOWN - KMFRI - P/DOG	1	[signature]				9.15AM	3.05PM	244260	37
7-11-20	2	P/DOG - KONDELE - TOWN - P/DOG	1	[signature]		65.18 Ltrs		8.58AM	9.37AM	244269	9
8-11-20	1	P/DOG - TOWN - KONDELE - KMFRI P/DOG	1	[signature]				4.43PM	5.30PM	244285	16
9-11-20	1	P/DOG - KISUMU - USENGE	4	[signature]				5.30AM	6.45PM	244385	100
10/11/20	1	USENGE - ANYANGA - USENGE	4	[signature]				7.30AM	6.35PM	244397	12

Date	Driver's No.	Details of Journey and Route in full	No. and Signature of person authorizing Journey		Oil drawn (Litres)	Fuel drawn (Litres)	Voucher No. or L.P.O. No. or Cash Voucher No.	Time		Speedo Reading end of Journey	Kilometres of Journey
			No.	Signature				Out	In		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1/11/20	1	USENGE - UWOMA - USENGE	4					7.30AM	7.30PM	244419	22
4/11/20	1	USENGE-OLE - KISEMA	4					6.00AM	10.12AM	244520	101

DRIVER'S REPORT OF DEFECTS		Action taken by Officer i/c	SUMMARY OF WORK TICKETS		Certified all entries checked. Details entered in Vehicle Log Book.
Date	Defects			Ltr. (fuel) Ltr. (Oil)	
			Totals - Fuel and Oil drawn		
			Fuel in Tank to be carried forward	Ltr.	
			Total Distance (km)		Designation
			Miles per litre (fuel)		Station
			Miles per litre (Oil)		

Appendix 8. Letter from the DD to the Director.

Appendix 9. Letter from the Director.

Appendix 10. Ecological status of cage culture in relation to wild fisheries in Lake Victoria- Fact Sheet.

KENYA MARINE AND FISHERIES RESEARCH INSTITUTE

FRESH WATER SYSTEMS

FACT SHEET

TARGET: KMF/RS/2021/C8

A technical report on the ecological status of cage-culture in relation to wild fisheries in Lake Victoria

JUNE, 2021

Authors: Guya, F; Ombwa, V; Ogwai, C; Babu, J; Aura, M.C., Nyamweya, C., Mwanchi, J; Akama, E. & Abaga, J.

Kenya Marine & Fisheries Research Institute
Kisumu Station
P. O. Box 1881 – 40100
KISUMU

BACKGROUND INFORMATION

- The Catch Per Unit Effort (CPUE) has drastically reduced with many fishermen now reverting to fish cage culture practices for alternative livelihood, without good husbandry practices.
- Cage culture practice is on the rise within the Kenyan waters with majority of cages sited within inshore areas of bays, where farmers believe the cages and attendants are safe from strong waves and currents.
- Many farmers have resorted to cage fish farming without adherence to laid down policies and proper fish husbandry. This is many instances have resulted in a shift in ecological integrity and losses through massive fish kills both in the cages and in the wild.
- KMFRI, under its mandate, has continuously undertaken monitoring surveillance to ascertain the ecological status of the aquatic ecosystem for informed management decisions and prompt interventions.

STUDY SITE

- Three cage practice sites were sampled with replication within Anyanga (intensive), Uwaria/Usigu (semi-intensive) and Oele (less intensive) and a control site for comparison was sampled as well.

