EAST AFRICAN COMMUNITY
LAKE VICTORIA FISHERIES ORGANIZATION

A REPORT OF THE LAKE VICTORIA 2021 HYDRO-ACOUSTIC SURVEY AND REANALYSIS OF HISTORICAL DATA (2007-2021)

Hydro-acoustics Regional Working Group

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EXECUTIVE SUMMARY

Since 1999, hydro-acoustics surveys have been used to monitor fish stocks in Lake Victoria with the goal of identifying and explaining the quantities (biomass) and distribution of major fish groups. Herein are the findings of the 24th survey, which was undertaken from October 26th to November 26th, 2021. Data were collected and analyzed in accordance with standard operating procedures (SOPs). The work also utilized a standardized approach to reanalyze all of the data collected by the EK60 split beam echosounders dating back to 2007, enabling direct comparisons of biomass estimations from various years. Current standard operating procedures (SOPs) can disaggregate and assign acoustic data to four (4) fish groups: Nile perch, Dagaa, Haplochromines and other fish, and the freshwater prawn *Caridina nilotica*. *Dagaa* accounted up 33% of the biomass in the 2021 research, followed by *Caridina* (28%), and the "*Haplochromines*" (21%). Only 18% of the expected biomass was accounted for by Nile perch.

The following significant observations were made:

- Total biomass of fish and *Caridina nilotica* in the lake was found to be 2.82 million tonnes (t), a 6% drop from the previous year (2020), which reported total biomass of 2.98 million tonnes.
- Nile perch biomass increased by 29% compared to the preceding 2020 study. The Tanzanian part of the lake had the greatest concentration. Kenya had a modest rise, whereas Uganda experienced a fall.
- Nile perch length frequency distribution is dominated by small sized individuals of leass 50 cm TL.
- Although the biomass of *Dagaa* declined by 7%, the estimated biomass per country increased by 17% and 7%, respectively, in Tanzania and Kenya, compared to the estimated biomass in 2020. In contrast, the estimated *Dagaa* biomass in Uganda decreased by 37% from the 2020 estimates.
- The biomass of haplochromines and other fish increased by 8% as compared to the previous study in 2020. In Tanzania and Kenya, biomass increased by 24% and 12%, respectively, during the 2020 study. However, in Uganda, the species' biomass declined by 15% during the same time span.
- *Caridina*'s biomass decreased by 24% as compared to the previous study. While biomass decreased by 19% and 35% in Tanzania and Uganda, respectively, it climbed by 17% in Kenya.
- Thermal stratification patterns were evident in the lakewide CTD sampling sites, particularly in the northwestern and north-eastern sectors. The DO profiles were much lower than the optimal for fish.
- Trend analysis demonstrated interannual variability in biomass for the fish groups studied, but no significant changes in trends were found.
- Patterns in density of the major fish groups did not differ considerably from previous patterns after strong enforcement and a decrease in the number of illegal gears.

We conclude and recommend, based on the current study's findings and experiences, that:

I. For the sustainability of Lake Victoria's fish stocks, enforcement should be guided by scientific evidence, and that functional co-management is better suited to achieving this paradigm shift than the existing military-led enforcement.
II. This, however, should be done within the framework of an ecological approach to fisheries management (EAFM)
III. Annual hydro-acoustic studies should be conducted in conjunction with stock assessments in order to offer clear management recommendations to supplement present enforcement efforts.

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1.0. INTRODUCTION

Lake Victoria is the largest freshwater body in Africa, shared by Kenya (6%), Uganda (43%) and Tanzania (51%). Its fishery contributes significantly to the GDP of three East African countries. The resource gives employment to thousands and feeds millions at a global level and in the riparian countries of Kenya, Uganda, and Tanzania. These are all beside the immense ecosystem services offered by the Lake. Fisheries are not inexhaustible; consequently, their management is crucial to guarantee their sustainability. The questions posed by fishery managers are often deceptively straightforward: what is the abundance of a given stock? How is it distributed? What is its size structure? How good is the estimate of abundance? To aid in answering such questions, resource managers and scientists have developed a number of tools.

The population abundance of the lake is being assessed using both Fishery-dependent; Catch assessment to obtain landing records, effort estimation using Frame and population characteristics using gill netting surveys and Fisheries-independent surveys; trawl, acoustic, video and side-scan sonar research surveys. Estimates of stock abundance are used to guide fisheries managers in making informed decisions to ensure sustainability and maximize economic benefits from the fishery.

Fisheries acoustics is one of the widely used methods to estimate stock abundance in marine and freshwater systems. The method involves the use of underwater sound(s) to detect, enumerate, and measure the distribution of fish and other living marine and freshwater resources and describe their habitat. Unlike other abundance estimation methods, the use of acoustic in fisheries management has increased over the years. This increase is as a result of its ability to collect data directly from the population, measure the distribution of organisms over large spatial scales. In addition, Hydro-acoustics can also cover a much greater area per unit of time, allowing large spatial scales to be studied which may be necessary to sample highly mobile species. The relatively fast data acquisition of hydro-acoustic methods is also cost effective in the long-run and non-destructive in nature and are not hampered by issues such as water clarity, strong currents or diver depth limits.

This report presents results of the 24th Lake Victoria regional Hydro-acoustics and environmental survey conducted from 26th October to 22nd November 2021. The biomass estimates reported here mainly focus on the four major groups; i.e. Nile perch, *dagaa*, *haplochromines*, and freshwater prawn, *Caridina nilotica*. For Nile perch, we report on distribution and biomass estimates for individual fish ≥10 cm total length (TL). The size structure of Nile perch is also presented to guide the focus of fisheries (especially on slot size). The work further utilized a standardized approach to reanalyze all of the data collected by the EK60 split beam echosounders dating back to 2007, enabling direct comparisons of biomass estimations from various years. The reanalysis was particularly useful in assessing how commercial fish stocks in the lake reacted to Uganda and Tanzania's strict enforcement of the illegal fishing gear ban. We also report on the catch composition, catch rates, and size structure from bottom trawl hauls to corroborate information from hydro-acoustics. Finally, information on physical, biological and chemical attributes is gathered and compared with fish distribution.

2.0. MATERIALS AND METHODS

1.1 Study area

The survey was conducted in Lake Victoria (surface area of 68,800 km^2). The lake area is partitioned by quadrant (SE, SW, NW, NE), depth (Deep, Coastal, Inshore)/special areas (Speke, Emin Pasha, and Nyanza gulfs and Sesse islands), and by country (Kenya, Tanzania, Uganda).

1.2 Organization of the cruise

This survey was conducted from 26th October to 22nd November 2021. There were five days of preparations during which the calibration of the echo-sounders and CTDs was done, and other research materials and equipment assembled and tested.

1.3 Calibration of echo-sounder

The first calibration was conducted on 26th October 2021 at the beginning of the survey in Mwanza gulf, and the second on 20th November 2021 in Ukara Island but was not successful due to bad weather. Tungsten carbide sphere was used in the calibration for the 70 and 120 kHz transducers.

The calibration protocol used for this survey is detailed in the new SOPs for hydro-acoustic surveys on Lake Victoria (LVFO 2018). At each calibration site, we lowered the CTD to determine the local environmental conditions. The water temperature measured at the calibration site was used to predict sphere target strength using the formula provided at https://swfscdata.nmfs.noaa.gov/AST/SphereTS/. Using the same CTD information and analysis protocol in the new SOPs, the temperature-dependent equivalent two-way beam angles was estimated and used to update transducer settings in the EK80 software, including sound speed and absorption values.

1.4 Cruise track

The cruise followed the radial design. On average one net haul and three CTD measurements were conducted on each day of the survey. Sampling was restricted to daylight hours.

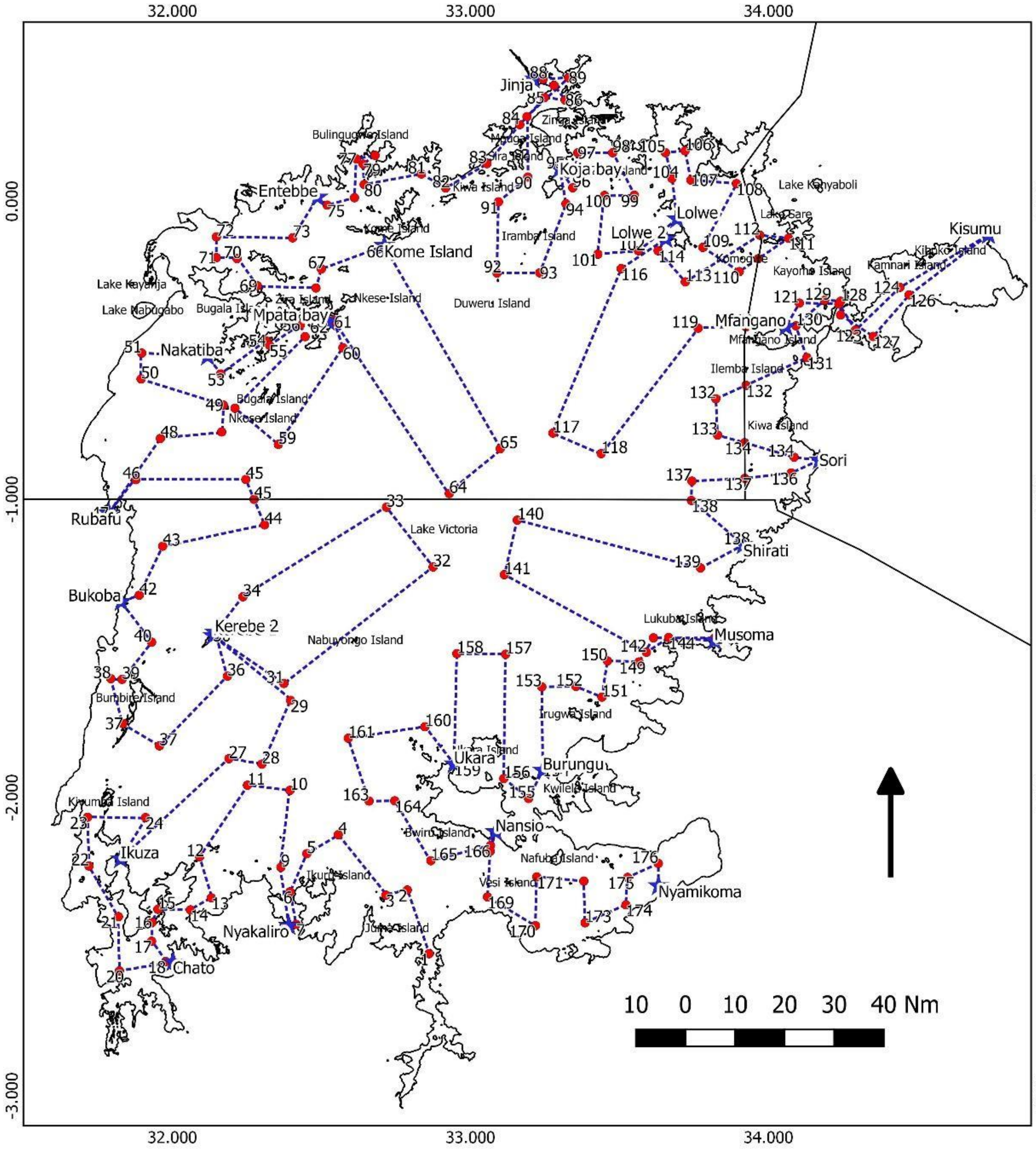

Figure 1. Survey cruise track. Numbers denote transects and deadheads (see appendix IV)

The organization of sampling and data collection procedures were structured according to the type of activity taking place. The following activities were organized;

a) Transect: an acoustic survey track with the vessel proceeding in the same nominal direction at constant speed (normally about 9 knots). The following types of transects were designated:

Deep Transect (Code TD) (>40 m deep strata);

Coastal Transect (Code TC) (20 – 40 m deep);

Inshore Transect (Code TI) (< 20 m deep);

Deadhead (Code DH), the track between two independent transects;

b) Net haul: During this survey only the bottom trawl (NB) was used for fish sample collection. Detailed results of net haul sampling are provided as appendix to this report.

c) CTD: Involving deployment of a CTD probe and Secchi disc, and other environmental observations at geo-referenced sampling points.

Groups of activities at the same nominal location were given the designation ‘Stations’ to indicate that they might be analyzed together. Transects in close proximity and occurring in the same stratum were allocated the same station number. The implication is that later high-resolution analyses could tie together transects and environmental data through stations. The detailed event log for the cruise is set out in Appendix II.

1.5 Acoustic data acquisition, processing and analysis

1.5.1 Data logging and storage

The echo-sounder operation parameters, particularly the Data recording Range (which was set to 120 m), were thoroughly reviewed and the recording was directory set at the start of each day. Data were logged in 1 GB files and then transferred to three different SSD disk drives.

1.5.2 Acoustic data preparation

Each day’s raw acoustic data files were loaded into Echoview v. 12 Myriax, Hobart, Australia software using a standardized template to ensure consistency, specifically for selected exports and analysis telegrams and saved as EV files using the day’s date as the file name. SIMRAD EK 80 echosounders were utilized in acoustic measurements. The transducers, which are mounted on the protruding instrument keel, operated at the frequency of 70 kHz and 120 kHz. All the two transceivers were calibrated before the survey. Calibration settings were applied in an Echoview calibration file to update the calibration of all variables within each EV file.

1.5.3 Setting analysis lines and definition of regions

Four analysis lines (checked bottom, test bottom, Dagaa and top lines) were set with specifications as detailed in the acoustic SOPs (LVFO 2018). Regions were defined by quadrant and strata, and according to the events given in the Event log. Occurrence of bottom echoes was checked between the "checked bottom" & "test bottom" lines and removed according to the standards detailed in the SOPs.

1.5.4 Estimation of EDSU

To ensure that all cells produced for analyses from the two frequencies in and between integration and single target analyses were similar, depth layers were set at 2 m intervals with a horizontal grid of 1 km (Elementary Distance Sampling Unit – EDSU). Data collected from regions designated as 'Transect' were used for analyses for the estimation of standing stock. For single target detections, analysis from each cell were exported by transect and by cell. To ensure that cells where no target was recorded are included in the calculation of average density, the option of "Output empty cells" was selected in Echoview – EV File properties Export window prior to data export.

The GPS positions of the start and end of each cell were used to determine the distance of the cell. Through the main part of each transect, these estimated distances correspond to the intended distance of 1 km. However, some cells produce distances well below 1 km, but these were all included in the analysis, weighted by their length.

1.5.5 Single target analysis

Estimation of Nile perch densities were done using single target detections (split beam Method 2, with no TVG range correction; LVFO (2018)) in Echoview version 12. Data were exported by transect and by cells (constituting individual EDSUs). To produce results comparable to the previous surveys, only data from the 120 kHz transducer were used for standing stock estimation. Single targets were thresholded at -50 dB, equivalent to a minimum detection length for Nile Perch of ca. 10 cm (LVFO 2018).

Data were exported within 2m depth strata in two parts from top line to dagaa line and from dagaa line to Checked-bottom-line and converted to mean numerical density and mean biomass densities using equations 1 and 2 respectively:

$$\boldsymbol{Density} = \left(\frac{\boldsymbol{NTargets}}{\boldsymbol{VBeam}}\right) \quad \textbf{(1)}$$

where *NTargets* and *VBeam* are the number of targets detected and the beam volume within the cell respectively.

$$\textbf{\textit{Biomass = Density × Mean weight}} \qquad \textbf{(2)}$$

The mean size was estimated from the mean TS and length/weight relationship. This was multiplied by the numerical density to give the estimated standing stock within the beam volume of each respective cell. Area density was estimated from the volume density by multiplying by the sampling effort (proportion of layer sampled) and the EDSU Area density estimated by summing the Layer Area densities.

Whereas the Length/Weight relationships used in analysis was the same as that used for the previous surveys under IFMP, the TS/Size relationship was that determined by Kayanda et al. (2012) (equations 3 and 4) . They are:

$$\textbf{\textit{TL=10((TS+84.14)/30.15)}} \qquad \textbf{(3)}$$

and

$$\textbf{\textit{Total weight = 0.0042 x TL3.26}} \qquad \textbf{(4)}$$

1.5.6 Integration analysis

Estimation of the standing stock of dagaa, the benthic crustacean *Caridina nilotica*, and the other species (haplochromines and others) were done by using echo integration.

1.5.6.1 Dagaa

Integration was undertaken in the layer from top line to the 'dagaa line' in the 120 KHz SQ1 telegram echogram and exported by regions (transects) and by cells (EDSUs) and marked "Integration dagaa". The exported volume scatter (Sv) values were converted to Area Backscattering Coefficient (ABC) using equation 5:

$$\boldsymbol{ABC = 10^{\,(sv/10)}} \qquad \textbf{(5)}$$

The ABC values from dagaa were summed up for each EDSU.

The ABC values due to Nile perch in the dagaa layer were estimated from Sv values obtained by exporting the numerical density of Nile perch in the layer top line to dagaa line in the 120 KHz split beam method 2 echogram. The Nile perch Sv values were estimated from the single target detections included in the integration range (from top line to dagaa line) according to a model developed from the previous survey (equation 6) through observations of several slow speed transects.

$$Sv\ Nile\ perch = TS\ mean + 10\ \log N\ Targets - 10\ \log Beam\ Vol - 2.3 \quad \mathbf{(6)}$$

Where TS = Target strength, N = No of Targets, Beam vol = Beam volume and 2.3 is an observed difference between corrected and uncorrected values for single targets detected during Slow Speed transects (February 2006, acoustic survey report).

The ABC for Nile perch were estimated from Sv values determined above from the following equation 7:-

$$\boldsymbol{BC\ Nile\ perch = 10^{((Sv\ Nile\ perch)/10)}} \quad \mathbf{(7)}$$

The ABC values due to dagaa alone denoted ABC_{dagaa} were obtained by subtracting ABC due to Nile perch in the dagaa range ($ABC_{Nileperchdagaarange}$) from the total ABC in the dagaa range (ABC dagaarange) according to equation 8:

$$\mathbf{ABCdagaa = ABC_{dagaarange} - ABC_{Nileperchdagaarange}} \quad \mathbf{(8)}$$

The ABC values for dagaa alone were converted into numerical densities and consequently into biomass using the TS/length relationship (equation 9) determined by Getabu *et al.*, 2003. TS = 20 log TL – 72.2, and TS per kilogram of -29.4dB. (9)

1.5.6.2 Caridina nilotica

Caridina that were noted to occupy the bottom layers of the water column were estimated by the difference in the volume scattering coefficient (Sv) between 70 and 120 kHz SQ1 telegram echograms. Integration was done between dagaa line and checked bottom in the 70 and 120 kHz echograms and exported by region and by cell. The exported Sv values of 120 kHz transducer were subtracted from the 70 kHz by EDSU and layer and whenever the Sv differences were between -5 and -10 dB, the Sv values from 120 kHz in those layers were accepted as Sv values due to *Caridina*. The protocol and logical equations used to estimate *Caridina* density are the same as those in the Feb 2008 acoustic survey report.

The selected Sv values due to *Caridina* were converted to density using TS per kg of -38.77 dB (TS for Krill – acoustically similar to *Caridina*) according to equation 10:

$$\textit{Caridina}\ \textbf{density} = 1000^{((Sv - TS)/10)} \qquad \textbf{(10)}$$

1.5.6.3 Haplochromines and others

In the case of haplochromines and other unidentified species, after taking out cells attributed to *Caridina*, the Sv values from the remaining cells were converted into ABC and summed up for each EDSU. Nile perch equivalents from the integration range (dagaa line to checked bottom) were estimated from single targets and converted to ABC due to Nile perch in a similar way to those in the dagaa range demonstrated above. Consequently, estimation of the standing stock of haplochromines and others was made by, subtracting the area backscattering ABC of Nile perch (ABC Nile-perch-other-taxa-range) from the total layer values (Integration other taxa - ABC other-taxa-range) according to equation 11:

$$ABC_{Other\text{-}taxa} = ABC_{other\text{-}taxa\text{-}range} - ABC_{Nile\text{-}perch\text{-}other\text{-}taxa\text{-}range} \qquad \textbf{(11)}$$

The ABC values for haplochromines and other taxa were then converted to Sv and finally to numerical density using the TS per kg of -25.17 dB according to equation 12:-

$$\textbf{Haplochromines and other taxa density} = 1000 * 10^{((Sv - TS)/10)} \qquad \textbf{(12)}$$

1.5.7 Estimation of Standing Stock

The mean transect density for each taxon for each EDSU was calculated as the mean of all EDSUs within the respective transect. The mean density of all EDSUs, within a stratum and their 95% Confidence interval (CI) calculated in through bootstrapping in the R statistical package, version 3.5 (R Development Core Team, 2018) (https://www.dropbox.com/sh/eeuahnjghp25y51/AAA5_GDMgrCLONJed3kWCOeNa?dl=0). Under the bootstrapping method, resampling is done n times, where n is the number of ESDUs in the zone in question, and the mean and confidence limits are determined from 5000 times repeat. Unlike in the previous surveys, ESDU values are weighted by ESDU length to enable all ESDUs to be used, and to prevent ESDUs of 0.9 km length being given equal weight in the bootstrap as 1 km ESDUs (LVFO, 2018).

The biomass of each taxon for each stratum was determined by multiplication of the mean densities and stratum area. The stratum areas are given in Table 1.

Table 1. Area of Lake Surface (km2) within each stratum

Quadrant	Deep	Coastal	Inshore	Special localities
South East	6,166	5,786	2,003	2,909 (Speke Gulf)
South West	6,251	6,601	3,181	2,022 (Emin Pasha)
North West	6,226	4,865	3,115	2,494 (Sesse Islands)
North East	4,724	3,786	5,729	1,335 (Nyanza Gulf)
TOTAL	23,367	21,038	14,028	8,760

1.5.7.1 Estimation of Standing Stock by country and by stratum

Stock of the three major taxa (Nile perch, dagaa, Haplochromine and others) were estimated by country and by strata. Any transect that crosses territorial boundaries was divided into two and marked "a" and "b". In respect to estimating biomass by strata and country, each part of the divided transect was analysed in the stratum of the country where it occurred. In addition, the boundary way of 17 points between Kenya and Uganda were plotted in NE quadrant and the areas occupied by the coastal and inshore strata in Kenya and Uganda were re-calculated from the map grid squares (Table 2). The rest of the strata were analysed by country and by quadrant.

Table 2. Strata areas (Sq. Km) by quadrant and by country

Quadrant	Deep	Coastal	Inshore	Gulfs/Inlets
SE	6166 (TZ)	5786 (Tz)	2003 (TZ)	2,909 (SG)
SW	6251 (TZ)	6601 (TZ)	3181 (TZ)	2,022 (EP)
NW	6226 (Ug)	4865 (Ug)	3115 (Ug)	2,494 (SI)
NE	4,724 (Ug)	2,704 (Ug)	3,966 (Ug)	1,335 (NG)
		1,082 (Ke)	1,763 (Ke)	
TOTAL	23,367	21,038	14,028	8760

Tz = Tanzania, Ug = Uganda and Ke = Kenya

1.6 Biological and environmental data acquisition

1.6.1 Biological Data

Bottom net hauls were used to collect biological samples and estimate catch rates from surveyed areas. Majority of the net hauls were done in coastal and inshore waters. In total, 24 net hauls were completed using the RV Lake Victoria Explorer stern trawler with propulsion power of 215 hp and length of 17 m, trawl head rope of 24.4 m and vertical opening of 3.5 m, and cod-end fitted with inner mosquito netting of 4 mm stretch mesh size to ensure retention of small fish and *C. niloticus*. The duration of each haul was generally 30 minutes and the towing speed was 2.9-3.2 knots. Start and end times, water depths and warp length were recorded.

Fish caches were all sorted into taxa at species level, except for the haplochromines, and individual weight and length recorded together with biometric data (LVFO. 2005; 2007); where possible, every fish in the catch was individually measured. For large catches, Nile perch above 30 cm TL were individually recorded and smaller fish were sub sampled. The catch was mixed thoroughly and a subsample was taken for recording lengths and weights. The results were raised by the proportion by weight of the total catch (after the large fish were removed) against the sub sample taken from it.

Specimens of Nile perch and other large species like tilapia were dissected for sex/maturity and dietary analysis. For fish stomach analyses the Point method was used to determine the contribution of each prey item to the diet according to the SOPs (LVFO 2007).

1.7 Environmental data

Location of the sampling points (CTD stations) for measurements of water physical and chemical attributes followed the provisions in the Standard Operating Procedures (SOPs) for Lake Victoria Hydro Acoustics Surveys(LVFO, 2018). The fifty-six (56) points were purposively and subjectively selected by stratified sampling strategy to ensure even distribution and representation of all the strata, special regions, countries, and quadrants, while logically coinciding with the bottom trawl (NB) sampling points. Hence, the sites occurred systematically and intermittently between acoustics cruise transects covering the entire lake and followed closely, the CTD stations for the previous surveys, with minor logistical deviations occasioned following local prevailing conditions like the weather and time of day.

Figure 2 shows the spatial positions of the CTD stations. More detailed descriptions of the CTD stations are presented in Annex II.

Measurement of water environmental attributes followed published standard methods for aquatic environmental studies (APHA, 2005). A depth-profiling system; a submersible was used to log the vertical profile data of the water physical and chemical parameters. Calibration of the probe was performed ahead of the survey by running analytical tests on sample waters for pH, DO and turbidity and comparing with sensor logged values. Corrective calibration was then done accordingly. Calibration for temperature measurements was done by comparing with readings of different thermometric instruments of same samples of water and mean deviation of temperature values noted for onward correction of field measured data. Periodically the instrument was serviced by clearing off clogging debris from the conduits and pump orifices to prevent instrument malfunction.

Water transparency was determined as Secchi depth using a standard Secchi disc and measured following standard procedures. Complimentary chlorophyll-a measurements were taken using Algal Torch®, a LED based algal reflectance meter, which was lowered to log data on total algae counts and chlorophyll a concentration down up to 5 metres.

Locations of CTD stations (GPS Coordinates) were logged on to a smart phone application-based GPS system, Maps. Me and collated with those displayed on the RV Explorer on board GPS and the echo-sounder system.

The habitat characteristics and weather conditions at the CTD stations were noted in detailed descriptive statement and referred to for data analysis and interpretation.

All data was compiled in comprehensive electronic datasheets, the main summaries, and statistical computing done using the R statistical package (R Core Team, 2020) while GIS mapping and spatial visualization was done on QGIS. The GIS base maps were obtained from Hamilton (2016).

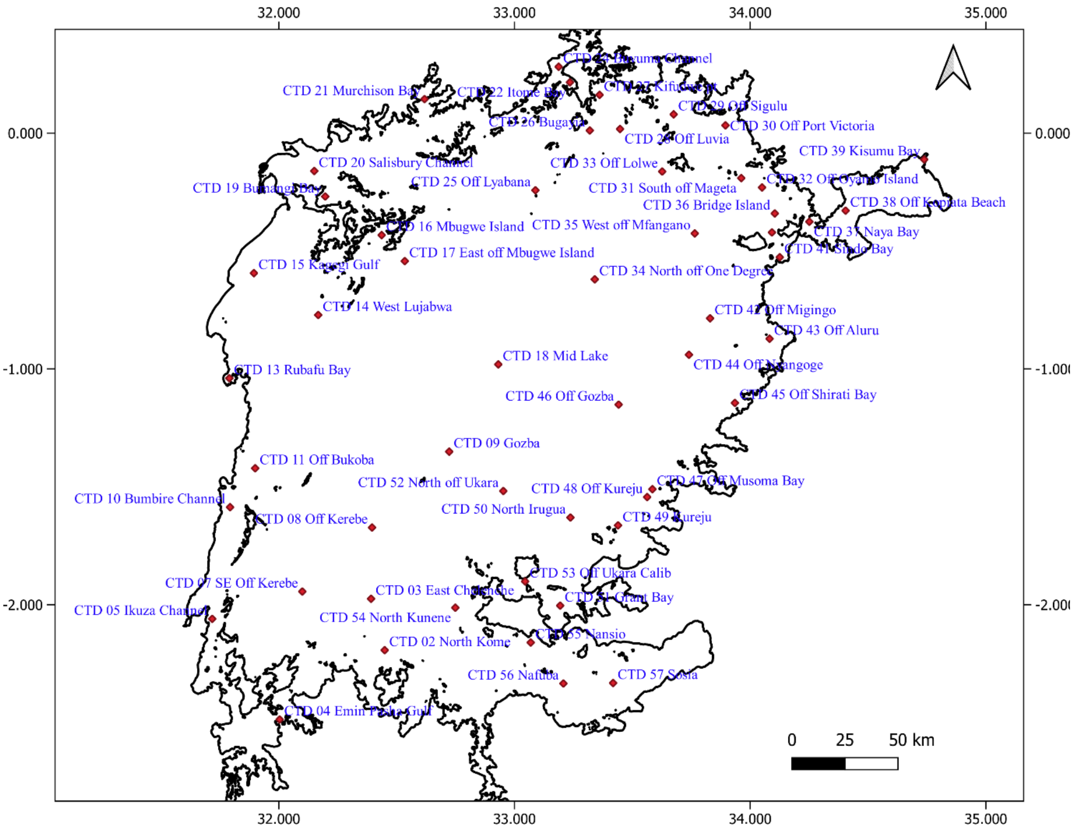

Figure 2. Map of Lake Victoria showing the CTD stations, October- November 2021

2 RESULTS AND DISCUSSION

This research estimated the biomass (standing stock) of Nile perch, *Dagaa*, Haplochromines and other fish, and *Caridina nilotica* using acoustic data from 2021. Additionally, the study determined the size structure of Nile perch populations. Further, the research reevaluated all of the acoustic data that had been collected with the EK60 split beam echosounders beginning in August of 2007 in order to estimate changes in the total biomass of the most important fish populations. This was done by using a standardized methodology. The reanalysis was also useful in assessing how the main populations responded to the stringent implementation of the ban on illegal fishing gear that was implemented since 2017 in the areas of Lake Victoria that are located in Uganda and Tanzania.

2.1 Nile perch

2.1.1 Standing stock of Nile perch

Table 3 shows the estimated standing stock of Nile perch more than 10 cm TL for the 2020 and 2021 surveys. The estimated mean total biomass in 2021 was 502,919 tonnes, 95 %CI [441,772, 569,783], which was 18% of the total fish biomass. The observed biomass for the species was 29% higher than the 389,860 tonnes, 95% CI [332,150, 456,055] recorded in 2020. The Tanzanian side of the lake had 67% of the Nile perch biomass, while Uganda and Kenya had 30% and 3%, respectively. Densities (mass per unit area of habitat) varied greatly across Lake Victoria's spatial zones (strata). Generally higher densities of Nile perch were observed in coastal and inshore areas of the lake (Figure 3). The South East quadrant of Tanzania has the greatest Nile perch densities, with coastal and inshore regions reporting 15.3 tonnes km-2, 95% CI [13.7, 17.0] and 11.0 tonnes km-2, 95% CI [9.7, 12.5], respectively. The Nyanza and Emin Pasha Gulfs, on the other hand, had the lowest concentrations (2.4 tonnes km-2, 95% confidence interval [1.8, 3.1]).

2.1.2 Temporal trends of Nile perch biomass

Since 2007, total Nile perch biomass has risen gradually with minor fluctuations (CV = 18.1) Figure 4. The biomass of the species increased steadily from a mean of 286,655 tonnes, 95% CI [240,085, 340,208] in August 2007 to a peak of 476,945 tonnes, 95% CI [412,146, 557,419] in 2014 before declining to a low of 326,259 tonnes, 95% CI [282,711, 374,939] in 2019. Following that, the trend proceeded to grow, with the largest biomass throughout the study period being 502,919 tonnes, 95% CI [441,772, 569,783] in 2021.

Table 3. Density and biomass estimates of Nile perch greater than 10 cm TL in Lake Victoria by country and stratum during the October-November 2020 and 2021 surveys.