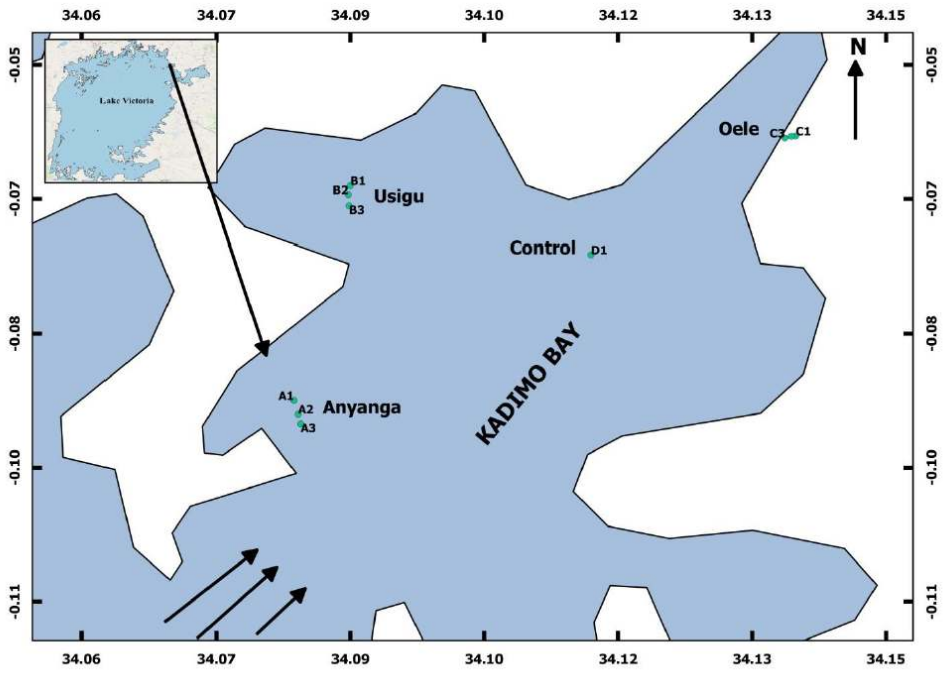


Figure 2. Map of Kadimo Bay in Lake Victoria showing sampled cage culture sites and the control.

RESULTS

Water Chemistry

- The trophic status of the water was generally eutrophic with Soluble Reactive Phosphorus (SRP) and Total Phosphorus (TP) exhibiting high concentrations within the cage culture sites (A, B, and C) as compared to control site (D).
- The concentrations were low at Site A (Anyanga) which had the highest number of cages, moderately high at site B (Uwaria) with moderate cages and highest in site C (Oele) with the least number of cages.
- Ammonium (NH_4^+) species of nitrogen and Total Nitrogen (TN) were higher in the cage sites than within the control site.
- Chlorophyll-a, a measure of primary productivity, was high within the cage culture sites as compared to the control site (D). Sites with high chlorophyll-a also expressed high TN concentrations.

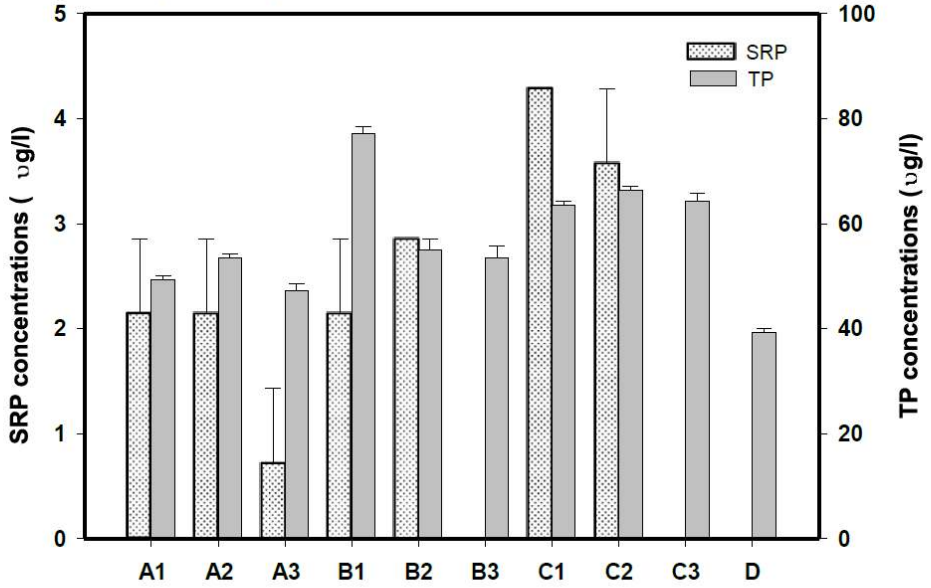


Figure 2. Graph showing the concentrations of Soluble Reactive Phosphorus (SRP) and Total Phosphorus (TP) across the sampled stations.

Phytoplankton

- The sampled stations were dominated by Diatoms which constituted 35% of the total phytoplankton bio-volume.
- Diatoms are highly preferred by fishes and are an indication of high environmental integrity. These were followed by cyanophytes which constituted 25%.