Region	Area	2020						2021					
		Densities (t/km2)			Biomass (tons)			Densities (t/km2)			Biomass (tons)		
Tanzania													
		Mean	**Low**	**Upper**	**Mean**	**Low**	**Upper**	**Mean**	**Low**	**Upper**	**Mean**	**Low**	**Upper**
TzSECoastal	5786	6.9	5.0	9.7	39,919	28,829	56,118	15.3	13.7	17.0	88,432	79,350	98,202
TzSEDeep	6166	3.5	3.0	3.9	21,286	18,434	24,187	8.9	7.9	9.9	54,797	48,533	61,315
TzSEInshore	2003	6.4	5.5	7.4	12,816	11,067	14,839	11.0	9.7	12.5	22,090	19,348	24,949
TzSESpekeGulf	2909	5.6	4.8	6.4	16,232	14,080	18,542	8.1	6.8	9.7	23,677	19,714	28,293
TzSWCoastal	6601	7.8	7.0	8.8	51,803	46,129	58,205	9.7	8.8	10.6	63,769	58,121	69,646
TzSWDeep	6251	5.8	4.8	6.9	36,138	29,871	42,897	8.3	7.2	9.6	52,098	44,751	60,080
TzSWEminPasha	2022	2.5	1.8	3.2	4,961	3,672	6,397	2.5	1.8	3.3	5,095	3,705	6,611
TzSWInshore	3181	5.2	4.6	5.8	16,566	14,737	18,545	7.9	7.1	8.9	25,212	22,509	28,170
Subtotal					**199,721**	**166,820**	**239,731**				**335,170**	**296,031**	**377,267**
Uganda													
UgNECoastal	2704	5.3	4.8	5.8	14,233	12,858	15,698	9.1	8.3	10.0	24,741	22,475	27,108
UgNEDeep	4724	7.9	7.0	9.0	37,528	32,875	42,591	4.1	3.7	4.6	19,584	17,508	21,784
UgNEInshore	3966	2.6	2.1	3.1	10,330	8,510	12,402	5.4	4.5	6.3	21,349	18,005	25,000
UgNWCoastal	4865	5.9	5.3	6.4	28,500	25,810	31,257	4.2	3.7	4.7	20,303	17,866	22,867
UgNWDeep	6226	6.9	6.1	7.7	42,996	38,278	47,710	5.7	5.1	6.3	35,776	32,058	39,523
UgNWInshore	3966	5.9	5.2	6.6	23,401	20,625	26,320	4.9	4.1	6.0	19,325	16,403	23,612
UgNWSesse	2494	8.1	6.8	9.5	20,207	16,852	23,700	3.9	3.3	4.7	9,807	8,192	11,643
Subtotal					**177,194**	**155,808**	**199,678**				**150,886**	**132,507**	**171,537**
Kenya													
KeNECoastal	1082	6.5	5.5	7.6	7,044	5,957	8,174	7.7	6.8	8.6	8,279	7,377	9,260
KeNEInshore	1763	3.2	2.0	4.6	5,691	3,475	8,115	3.0	2.0	4.3	5,371	3,516	7,533
KeNENyanzaGulf	1335	0.2	0.1	0.3	210	91	356	2.4	1.8	3.1	3,213	2,341	4,187
Subtotal					**12,945**	**9,523**	**16,645**				**16,863**	**13,234**	**20,979**
Total					**389,860**	**332,150**	**456,055**				**502,919**	**441,772**	**569,783**

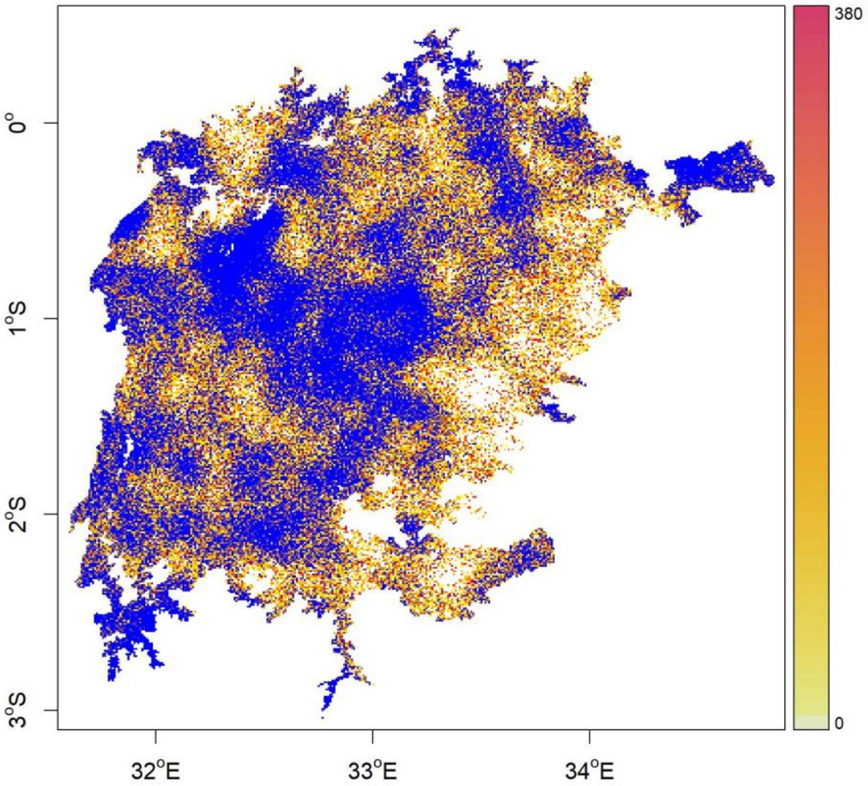

Figure 3. Spatial distribution of Nile perch in Lake Victoria during the 2021 October-November hydro-acoustic survey. (The heat map is derived from kriging interpolation of fish densities observed in individual EDSUs on the cruise track).

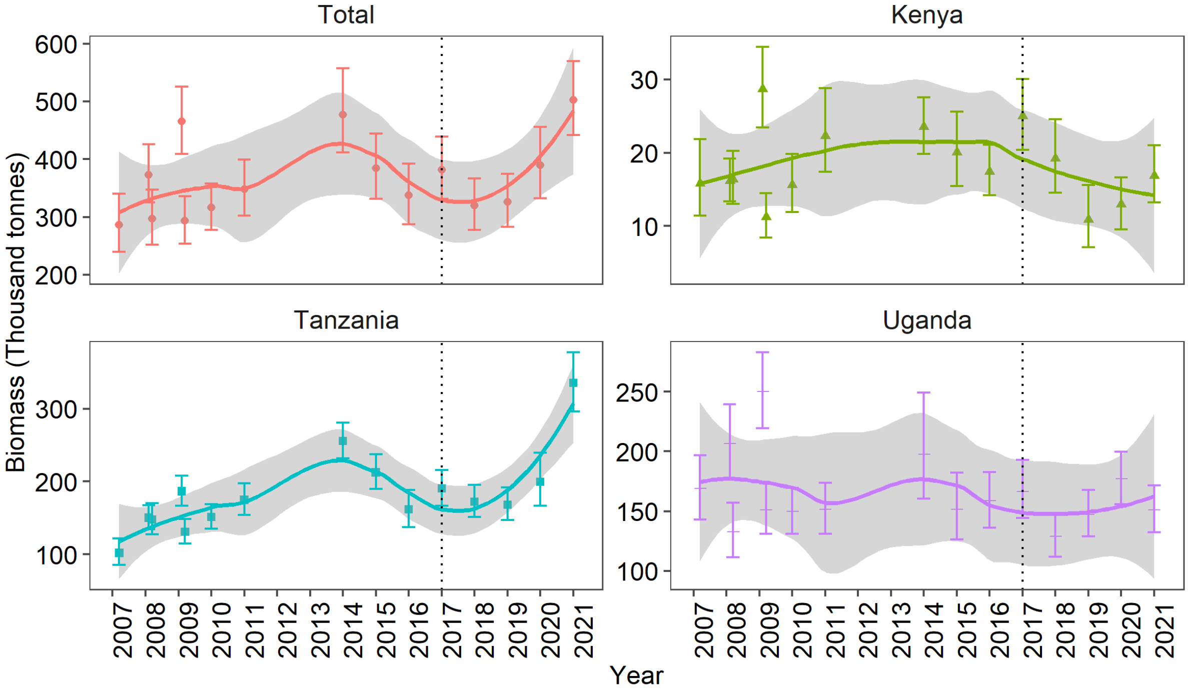

Figure 4. Temporal trends of Nile perch biomass trends in three countries sharing Lake Victoria from 2007 to 2021.

In Tanzania, the progression of Nile perch biomass followed the overall trend, however in Uganda, the trajectory has remained flat in the considered period. In Kenya, however, the species' biomass has steadily dropped since 2016.

2.1.3 Size structure

The length frequency distribution of Nile perch above 10 cm total length (TL) is shown in Figures 5 & 6. Nile perch in the lake (in terms of numbers) continued, as expected, to be dominated by small-sized individuals less than 50 cm TL (the minimum recommended harvestable size).

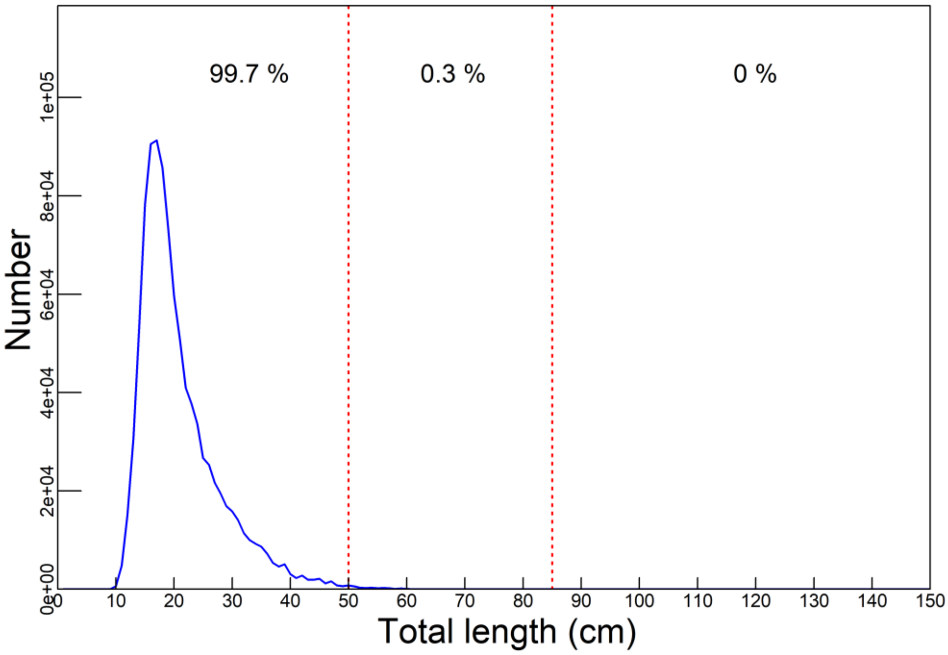

Figure 5. Length frequency distribution of Nile perch determined from acoustic single target detections during the October-September 2021 survey.

2.1.4 Response of Nile perch stock to management interventions

Overall, we found no evident association between enforcement and stock biomass in Uganda or Kenya, and the rise seen in Tanzania was not statistically significant. These findings go counter to the purpose of strict enforcement. Similarly, the enforcement had minimal influence on Nile perch's overall size structure. These data suggest that strict enforcement may not achieve short-term biomass-related fishing objectives or increase the average size of caught fish. Nonetheless, the data are not definitive since Nile perch is a long-lived species and the influence of enforcement may be seen in the long term. Age information is needed to better understand how such stocks may be managed, which is presently lacking in Lake Victoria stock assessments. Understanding the age structure of Nile perch and other stocks, for example, may provide information about their current status as well as their prior history. This, in turn, will help determine spawning and recruitment ages, allowing management to put measures in place to reduce recruitment overfishing (Ono et al., 2015).

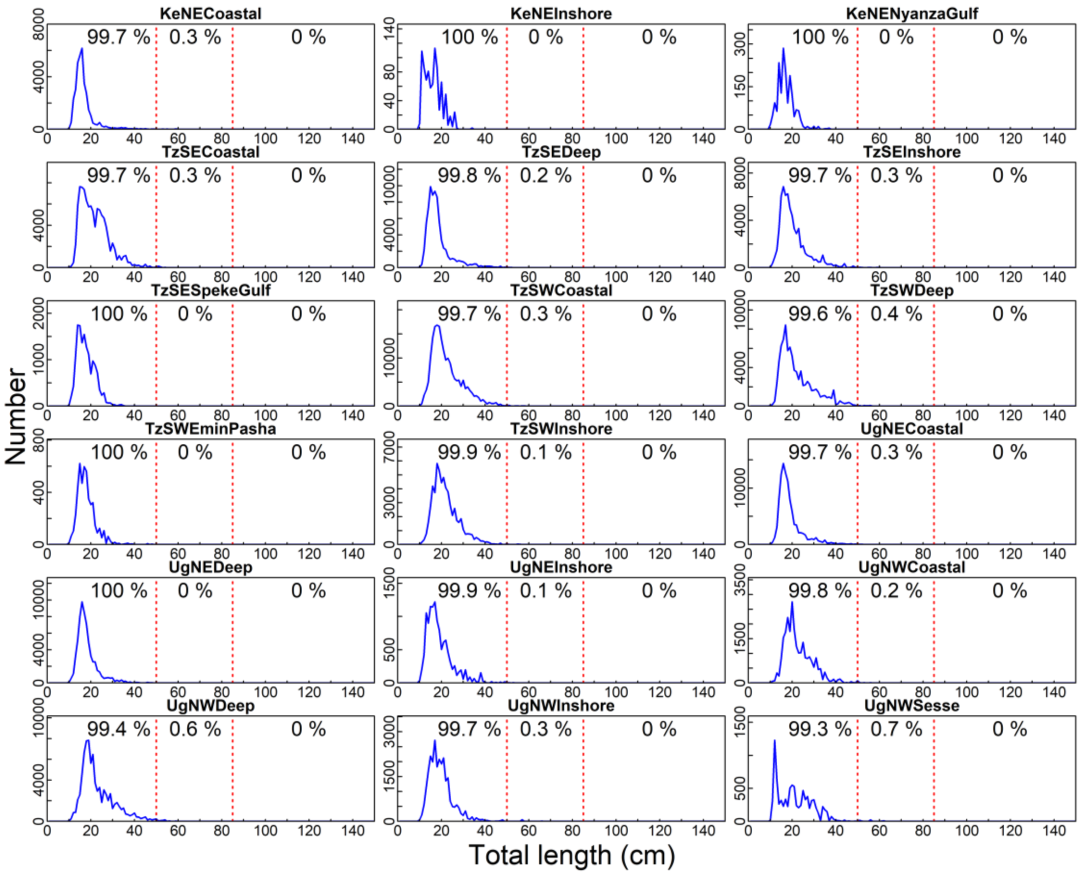

Figure 6. Length frequency distribution of Nile perch determined from acoustic single target detections in the various strata in Lake Victoria during the October-September 2021 survey.

The goal of strict enforcement in Uganda and Tanzania was to increase the size of commercial fisheries' stocks. Nile perch stocks were declining, according to Kayanda et al. (2017). This decrease has been attributed to increased fishing effort (LVFO, 2017). However, in this study, the total biomass of the considered fish stocks showed no significant changes in trends. The most recent catch records, on the other hand, show that landings of most fish categories increased from 2015 levels. In 2021, Nile perch contributed 221,640.0 tonnes to total catches, up from 165,083.4 tonnes in 2015 (LVFO, 2022). The insensitivity of biomass to enforcement indicates that either the prohibited gear has no significant impact on stock biomass or that the measures did not eliminate them, as evidenced by their presence in significant quantities during the most recent Frame survey (LVFO, 2021).

2.2 *Dagaa*

2.2.1 Standing stock of *Dagaa*

Table 4 shows the estimated densities and biomass of *Dagaa* in various regions of the lake. The estimated average standing stock for the whole lake was 927,688 tonnes, with a 95% confidence interval (CI) of [763,564, 1,114,936] representing 33% of the total fish biomass. This was a 7% decrease in biomass compared to the previous year's estimate (2020), when the standing stock was 1,000,215 tonnes, 95% CI [830,265, 1,186,822]. Estimated biomass varied by country, with Tanzania and Kenya showing biomass increases of 19% and 7%, respectively, compared to the estimated biomass in 2020. In contrast, the estimated *Dagaa* biomass in Uganda decreased by 37% when compared to *Dagaa* 2020 biomass. The greatest Dagaa densities were observed in Speke Gulf in 2021, with 28.6 tonnes km^{-2}, 95% CI [21.3, 37.4], followed by the Kenya North East Coastal region, with 27.0 tonnes km^{-2}, 95% CI [23.2, 31.0]. *Dagaa* densities were similarly high (> 20 tonnes km-2) in Tanzania's South East Deep and Inshore. The Uganda North West Coastal and Emin Pasha Gulf, on the other hand, exhibited the lowest species' densities (i.e. 2.0 tonnes km^{-2}, 95% CI [2.0, 3.7] and 4.0 tonnes km^{-2}, 95% CI [3.0, 5.1] respectively). *Dagaa* densities were generally greatest in coastal and deep regions of the lake (Figure 7).

2.2.2 Temporal trends of *Dagaa* biomass

From 2007 until 2015, the *Dagaa* biomass did not show any discernible trend until 2016, when it dropped by almost half, from 1,146,300 tonnes, 95%CI [954,327, 1,358,006] in 2015 to 596,897 tonnes, 95% CI [498,388, 703,203] in 2016. During that time period, the *Dagaa* biomass did not change significantly (Figure 8). After then, the biomass amount on *Dagaa* continuously increased, reaching its highest point in 2020 at 1,000,215 tonnes, 95% CI [830,265, 1,186,822]. The quantity of biomass fell to 927,688 tonnes in 2021, with a 95% CI of [763,564,1,114,936]. There has been little change in the *Dagaa* biomass's long-term trend, although there have been significant oscillations. Despite increased fishing effort and catch, the biomass of *Dagaa* has not changed significantly. This could be due to the species' high turnover rates, which indicate a high level of resistance to overfishing (Nikolsky, 1969), or it could be due to environmental factors..

Table 4. Density and biomass estimate of *Dagaa* in Lake Victoria by country and stratum

Region	Area	2020						2021					
		Densities (t/km2)			Biomass (tons)			Densities (t/km2)			Biomass (tons)		
Tanzania													
		Mean	**Low**	**Upper**	**Mean**	**Low**	**Upper**	**Mean**	**Low**	**Upper**	**Mean**	**Low**	**Upper**
TzSECoastal	**5786**	**16.9**	**13.6**	**20.6**	**98,009**	**78,708**	**119,121**	**19.9**	**16.6**	**23.3**	**115,019**	**96,237**	**134,721**
TzSEDeep	6166	5.7	4.9	6.5	35,062	30,341	40,067	24.6	20.3	29.5	151,389	125,467	181,681
TzSEInshore	2003	16.3	14.3	18.5	32,743	28,613	37,036	21.7	18.2	25.5	43,448	36,425	51,019
TzSESpekeGulf	2909	14.5	11.7	17.4	42,054	34,016	50,591	28.6	21.3	37.4	83,102	61,924	108,748
TzSWCoastal	6601	14.7	12.6	17.1	97,027	83,327	112,801	10.0	8.9	11.3	66,184	58,827	74,517
TzSWDeep	6251	20.4	16.2	25.1	127,455	101,052	156,922	8.6	7.4	9.8	53,638	46,478	61,329
TzSWEminPasha	2022	6.5	4.9	8.3	13,065	9,894	16,707	4.0	3.0	5.1	8,149	6,139	10,394
TzSWInshore	3181	7.4	6.2	8.8	23,528	19,604	27,837	11.4	9.5	13.6	36,383	30,259	43,326
Subtotal					**468,943**	**385,555**	**561,081**				**557,313**	**461,756**	**665,736**
Uganda													
UgNECoastal	2704	21.2	18.5	24.1	57,398	49,894	65,289	15.0	13.1	17.1	40,499	35,343	46,347
UgNEDeep	4724	33.0	27.8	38.6	156,005	131,456	182,527	11.2	10.1	12.2	52,798	47,926	57,682
UgNEInshore	3966	9.2	8.1	10.5	36,666	31,950	41,784	10.3	8.3	12.4	40,727	33,078	49,124
UgNWCoastal	4865	4.3	3.4	5.3	20,738	16,388	25,582	2.7	2.0	3.7	13,308	9,520	18,045
UgNWDeep	6226	13.9	11.5	16.4	86,549	71,848	102,289	8.7	7.3	10.2	53,900	45,240	63,214
UgNWInshore	3966	12.3	10.6	14.1	48,722	42,173	55,854	12.7	11.0	14.5	50,389	43,723	57,320
UgNWSesse	2494	19.3	16.3	22.6	48,208	40,565	56,344	14.4	8.7	22.3	36,035	21,745	55,723
Subtotal					**454,285**	**384,274**	**529,670**				**287,656**	**236,575**	**347,455**
Kenya													
KeNECoastal	1082	40.7	34.4	47.3	44,058	37,227	51,227	27.0	23.2	31.0	29,210	25,070	33,533
KeNEInshore	1763	14.1	9.7	19.6	24,774	17,053	34,617	18.5	14.0	23.5	32,671	24,725	41,350
KeNENyanzaGulf	1335	6.1	4.6	7.7	8,155	6,156	10,227	15.6	11.6	20.1	20,839	15,438	26,862
Subtotal					**76,987**	**60,436**	**96,071**				**82,719**	**65,232**	**101,745**
Total					**1,000,215**	**830,265**	**1,186,822**				**927,688**	**763,564**	**1,114,936**

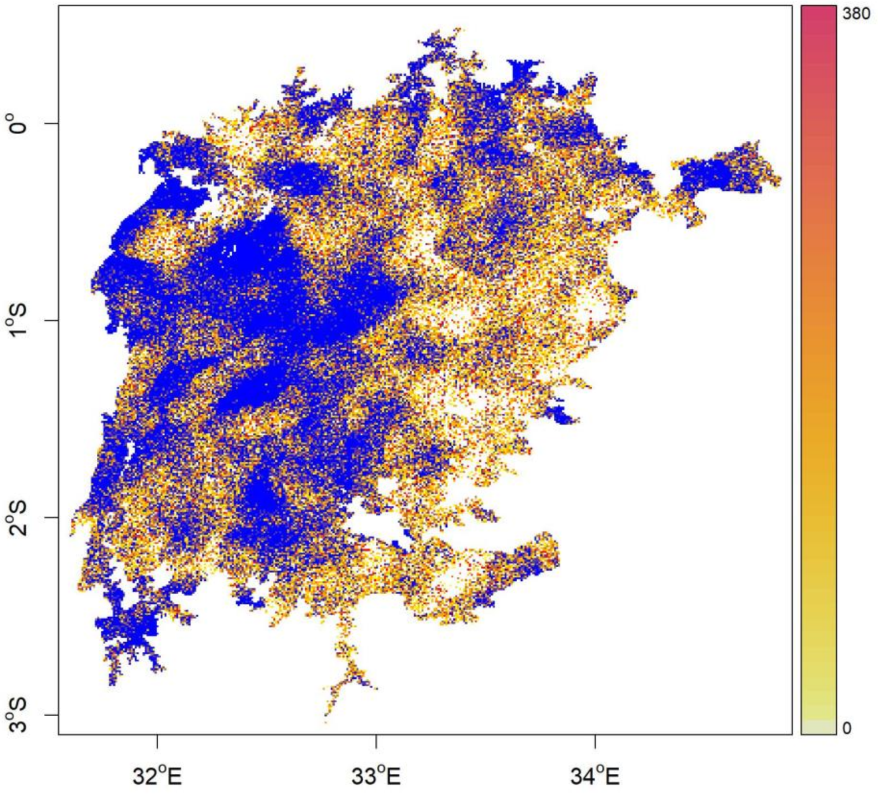

Figure 7. Spatial distribution of *Dagaa* in Lake Victoria during the 2021 October-November hydro-acoustic survey.

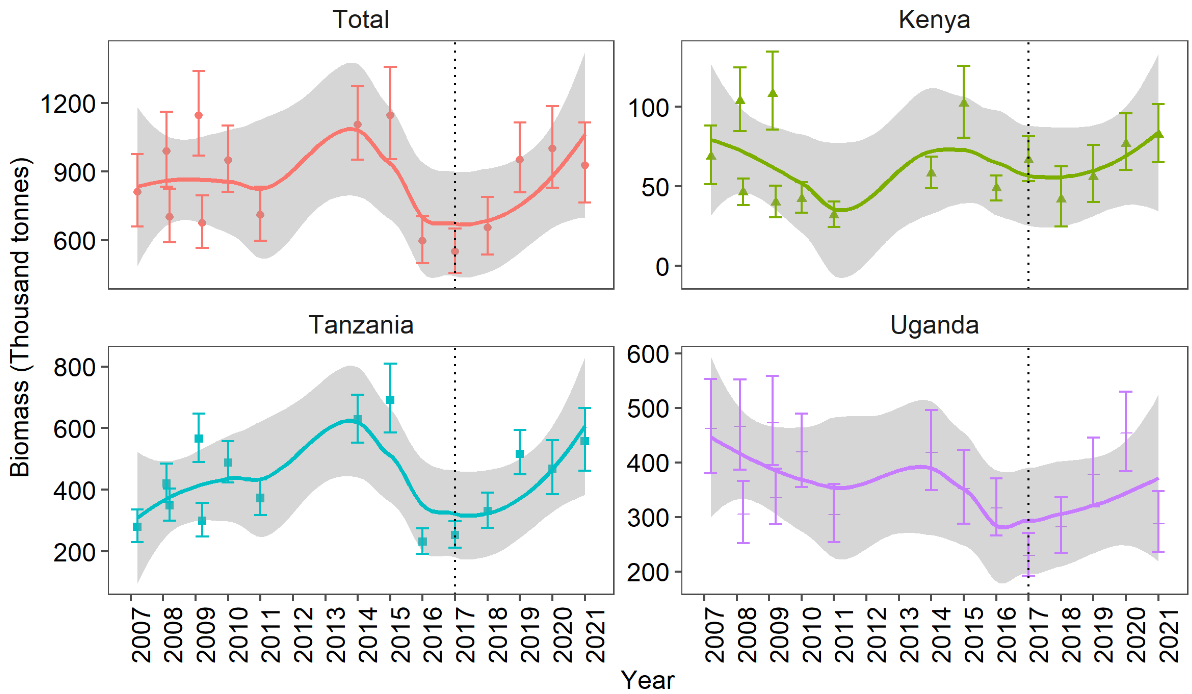

Figure 8 .Temporal trends of *Dagaa* biomass trends in three countries sharing Lake Victoria from 2007 to 2021.

2.3 Haplochromines and others

2.3.1 Standing stock of Haplochromines and others

The estimated densities and biomass of haplochromines and other species in different lake areas are shown in Table 5. The estimated average biomass for the whole lake was 600,942 tonnes, 95% CI [517,028, 700,840], representing roughly 21% of the total biomass. This forecast assumes an 8% increase in lakeside Haplochromine biomass from the last study in 2020. Tanzania and Kenya saw biomass increases of 24% and 12%, respectively, as compared to the 2020 study. In Uganda, however, the species' biomass decreased by 15% over the same time period. The greatest haplochromine concentrations were found in Tanzania's South East area, followed by the Speke Gulf (i.e. 17.6 tonnes km^{-2}, 95% CI [15.8, 19.6] and 15.5 tonnes km^{-2}, 95% CI [13.3 17.8]). Kenya North East Inshore, Uganda North East Inshore, Sesse Islands, and Tanzania South East all had concentrations more than 10 tonnes per square kilometer. Uganda had the lowest concentrations of the species (5 tonnes km^{-2}) (i.e, all the Deep and North West Coastal areas of the lake). On a spatial scale, there was no discernible pattern of the species' distribution (Figure 9).

2.3.2 Temporal trends of Haplochromines and others biomass

The "Haplochromines and Others" category showed a minor but non-significant rise in biomass over the whole lake over time (Figure 10). The biomass of the group grew from 416,561 tonnes (95% CI [347,733, 496,564] in 2007 to 532,628 tonnes (95% CI [466,175, 608,498] in 2014. The group's biomass then began to decline in 2017, with the lowest biomass of 374,133 tonnes, 95% CI [312,664, 445,266] in the study period reported in 2019, before rebounding in succeeding years. This group performs an essential ecological function (it provides the majority of the food for Nile perch) and is therefore a critical driver of the development of other fish (Nyamweya et al., 2016). Despite their vital ecological significance, fishermen are increasingly targeting haplochromines, as indicated by their rising contribution to fish landings (LVFO, 2022). Fishing for haplochromines should be prohibited for the sustainability of economically significant Nile perch, as demonstrated by Nyamweya et al. (2017), who demonstrated that such an approach will give optimum ecological and socioeconomic returns.

Table 5. Estimated standing stock of Haplochromine cichlids and other unidentified fish species in Lake Victoria by country and by strata during the October-November 2021 survey

Region	Area	2020						2021					
		Densities (t/km2)			Biomass (tons)			Densities (t/km2)			Biomass (tons)		
Tanzania													
		Mean	**Low**	**Upper**	**Mean**	**Low**	**Upper**	**Mean**	**Low**	**Upper**	**Mean**	**Low**	**Upper**
TzSECoastal	5786	10.9	8.0	14.9	63,302	46,073	86,141	17.6	15.8	19.6	102,045	91,369	113,535
TzSEDeep	6166	4.6	4.0	5.2	28,525	24,821	32,318	7.5	6.3	9.1	46,493	38,591	55,968
TzSEInshore	2003	11.3	8.5	14.9	22,687	16,966	29,798	10.6	9.1	12.3	21,267	18,259	24,684
TzSESpekeGulf	2909	8.4	7.1	9.9	24,333	20,535	28,737	15.5	13.3	17.8	44,976	38,807	51,818
TzSWCoastal	6601	8.5	7.3	9.8	55,989	48,229	64,928	9.9	9.0	10.8	65,285	59,709	71,190
TzSWDeep	6251	10.1	8.2	12.2	63,063	51,413	76,171	7.4	6.2	8.6	46,140	39,065	53,739
TzSWEminPasha	2022	5.8	4.7	7.0	11,689	9,566	14,124	5.5	4.8	6.3	11,114	9,710	12,639
TzSWInshore	3181	6.3	5.5	7.2	19,992	17,416	22,943	7.3	6.6	8.0	23,064	20,875	25,417
Subtotal					**289,580**	**235,018**	**355,158**				**360,384**	**316,385**	**408,990**
Uganda													
UgNECoastal	2704	3.2	2.8	3.6	8,655	7,621	9,759	8.5	7.8	9.3	22,947	20,962	25,051
UgNEDeep	4724	2.6	2.3	2.8	12,171	10,921	13,455	4.1	3.7	4.6	19,428	17,475	21,687
UgNEInshore	3966	4.7	3.9	5.6	18,495	15,310	22,166	11.2	8.1	16.1	44,323	32,011	63,967
UgNWCoastal	4865	5.1	4.5	5.7	24,597	21,781	27,614	4.6	3.9	5.3	22,198	18,989	25,939
UgNWDeep	6226	5.1	4.6	5.7	31,924	28,772	35,225	4.9	4.5	5.4	30,447	27,843	33,361
UgNWInshore	3966	23.1	18.2	28.7	91,787	72,218	113,702	7.2	6.0	8.8	28,488	23,721	34,953
UgNWSesse	2494	16.5	11.4	22.3	41,202	28,319	55,549	11.0	8.4	13.9	27,510	20,839	34,787
Subtotal					**228,831**	**184,942**	**277,469**				**195,342**	**161,840**	**239,746**
Kenya													
KeNECoastal	1082	7.2	5.7	8.8	7,772	6,197	9,512	8.9	7.2	10.8	9,623	7,782	11,723
KeNEInshore	1763	14.4	10.8	18.3	25,354	19,028	32,261	13.2	11.6	14.8	23,314	20,503	26,166
KeNENyanzaGulf	1335	2.9	2.6	3.1	3,814	3,490	4,156	9.2	7.9	10.6	12,280	10,518	14,215
Subtotal					**36,940**	**28,715**	**45,929**				**45,216**	**38,803**	**52,104**
Total					**555,350**	**448,676**	**678,557**				**600,942**	**517,028**	**700,840**

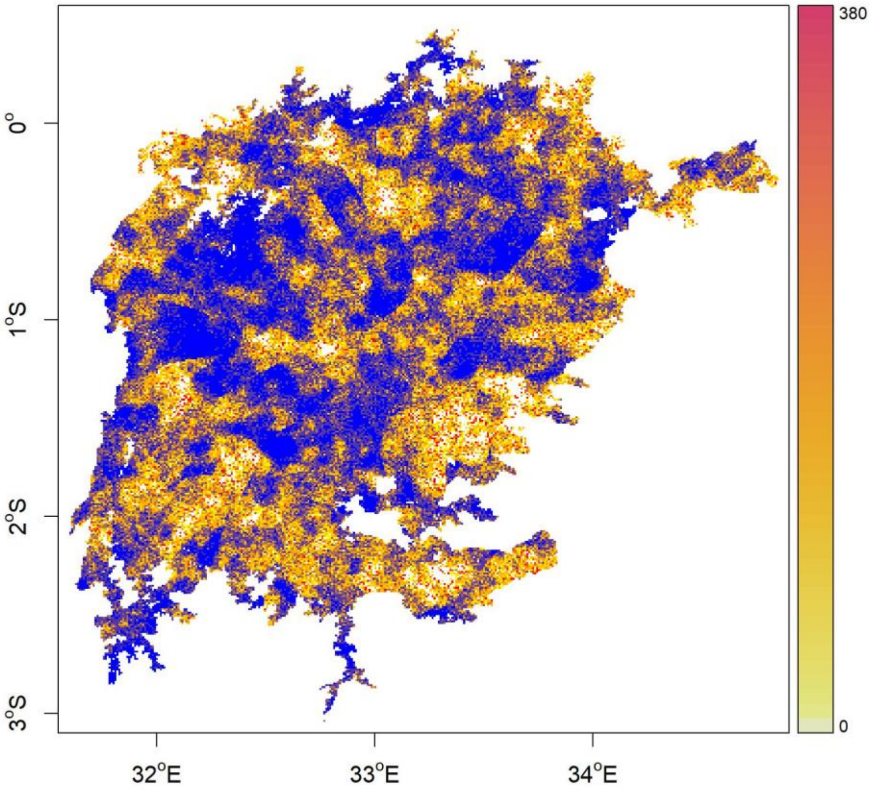

Figure 9. Spatial distribution of haplochromines and other fish in Lake Victoria during the 2021 October-November hydro-acoustic survey.