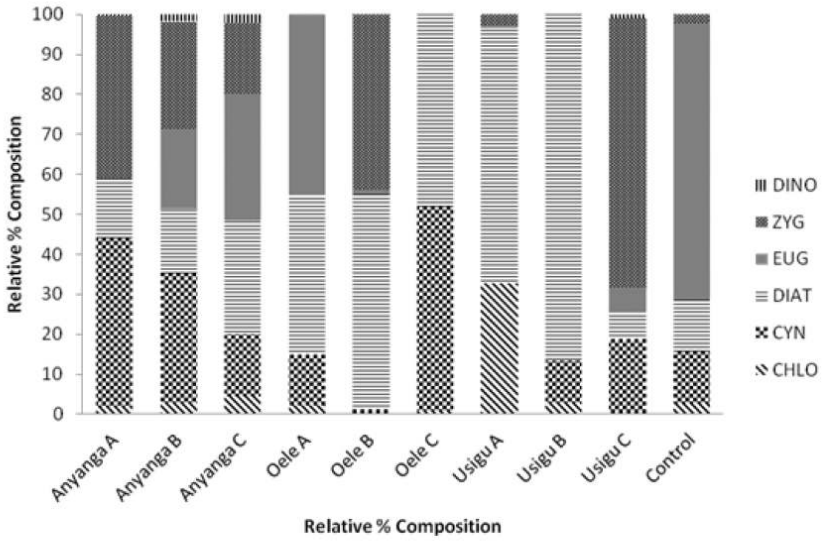


Figure 3 Percentage phytoplankton composition ($mm^3\ l^{-1}$) assigned to phytoplankton classes or families as recorded at different sites of the cages in Victoria, Kenya

Zooplankton

- Zooplankton densities within the 10 sampled sites decreased in the following order: Anyanga C 293.7, Control 288.9, Anyanga B 256, Uwaria B 247.5, Oele C 248.6. Comparatively low abundance was recorded at Anyanga A which is toward the littoral sampling stations.

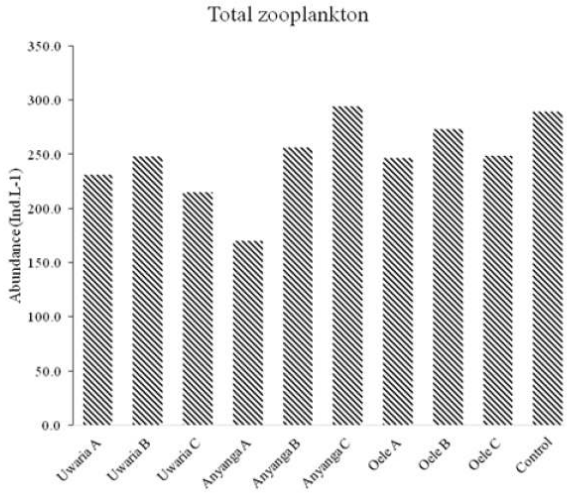


Figure 4. Total zooplankton abundance at the 10 stations in Lake Victoria

Macro-invertebrates

- A total of (5) orders representing (7) families and (8) genera (Table 1) were found in the study sites. The highest number of genera were recorded at all Anyanga sample stations and Uwaria (A) with total collection (5) each.

Table 1, Shows the Orders, families and genera of the macro-invertebrates studied.

Order	Family	Genus	Species
Prosobranchiata	Hydrobidae	Cillias	Cillia altilis
			Melanoides
	Thairidae	Melanoides	tuberculata
Unionoida	Unionoidae	Anadonta	Anadouta cygneae
		Unio	Uniopictorum
Trichoptera	Leptoceridae	Antripsodes	Antripsodes sp
Haplotaxidae	Tubificidae	Tubifex	Tubifex tubifex
	Naididae	Naids	Naids sp
			Lumbriculus
	Lumbriculidae	Lumbliculus	vanagalus