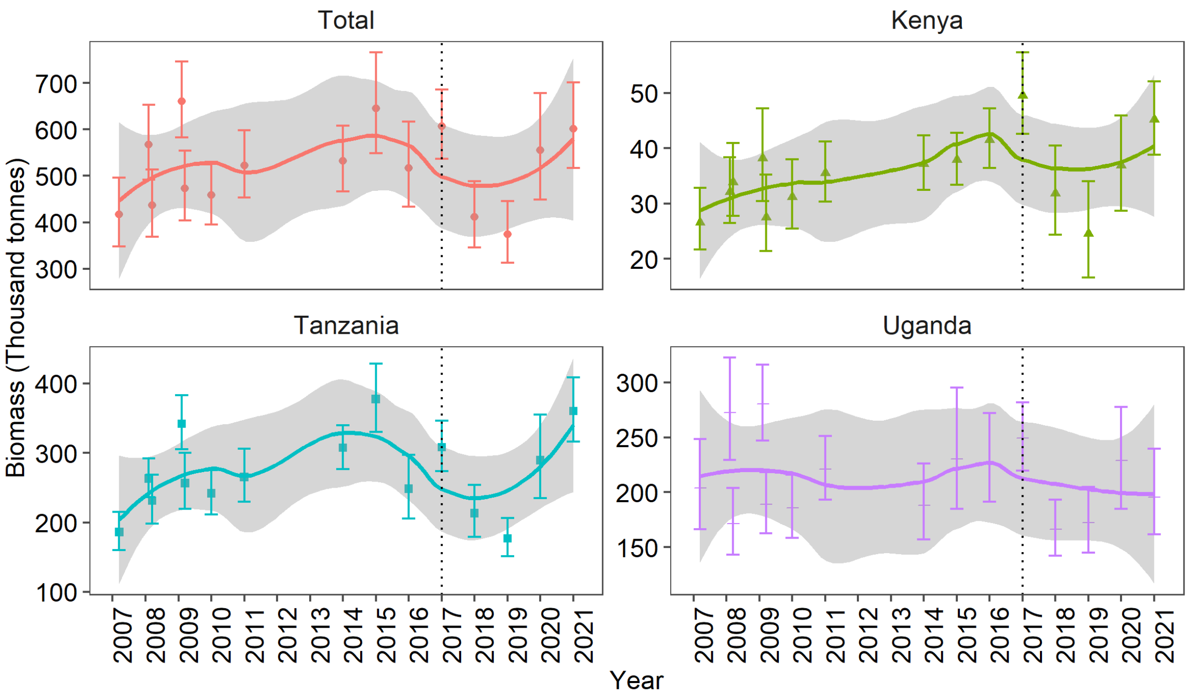

Figure 10. Temporal trends of Haplochromines and other fish biomass trends in three countries sharing Lake Victoria from 2007 to 2021.

2.4 *Caridina*

2.4.1 Standing stock of *Caridina*

The estimated densities and biomass of *Caridina* in various regions and depth strata of the lake are presented in Table 6. Caridina accounted for almost 28 percent of the lake's total biomass, with a mean biomass of 788,426 tonnes, 95% CI [484,508, 1,181,707]. The reported biomass for 2021 was 24% lower than the 1,039,065 tonnes, 95% CI [704,520, 1,441,115] recorded in the survey of 2020. Whereas the biomass dropped in Tanzania and Uganda by 19% and 35%, it increased in Kenya by 17%. The highest densities for the species were recorded in the North East Coastal region spanning Uganda and Kenya. Caridina were much lower in all the Deep and most of the Coastal strata but generally lacked a clear spatial distribution pattern (Figure 11).

2.4.2 Temporal trends of *Caridina* biomass

The species' biomass increased steadily from 2027 before plateauing in the period after 2014. Densities of *Caridina* were comparable in Tanzania and Uganda, but significantly higher in Kenya. The lowest biomass of 244,160 tonnes, 95% CI [87,720, 488,449] recorded in 2010 and the greatest (922,424 tonnes, 95% CI [549,588, 1,377,338]) recorded in 2014 (Figure 12).

Table 6. Density and biomass estimate of *Caridina nilotica* in Lake Victoria by country and stratum

Region	**Area**	**2020**						**2021**					
		Densities (t/km2)			**Biomass (tons)**			**Densities (t/km2)**			**Biomass (tons)**		
Tanzania													
		Mean	**Low**	**Upper**	**Mean**	**Low**	**Upper**	**Mean**	**Low**	**Upper**	**Mean**	**Low**	**Upper**
TzSECoastal	5786	14.6	8.9	22.4	84,687	51,572	129,676	10.3	7.8	13.0	59,552	45,258	75,268
TzSEDeep	6166	14.0	10.7	17.6	86,125	66,213	108,551	6.3	4.9	7.8	38,742	30,024	48,138
TzSEInshore	2003	7.5	5.0	11.1	15,029	9,915	22,165	13.1	8.8	18.1	26,256	17,630	36,185
TzSESpekeGulf	2909	15.6	4.6	30.1	45,442	13,352	87,451	11.7	5.3	19.0	33,954	15,362	55,158
TzSWCoastal	6601	17.9	14.1	22.1	117,946	93,371	146,169	16.2	11.2	22.1	106,705	73,624	146,209
TzSWDeep	6251	19.7	14.2	25.8	122,923	88,996	161,372	15.6	10.6	21.2	97,400	66,149	132,221
TzSWEminPasha	2022	10.9	4.3	18.7	22,054	8,714	37,886	11.2	4.6	19.3	22,652	9,352	39,047
TzSWInshore	3181	16.5	12.3	21.4	52,602	39,160	68,177	17.8	10.1	29.1	56,704	32,151	92,587
Subtotal					**546,808**	**371,294**	**761,448**				**441,967**	**289,550**	**624,811**
Uganda													
UgNECoastal	2704	6.9	5.0	9.3	18,593	13,562	25,015	20.5	14.4	27.3	55,314	39,019	73,930
UgNEDeep	4724	8.4	7.2	9.6	39,460	34,041	45,443	6.1	4.5	7.9	28,786	21,284	37,548
UgNEInshore	3966	9.0	6.0	12.5	35,546	23,614	49,432	8.7	4.2	14.2	34,596	16,557	56,238
UgNWCoastal	4865	17.4	11.7	23.8	84,873	56,772	115,589	8.8	5.3	12.9	42,708	25,615	62,992
UgNWDeep	6226	10.8	6.4	16.2	67,150	39,866	100,707	9.7	7.0	12.8	60,401	43,388	79,871
UgNWInshore	3966	41.6	29.9	55.2	165,114	118,452	218,821	10.5	6.9	15.0	41,836	27,240	59,477
UgNWSesse	2494	12.7	6.1	21.0	31,636	15,221	52,392	9.7	5.3	15.4	24,254	13,109	38,373
Subtotal					**442,371**	**301,528**	**607,399**				**287,895**	**186,213**	**408,429**
Kenya													
KeNECoastal	1082	11.6	7.7	16.9	12,554	8,331	18,259	7.6	4.6	11.3	8,257	5,014	12,207
KeNEInshore	1763	8.2	3.2	14.5	14,468	5,590	25,539	20.1	0.3	59.4	35,464	578	104,757
KeNENyanzaGulf	1335	17.1	13.3	21.3	22,865	17,777	28,469	11.1	2.4	23.6	14,843	3,153	31,503
Subtotal					**49,887**	**31,698**	**72,268**				**58,563**	**8,746**	**148,466**
Total					**1,039,065**	**704,520**	**1,441,115**				**788,426**	**484,508**	**1,181,707**

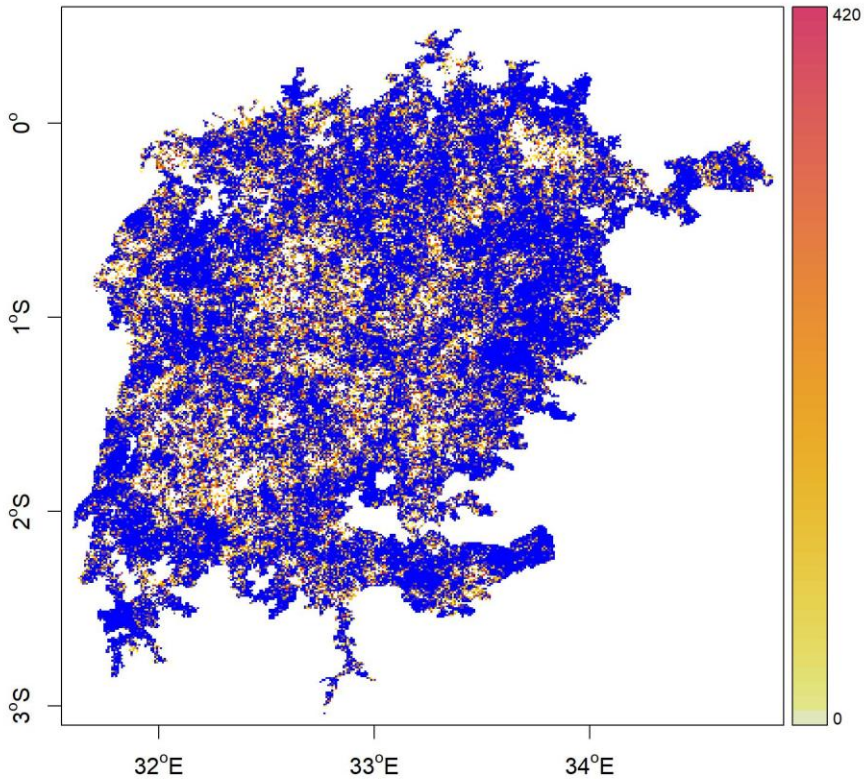

Figure 11. Spatial distribution of *Caridina nilotica* in Lake Victoria during the 2021 October-November hydro-acoustic survey.

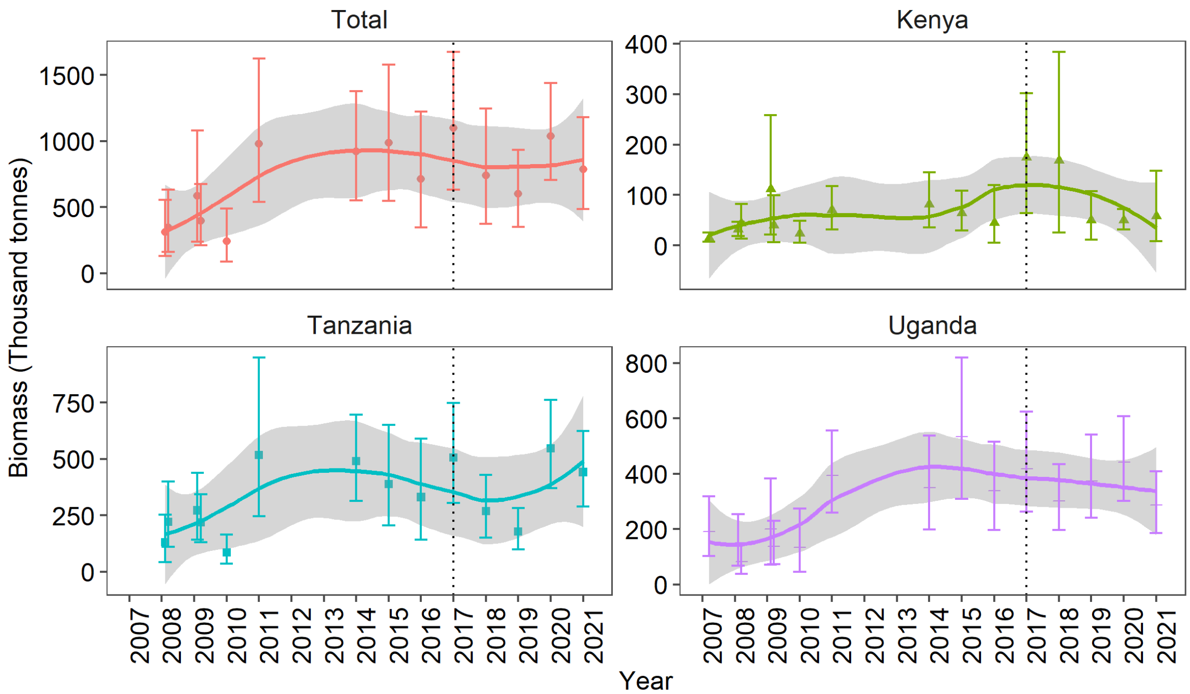

Figure 12. Temporal trends of *Caridina nilotica* biomass trends in three countries sharing Lake Victoria from 2007 to 2021.

2.5 Relative proportion of biomass of fish groups.

Dagaa accounted for 33% of the biomass in the 2021 survey, followed by *Caridina* (28%), and the "Haplochromines" (21%). Only 18% of the estimated biomass was accounted for by Nile perch (Figure 13). Because Haplochromines and *Caridina* are the principal food prey items for large and young Nile perch, their abundance influences the latter's biomass. From 2007 to 2021, the proportions of Nile perch and Haplochromines remained very steady (Figure 14). The proportions of *Dagaa* and *Caridina*, on the other hand, fluctuated over the study period, indicating that the two groups' abundance might be influenced by environmental factors even on short time periods.

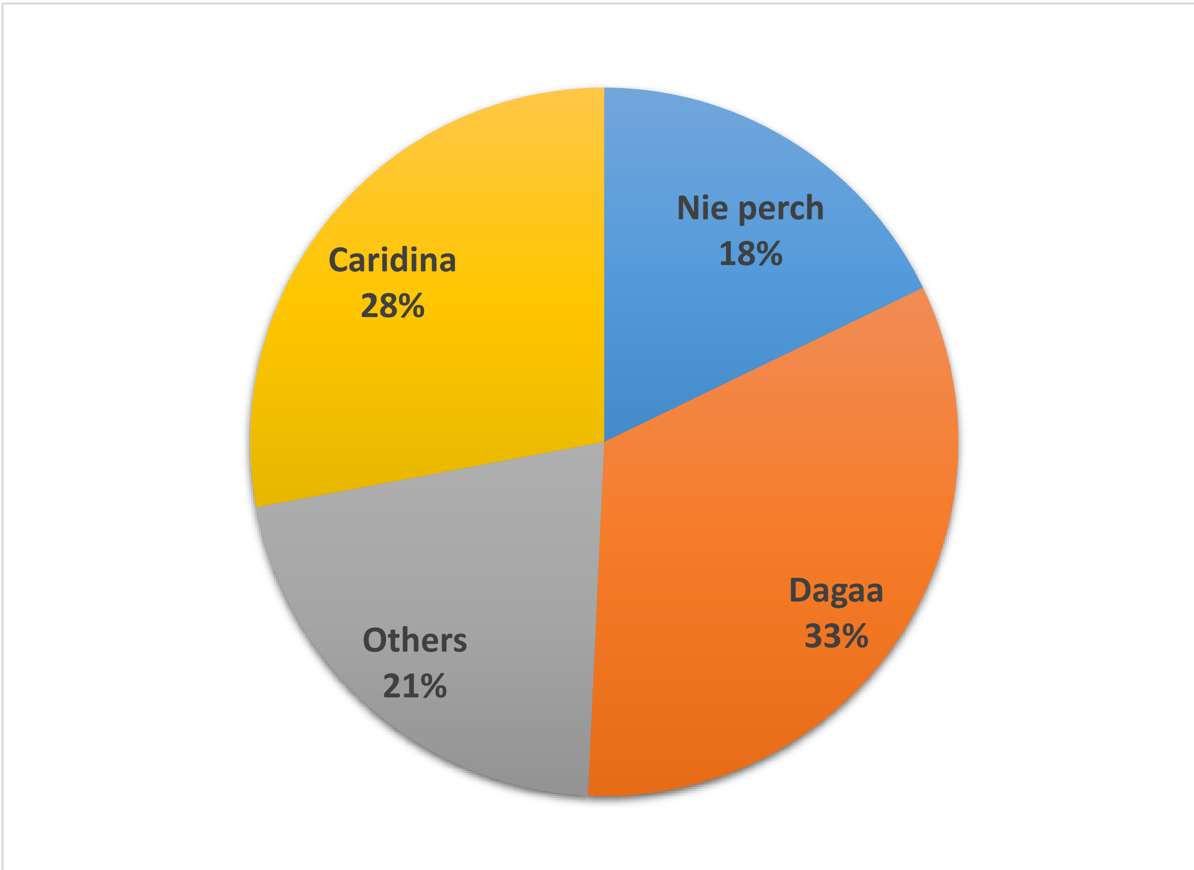

Figure 13. Proportion of biomass of fish groups estimated during the 2021 Lake Victoria Hydroacoustic survey.

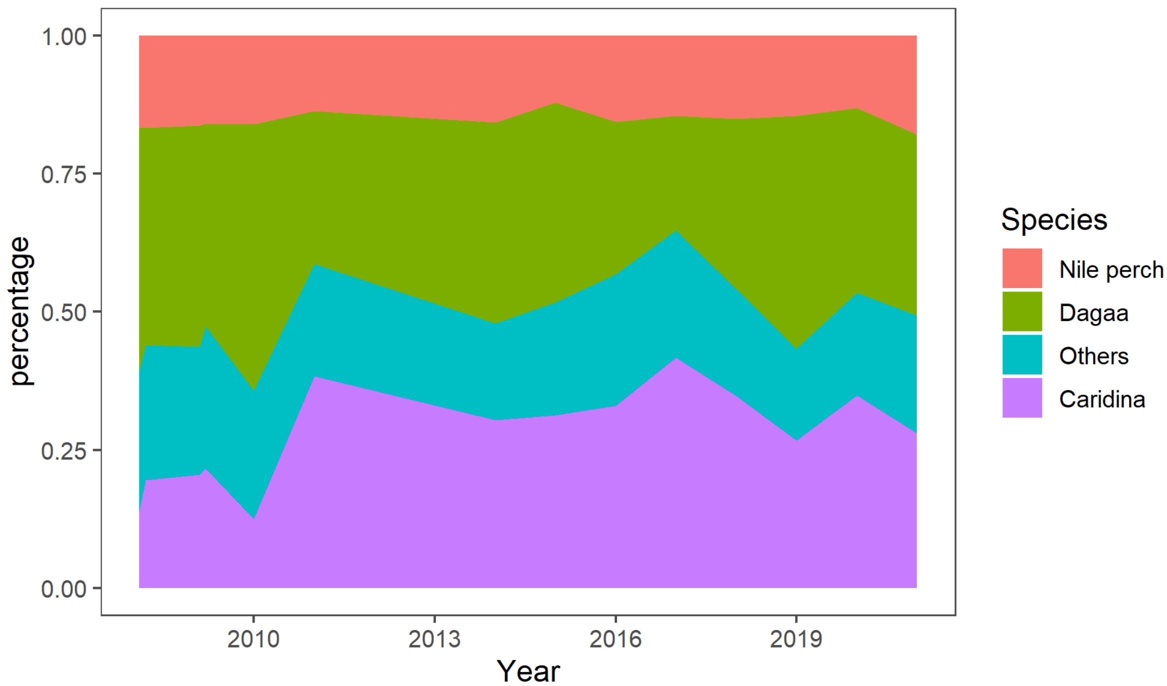

Figure 14. Temporal trends of relative proportions of fish biomass groups in Lake Victoria

2.6 Catch per Unit Effort as an index of Relative abundance

The relative abundance stated as Catch per Unit Effort (CPUE) for seven consecutive years expressed as Kg/haul has been shown in the Table 7 for the Nile perch, Haplochromines, *Dagaa* and Other fish species combined as others. Although CPEU for the Nile perch shows to fluctuate up and down since 2015, but for the consecutive three year since 2019 shows to decline progressively, from 116.36±26.69 Kg/Haul in 2019 to 58.13±9.83. This is inversely proportional to Haplochromine which are preferable feeds for large Nile perch. Haplochromine were observed to increase progressively from 2.43±0.83 in 2019 to 16.71±7.61 in 2021. However previously from 2015 to 2017 were observed to decline. The observed data from 2017 to 2020 does not shows any significant different as food to support Nile perch. Dagaa catches also decreases, however dagaa catches from the trawl nets cannot shows proper picture of what we have in the stock. The rest fish species combined as others, observed to be constant since 2015 survey although there was a significant increase in 2017 survey to 7.58±2.07 Kg/haul. However, data from the current survey shows to decreases to 2.35±0.65 from7.58±2.07 Kg/haul, in 2017.

Table 7. Changes in CPUE (Kg/haul) (Kg ± SE) since 2015 to 2021

Period	**n**	**Nile perch**	**Haplochromines**	***Dagaa***	**Other sp**
Oct 2021	31	58.13±9.83	16.71±7.61	0.99±0.39	2.35±0.65
Oct 2020	24	85.67±21.71	3.39±1.35	0.23±0.11	2.71±1.10
Sep 2019	24	116.36±29.69	2.43±0.83	1.12±0.54	5.05±1.43
Sep 2018	25	79.88±21.40	7.81±2.32	0.73±0.37	5.52±1.42
Sep 2017	30	103.55±14.71	6.29±1.40	1.69±0.71	7.58±2.07
Sep 2016	24	42.16±6.72	16.78±3.94	4.77±1.66	1.95±0.62
Nov 2015	25	46.03±13.55	17.29±5.25	4.22±1.32	4.92±1.77

3 CONCLUSIONS AND RECOMMENDATIONS

The goal of this survey was to use acoustic techniques to assess the standing stock of main commercial fish species (Nile perch, Dagaa, haplochromines, and freshwater shrimp) in Lake Victoria. The study also used a standardized technique to reanalyse all of the data acquired by the EK60 split beam echosounders going back to 2007, allowing for direct comparisons of biomass estimates from different years. In the 2021 study, Dagaa accounted for 33% of the biomass, followed by Caridina (28%), and the "Haplochromines" (21%). Nile perch accounted for just 18% of the projected biomass. Trend analysis revealed interannual variability in biomass of the examined fish groups, but no significant changes in trends were observed. Furthermore, patterns in densities of the main fish groups following strict enforcement and a reduction in the number of illegal gears did not change significantly from past trends. This leads us to the conclusion that if the purpose of the fishery is to enhance fish biomass, investment in the application of fisheries regulations limiting the size and type of gear may not result in a significant increase in fish biomass. Furthermore, the same restrictions may not result in an increase in the harvested stock's individual fish size, notably for Nile perch. Selective fishing for larger fish, on the other hand, is likely to increase the risk of further narrowing the size structure of the harvested population, thus affecting future recruitment and production via fishing-induced evolution. Given the high cost of top-down enforcement (due to the large size of the lake and the number of fishers involved) and the large trade-off between maintaining a large stock size and the social cost associated with lost employment and livelihoods, it is unclear whether military-led enforcement will be sustained indefinitely. In any case, we think that enforcement should be directed by scientific evidence, and that functional co-management is more suited to achieving this paradigm change than the existing military-led enforcement.

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3.1 Appendix I: Detailed results from net bottom hauls

3.2 A1.3.1. Catch composition

Fish catch composition for November 2021 survey recorded twelve fish species through 31 net hauls compared to eleven and thirteen fish species in 24 hauls recorded during October-November 2020 and 2019 surveys respectively. The composition is equivalent to two less fish taxa compared to September 2018 survey. During the current survey, *Lates niloticus* with 72.21% dominated the catch by weight, followed by Haplochromines with 21.33%. The dominance of 72.21% for Nile perch in 2021 catches seems to be smaller compared to the catches of the last year two years but bigger than those of (2015), (2016) and (2018), while the composition for Haplochromine species in 2021 seems to be significantly higher compared to the catch composition for the last four years (2017-2020). This is an index of prey-predator's relationship where by Nile perch as predator seems to decline and give more room for Haplochromie to increase in catches. Haplochromine species which shows to improve from 23.00% (2015) to 25.5% (2016) then observed to decline to progressively to 1.95% (2019). The rest fish species insignificantly contributed the other portion of the composition as presented in (Figure 1a & 1b).

In the order of dominance, the species recorded were *Lates niloticus*, Haplochromines sp, *Rastrineobola argentea*, *Caridina nilotica*, *Oreochromis niloticus, Synodontis victoriae, Barbus profoundus, Bagrus dockmac, Clarius gariepinus, Synodontis afrofischeri.* Momyrus kanume, *Schilbe intermedius,* other fish species which are common and were found in the previous surveys were not encountered in this survey. These included, *Labeo victorianus Protopterus aethiopicus, Brycinus sadleri, Afromastercemblus frenatus, Brycinus* jacksonii, *Tilapia rendali,* and *Tilapia zillii.* These two organisms *Caridina nilotica*, and Molluscs were recorded because are ecologically very important as food for fish.

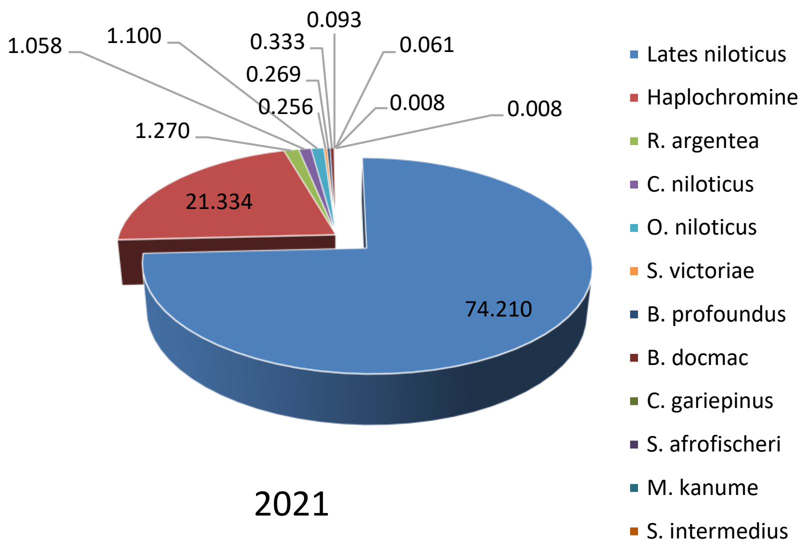

Figure A1. 1a: Catch composition for the 2021 survey

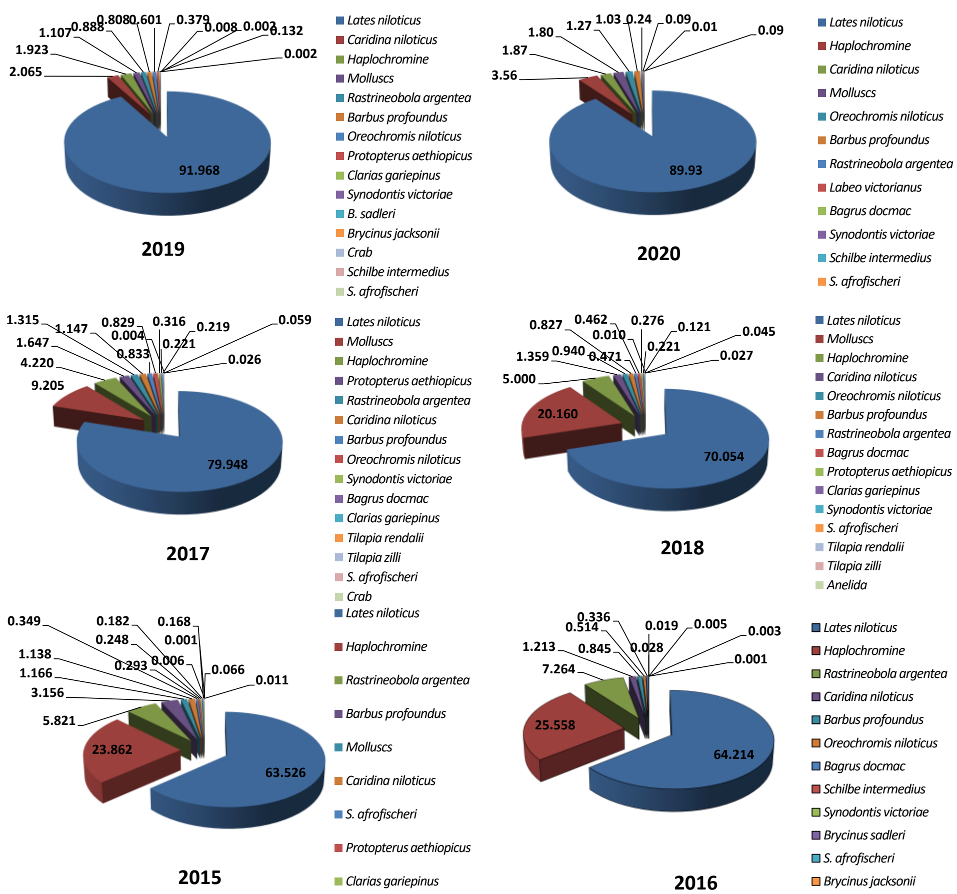

Figure A1. 15b: Catch composition for the survey period of 2015-2020

Table A1. 1: Changes in % catch composition by weight in Lake Victoria

Species	Nov 2015	Sep 2016	Sep 2017	Sep 2018	Sep 2019	Oct 2020	Oct 2021
Nile perch	64.27	64.210	87.08	83.85	93.12	89.93	74.21
Haplochromines	24.14	25.56	5.29	8.19	1.95	3.56	21.33
Dagaa	5.89	7.26	1.42	0.77	0.90	0.24	1.27
Others	1.16	0.36	3.22	2.14	0.65	4.48	3.19

AI.3.2. Catch per Unit Effort as an index of Relative abundance

The relative abundance stated as Catch per Unit Effort (CPUE) for seven consecutive years expressed as Kg/haul has been shown in the table 2 for the Nile perch, Haplochromines, Dagaa and Other fish species combined as others. Although CPEU for the Nile perch shows to fluctuate up and down since 2015, but for the consecutive three year since 2019 shows to decline progressively, from 116.36±26.69 Kg/Haul in 2019 to 58.13±9.83. This is inversely proportional to Haplochromine which are preferable feeds for large Nile perch. Haplochromine were observed to increase progressively from 2.43±0.83 in 2019 to 16.71±7.61 in 2021. However previously from 2015 to 2017 were observed to decline. The observed data from 2017 to 2020 does not shows any significant different as food to support Nile perch. Dagaa catches also decreases, however dagaa catches from the trawl nets cannot shows proper picture of what we have in the stock. The rest fish species combined as others, observed to be constant since 2015 survey although there was a significant increase in 2017 survey to 7.58±2.07 Kg/haul. However, data from the current survey shows to decreases to 2.35±0.65 from7.58±2.07 Kg/haul, in 2017. Table 2

Table A1. 2: Changes in CPUE (Kg/haul) (Kg ± SE) since 2015 to 2021

Period	n	Nile perch	Haplochromines	Dagaa	Other sp
Oct 2021	31	58.13±9.83	16.71±7.61	0.99±0.39	2.35±0.65
Oct 2020	24	85.67±21.71	3.39±1.35	0.23±0.11	2.71±1.10
Sep 2019	24	116.36±29.69	2.43±0.83	1.12±0.54	5.05±1.43

Sep 2018	25	79.88±21.40	7.81±2.32	0.73±0.37	5.52±1.42
Sep 2017	30	103.55±14.71	6.29±1.40	1.69±0.71	7.58±2.07
Sep 2016	24	42.16±6.72	16.78±3.94	4.77±1.66	1.95±0.62
Nov 2015	25	46.03±13.55	17.29±5.25	4.22±1.32	4.92±1.77

3.3 A1.3.3 Catch per unit effort of Nile perch in different quadrants

Catch per unit effort (CPEU) of all the commercial species in different quadrants behave differently. CPUE for five successive years expressed as Kg/haul in both quadrants is shown in Table 3. The Overall CPEU for Nile perch which observed to increases from 79.88±21.40 Kg/haul (2018) to 116.36±29.69Kg/haul (2019), this time decreased significantly by 50.04% from 2019 to 58.13±9.83Kg/haul (2021), and 32.15% from 2020 results (Table 3). Moreover, Nile perch shows to fluctuate in all the quadrant strata. The highest catch rate was observed in SW quadrant strata with 78.23±27.34 Kg/haul, however this value dropped by 46.91% from 147.35±35 Kg/haul (2020). Except for NE where there are significant increases in CPUE from 15.09±7.24 (2020) to 29.14±16.82 (2021) equivalent to 93.37% but in all the quadrant the catch rate dropped significantly. The highest drop of CPUE in quadrants equivalent to 46.91% were observed in South West quadrants, however the biggest drop equivalent to 82%, were observed in 2018 in the same south west quadrant. The declining in catch rate is shown in Table 3. Haplochromines CPUE which shows to decreases tremendously from 7.81±2.32 Kg/haul in 2018 to 2.43±0.83 Kg/haul in 2019 increases tremendous to 16.71±7.61 Kg/haul in overall catch rates, this is a good sign for the survival of Nile perch. However, Haplochromine CPUE behave in inversely correlation with Nile perch. In all the quadrants, Haplochromine Increases, the highest increase is in the NW where by it raised tremendously from 0.42±0.18 Kg/haul (2020) to 34.18±27.83 Kg/haul in 2022. Dagaa catches from the last two surveys do not differ much except for the NW where the drop is higher from 5.39±3.33 Kg/haul in 2017 to 1.06±0.60 Kg/haul in 2019 then decreased slightly to 0.54±0.18 Kg/haul for 2021 survey. The Catch rates for other fish species combined as others shows to decreases progressively for the overall catch rates from 7.58±2.07 Kg/haul in 2017 to 2.35±0.65 Kg/haul in 2021, however, generally the same trend of declining observed in all other quadrant.