RESULT'S INTERPRETATION

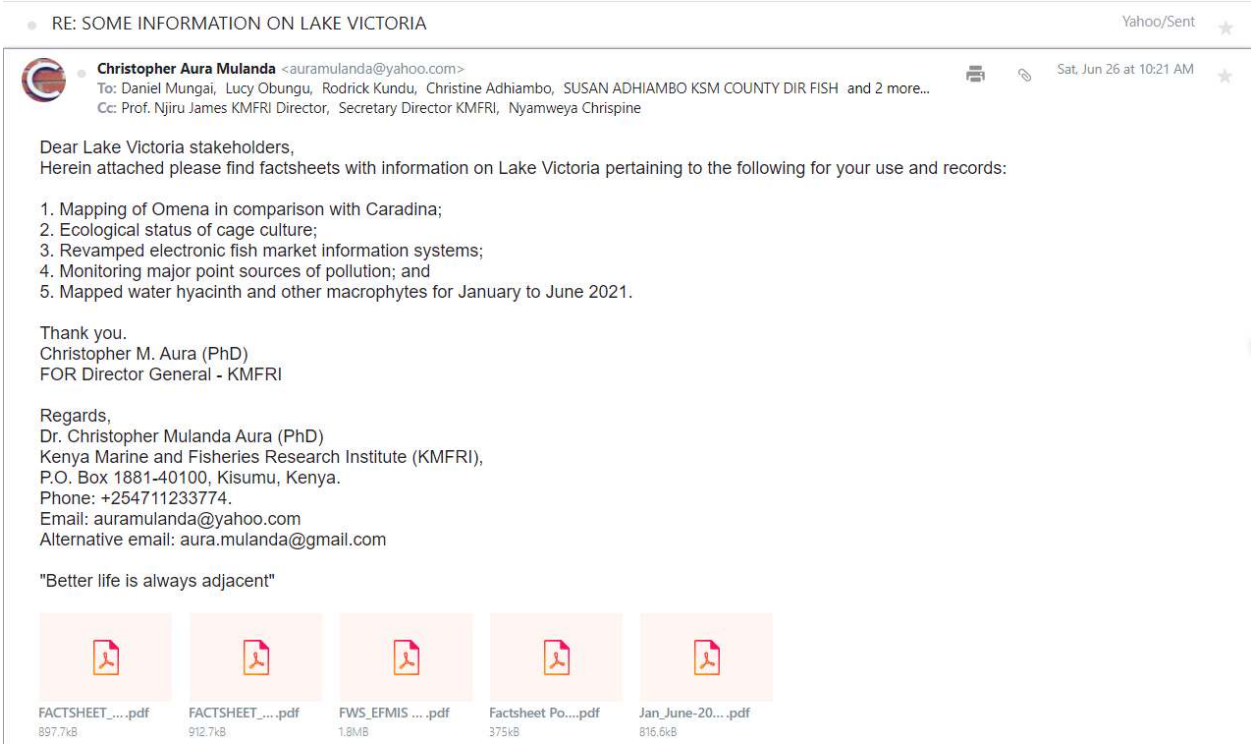
- The nutrient concentrations, though within permissible levels, were relatively higher within the cage culture sites as compared to the control station. This is an indication of negative impact of cage culture practices and thus keen monitoring of changes should be maintained.
- Similarly, the plankton density and structure (Phytoplankton and Zooplankton), does not show signs of environmental degradation, however there were observed low densities which could be attributed to internal predation.
- The calculated Hilsenhoff Biotic Indices (HBI) shows that there is less pollution results although tubificid, which is highly tolerant to pollution and occasionally used as bio-indicator of pollution were present.

RECOMMENDATION

- Since the ecological state is dynamic depending on the integrity of fish husbandry, there is need for continuous monitoring for prompt intervention.

- There is need to undertake further studies to establish the causative factors influencing low diversities of plankton communities.
- The farmers needs further sensitization on proper husbandry techniques i.e. quality, quantity and frequency of feeds and feeding regimes.
- Relevant implementing institutions should enforce existing policies that are in place to guide the industry.

Appendix 11. Dissemination



RE: SOME INFORMATION ON LAKE VICTORIA

Yahoo/Sent

Christopher Aura Mulanda <auramulanda@yahoo.com>
To: Daniel Mungai, Lucy Obungu, Rodrick Kundu, Christine Adhiambo, SUSAN ADHIAMBO KSM COUNTY DIR FISH and 2 more...
Cc: Prof. Njiru James KMFRI Director, Secretary Director KMFRI, Nyamweya Chrispine

Sat, Jun 26 at 10:21 AM

Dear Lake Victoria stakeholders,
Herein attached please find factsheets with information on Lake Victoria pertaining to the following for your use and records:

1. Mapping of Omena in comparison with Caradina;
2. Ecological status of cage culture;
3. Revamped electronic fish market information systems;
4. Monitoring major point sources of pollution; and
5. Mapped water hyacinth and other macrophytes for January to June 2021.

Thank you.
Christopher M. Aura (PhD)
FOR Director General - KMFRI

Regards,
Dr. Christopher Mulanda Aura (PhD)
Kenya Marine and Fisheries Research Institute (KMFRI),
P.O. Box 1881-40100, Kisumu, Kenya.
Phone: +254711233774.
Email: auramulanda@yahoo.com
Alternative email: aura.mulanda@gmail.com

"Better life is always adjacent"

FACTSHEET_....pdf 897.7kB
FACTSHEET_....pdf 912.7kB
FWS_EFMIS ... .pdf 1.8MB
Factsheet Po....pdf 375kB
Jan_June-20....pdf 816.6kB