Table A1 3: Changes in CPUE (Kg/haul) (Kg ± SE) of major fish species based on Quadrants

Quadrant	YEAR	Nile perch	Haplochromine	Dagaa	Other sp
Overall	2021	58.13±9.83 (-32.15%)	16.71±7.61	0.99±0.39	2.35±0.65
	2020	85.67±21.71	3.39±1.35	0.23±0.11	2.71±1.10
	2019	116.36±29.69	2.43±0.83	1.12±0.54	5.05±1.43
	2018	79.88±21.40	7.81±2.32	0.73±0.37	5.52±1.42
	2017	103.55±14.71	6.29±1.40	1.69±0.71	7.58±2.07
SW	2021	78.23±27.34 (-46.91%)	20.63±8.49	1.37±0.99	4.11±1.82
	2020	147.35±68.70	2.03±1.14		0.56±0.56
	2019	45.26±26.91	3.55±2.29	1.53±1.29	8.39±4.05
	2018	24.197±5.35	8.12±3.13	1.31±1.17	9.80±3.23
	2017	134.50±26.97	4.82±1.99	1.55±1.33	8.94±4.72
NW	2021	55.55±11.34 (-35.93%)	34.18±27.83	0.54±0.18	0.41±0.30
	2020	86.70±30.67	0.42±0.18		1.93±1.90
	2019	181.36±102.44	3.04±2.42	1.06±0.60	0.75±0.47
	2018	153.83±55.89	4.75±2.57	0.01±0.01	2.97±1.24
	2017	101.62±28.17	4.16±1.37	5.39±3.33	9.62±5.05
NE	2021	29.14±16.82 (+93.37%)	4.75±4.43	1.82±1.76	3.75±1.12
	2020	15.09±7.24	1.86±0.68		3.36±0.48

	2019	93.46±33.41	1.09±0.31	1.77±1.75	7.59±3.59
	2018	38.86±16.62	6.43±4.76	0.92±0.55	3.88±2.76
	2017	59.67±19.99	6.45±2.48	0.71±0.59	4.19±2.03
SE	2021	56.44±14.58 (-46.49%)	3.91±1.54	0.56±0.29	1.55±0.85
	2020	105.48±35.35	9.00±4.79		1.70±0.41
	2019	145.37±41.95	2.05±0.92	0.14±0.09	3.45±0.72
	2018	103.52±55.33	13.30±9.01	0.71±0.59	5.07±3.83
	2017	132.23±38.75	9.26±4.36	0.63±0.23	9.43±5.85

3.4 A1.3.3.2. Length frequency distribution of Nile perch (Lates niloticus)

The size structure of Nile perch caught during the October-November 2021 surveys ranged from 1cm TL to 130 cm TL, compared to 1cm TL to 150 cm TL for 2020 survey, while total mean length shows slightly increase from 18.46 cm TL (2020) to 20.86 cm TL (2021). The overall mean size for Nile perch still low compared to historical one of 25.17 cm TL recorded in the year 2018. The mean length for Nile perch observed to increases by 58.3% from 15.9 cm TL in 2017 to 25.17cm TL in 2018 before dropping to 18.46 cm TL in 2020. This time raised gradually to 20.86 cm TL. Moreover 96.87 % of the Nile perch caught were below the lower limit of slot size (50 cm TL). This means out of 14114 Nile perch caught only 423 equivalents to 2.99% by number were within the slot size of 50-85 cm TL.

Overall mode distribution for the 2021 length distribution pattern of the Nile perch is at 12 cm TL differ from that of 2018 survey results, while the current 2019 had mode at 7 cm TL. Although there are some increases in mean size of the *Lates niloticus,* when you compared to the two modes the increases is not much significant. The maximum and minimum length of *Lates niloticus* for the five consecutive years fluctuate but with no significant different in maximum size of Nile perch and 1 (2019), 106 and 2 (2018), 120 and 3 (2017), 124 and 2 (2016), 119 and 1 (2015) and 95 and 3 cm TL for the year 2014 survey which had the lowest maximum size. However, the population structure for Nile perch within the different sampled period has no differences Figure 2, the population structure in all sampled period were dominated with juvenile fish (small sized fishes). Although the mode size during 2021 survey was 12 cm TL but it always ranges between 7.0 to 9.0 cm TL (Table 4)

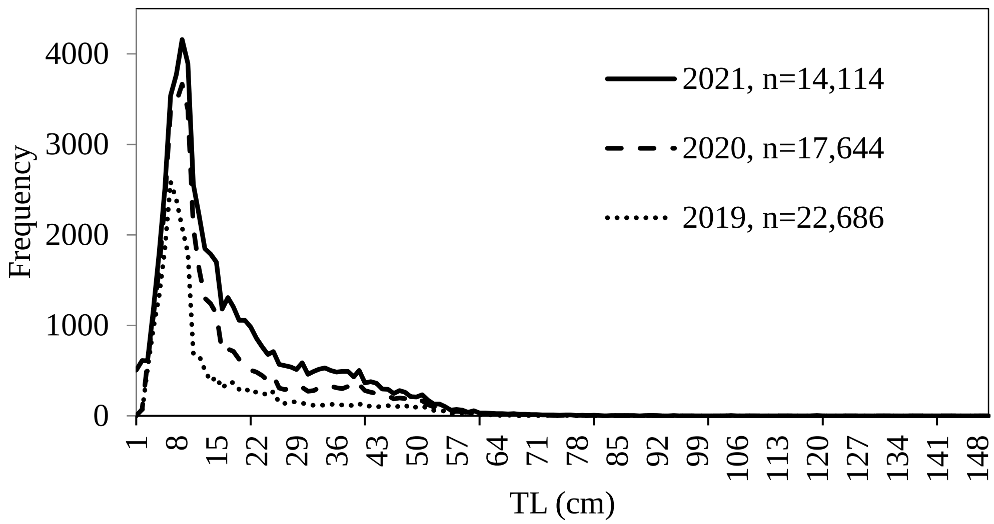

Figure A1. 2: Overall population structure of *Lates niloticus* for three consecutive surveys

Table AI. 4: Size characteristics of Nile perch in Lake Victoria

Year	n	Mean Size (cm TL)	Mode Size (cm TL)	% Within Slot size	% Above (>50 cm TL)	% Below (<50 cm TL)	Max. Size (cm TL)
2021	14,114	20.86	12.0	2.99	3.13	96.87	130
2020	17,644	18.46	9.0	2.83	2.93	97.07	150
2019	22,686	14.67	7.0	2.97	2.99	97.01	103
2018	12,202	25.17	9.0	4.98	5.06	94.94	104
2017	29,514	15.96	9.0	0.9	0.94	99.06	120
2016	11,100	13.95	8.0	1.13	1.19	98.81	124
2015	23,166	12.3	9.0	0.43	0.45	99.55	119

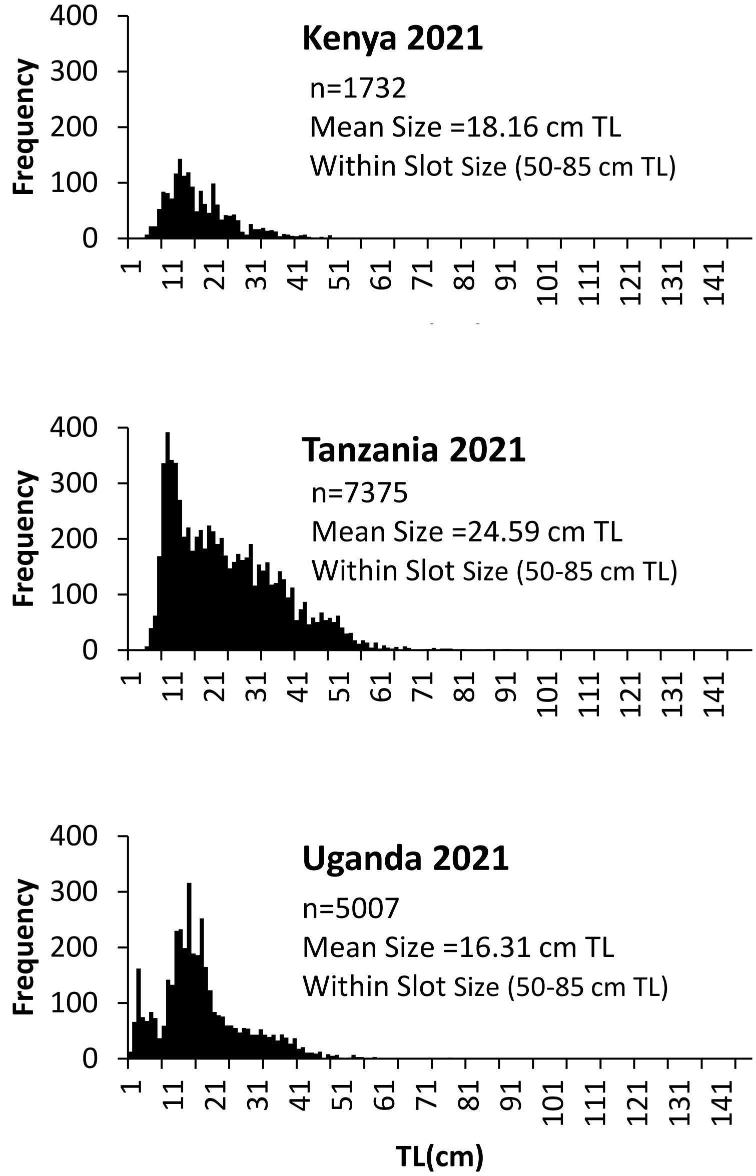

Figure A1. 3: Population structure of Lates niloticus in partner states for the 2021 survey.

General size characteristic of Nile perch including the sample size for the consecutive seven year is shown in Table 4 above. Where by the mean size shows two phases of an increasing trend between 12.3 cm TL year 2015 to 25.17 cm TL in 2018, and 14.67 cm TL in 2019 to 20.86 cm TL in 2021. The highest mean size is observed in Tanzania 24.59 cm TL Figure 4 compared to other partner states where by Kenyan water was 18.16 cm TL and Ugandan water 16.31 cmTL.

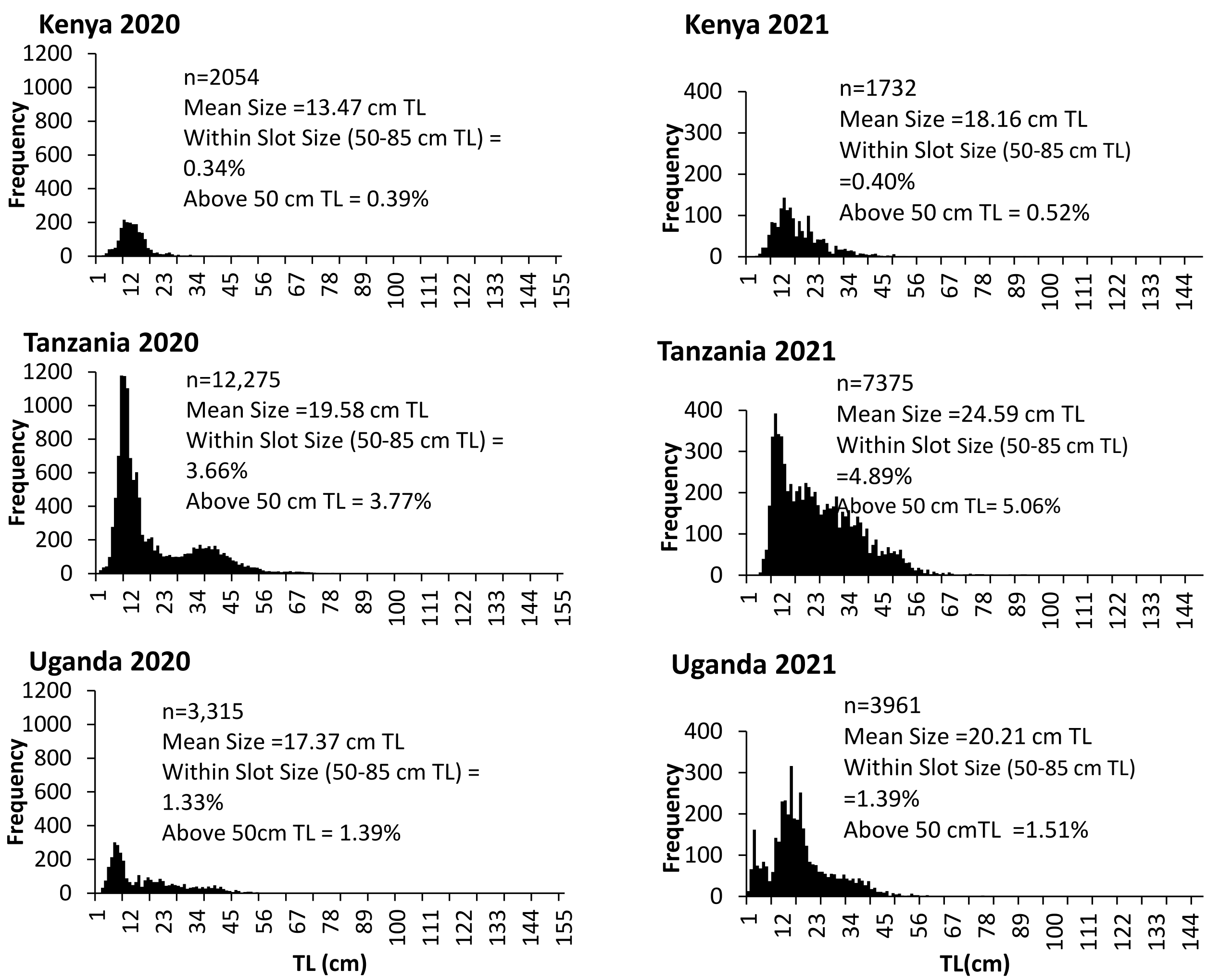

Figure A1. 4: Population structure of *Lates niloticus* in partner states for the 2020 & 2021 survey.

Size characteristics of Nile perch by quadrants in Lake Victoria is shown in Table 5 below. Small sized fish dominated in all four quadrants as well as in to the overall population structure. The smallest mean size of the Nile perch was recorded in NW quadrant with mean size of 16.27 cm TL (Table 5) where by only 1.17% of the total catch were above the 50cm TL. The biggest mean size of 24.27 cm TL were recorded in SW quadrant with 6.77% of the total catch above 50.0cm TL. In general, southern quadrants had recorded bigger size of Nile perch compared to the Northern quadrants (Table 5).

Table A1. 5: Size characteristics of Nile perch by quadrants in Lake Victoria

Quadrant	Year	Mean T L (cm)	n	%>50.0 cm TL
SW	**2021**	**24.27**	**4566**	**6.77**
	2020	22.0	2575	14.50
	2019	10.18	4200	2.00
	2018	29.89	2386	5.87
	2017	21.8	4570	2.16
	2016	18.6	1336	2.17
NW	**2021**	**16.27**	**4949**	**1.17**
	2020	16.0	2630	4.53
	2019	15.12	5277	6.78
	2018	32.58	2596	7.01
	2017	17.3	3366	0.86
	2016	25.13	274	0.36
NE	2021	18.19	1790	0.6
	2020	23.0	1351	1.8
	2019	15.81	576	1.99
	2018	18.62	3249	2.00
	2017	20.70	5678	0.53
	2016	15.39	2289	0.92
SE	**2021**	**25.09**	**2809**	**2.28**
	2020	**15.0**	**5754**	**3.09**
	2019	15.52	9373	1.79
	2018	22.85	3971	2.04
	2017	12.3	15900	0.48
	2016	12.2	7201	0.71

3.5 A1. 3.3.3. Size characteristics of Nile perch in the relation to their weight for different year

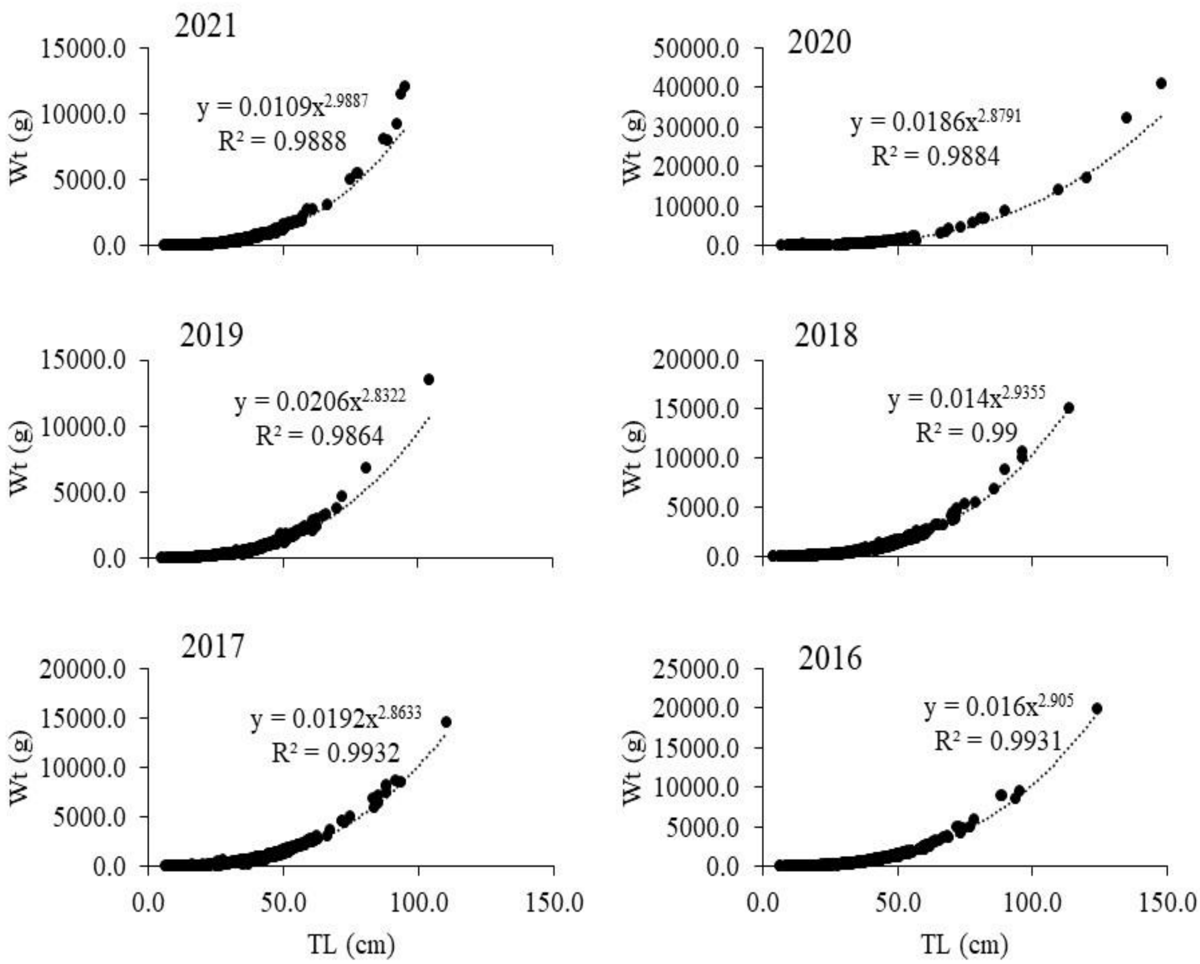

Figure A1. 5: Length Weight Relationship of *Lates niloticus*

Table A1. 6: Characteristics of the L-W-Coefficient of Nile perch for different sampling year

YEAR	**a**	**b**	**r2**	**n**
2015	0.0175	2.8748	0.9869	513
2016	0.0160	2.9050	0.9931	529

2017	0.0192	2.8633	0.9932	523
2018	0.0140	2.9355	0.9900	502
2019	0.0206	2.8322	0.9864	342
2020	0.0186	2.8791	0.9884	163
2021	0.0109	2.9887	0.9888	327
Average	**0.0166**	**2.9006**	**0.9900**	

Length weight relationship of the Nile perch has been shown in figure 5 above while the length weight coefficient for the sampled period of 2015 -2022 are presented in Table 6 above.

3.6 A1. 3.4. Food and feeding for Nile perch

3.7 A1. 3.4.1. Food composition

A total of 327 Nile perch stomachs were gutted compared to 164, 457 and 502 stomachs for the 2021, 2020 and 2019 survey, respectively, out of 327 gutted stomachs only 174 equivalents to (53.21%) stomachs contained food items with different fullness. Thirty-one stomachs were empty stomach and 122 stomachs were extruded due to pressure difference caused by depth effects during net hauling. Out of 174 gutted stomachs with prey, 84 were full stomach, 18 were three quarters stomach, 41 were half stomach, and 31 were quarter stomach. The diet of Nile perch was dominated by Caridina niloticus 38.6%, Haplochromines 35.5% and followed by Dagaa 12.0% (Figure 6). The dominance of these prey types has no significant different compared to 2019 and 2018surveys. Unidentified fish remains, Insects, Molluscs, barbus, and Synodontis contributed least to Nile perch diet (Figure 6). However, a change in diet of Nile perch with size was observed (Figure 7). *Caridina niloticus* formed an important food item for the diet of young *L. niloticus* especially the fishes below 40 cm TL. Caridina contributing to more than 50% of their diet, while haplochromines dominated in the diet of Nile perch above 40 cm TL. However, there is other fish species cotributed to the died of *L niloticus.* Canibalism characteristics was also observed for the Nile perch diet especially those above 60 cm which feed on their own youngs (Figure 7).

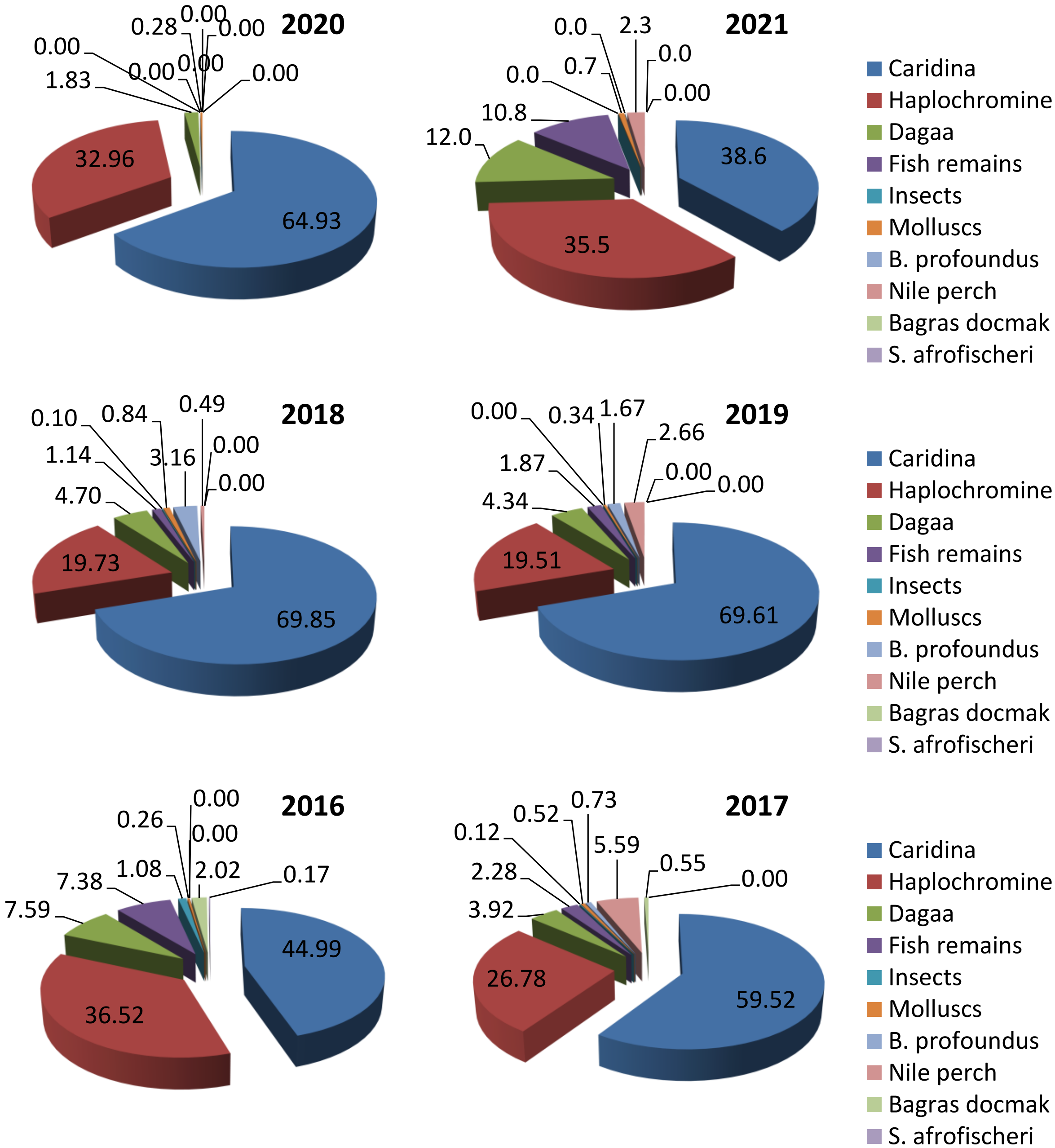

Figure A1. 6: Percentage contribution of different prey items to the diet of *Lates niloticus*

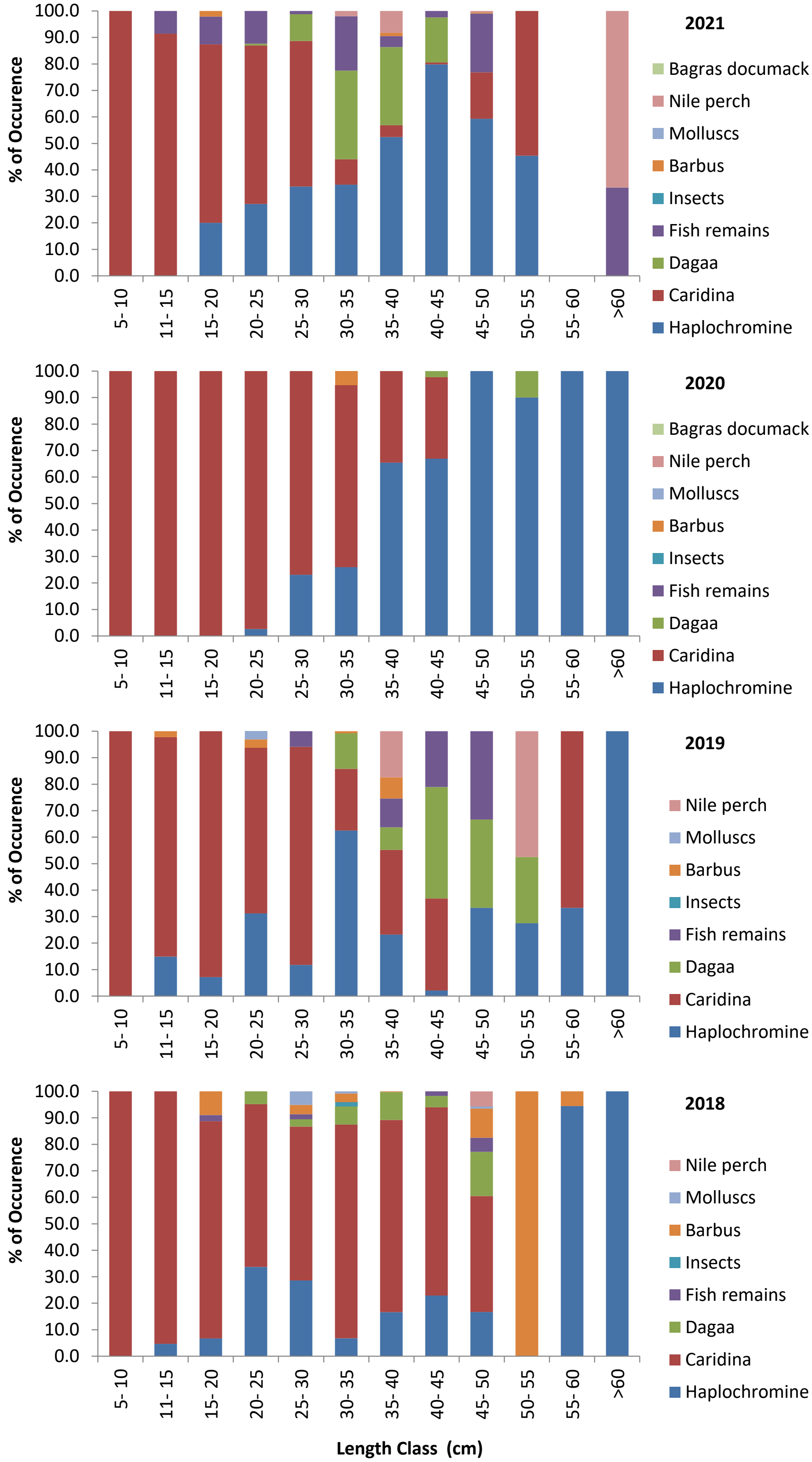
2021
2020
2019
2018
% of Occurence
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
5- 10
11- 15
15- 20
20- 25
25- 30
30- 35
35- 40
40- 45
45- 50
50- 55
55- 60
>60
Bagras documack
Nile perch
Molluscs
Barbus
Insects
Fish remains
Dagaa
Caridina
Haplochromine
Length Class (cm)

Figure A1. 7: The ontogenic shift of Lates niloticus for its prey

3.8 A1. 4.0. Discussion

3.9 A1. 4.1.0. Fish species composition

Throughout the November 2021 survey, 31 net hauls were conducted compared to 24 hauls in 2020 survey and 30 net hauls in 2017. Though, the number of hauls is equivalent to the survey conducted in March 2010 but still lower compared to the previous initial survey where the number of hauls were 41 net hauls in August 2009. The number of species encountered during this survey where more or less the same as preceding surveys.

Results show that there is a decrease in percentage composition by weight of *Lates niloticus* from 89.93% (2020) to 74.21% (Figure 1a & 1b; Table 1). There are progressive decreases in percentage composition by weight of *Lates niloticus* from 2019 with 93.12% to 89.93% and currently to 74.21% while other species like Haplochromines, and caridina which are ecologically important feed for Nile perch increases. This increase of other species apart from *Lates niloticus* could be attributed to the natural oscillation between prey-predator relationships since haplochromines are preferred food item for Nile perch whose abundance reduced. The reason for declining in percentage composition of *L. niloticus* by weight could be due to the current high fishing pressure on Nile perch fishery targeting large Nile perch fish, this is stirred by the current growth of fish maw business in East Africa and Asia due to fish maw value. Large Fish maw has higher value and this drive the most of the fishers to target big Nile perch. According to the study conducted by TAFIRI in 2017 and 2018, these studies reported that, there is a direct proportionality between the swim bladder length and the total length of Nile perch, as the fish length increases its swim bladder length also increases. (TAFIRI Report 2017 &2018). Apart from that reason, the other reason why there is decline in Nile perch composition by weight could be changes of our fisheries regulation by removing the upper limit of slot size and allow fishers to harvest lager Nile perch beyond the upper limit of slot size 85 cm TL, this stock of large Nile perch is the one considered as the brood-stock for the Nile perch. Removing the brood stock from the population will result in declining the population. Data of Nile perch from different survey and studies already justified that female Nile perch mature for the first time at a length 75-90 cm TL. (Taabu et al, 2005; Ogutu-Ohwayo, R. 2004; Wandera et al.2003).

3.10 A1. 4.2 Characteristics of the Major fish Species Stocks dynamics

3.11 A1. 4.2.1. Catch rates

Catch rates is an index of biomass for the aquatic organisms, which can be used to tell the status of the fish stock in aquatic environment. Catch per unit effort (CPEU) of all the commercial species in different quadrants behave differently (Table 2). CPUE for five successive years expressed as Kg/haul in both quadrants is shown in Table 2 and Table 3. The Overall CPEU for Nile perch which observed to increases from 79.88±21.40 Kg/haul (2018) to 116.36±29.69Kg/haul (2019), this time decreased significantly by 50.04% from 2019 to 58.13±9.83Kg/haul (2021), and 32.15% from 2020 results (Table 3). Moreover, Nile perch shows to fluctuate in all the quadrant strata. The highest catch rate was observed in SW quadrant strata with 78.23±27.34 Kg/haul, however this value dropped by 46.91% from 147.35±35 Kg/haul (2020). Except for NE where there are significant increases in CPUE from 15.09±7.24 (2020) to 29.14±16.82 (2021) equivalent to 93.37% but in all the quadrant the catch rate dropped significantly. The highest drop of CPUE in quadrants equivalent to 46.91% were observed in South West quadrants, however the biggest drop equivalent to 82%, were observed in 2018 in the same south west quadrant. The declining in catch rate is shown in Table 3. Haplochromines CPUE which shows to decreases tremendously from 7.81±2.32 Kg/haul in 2018 to 2.43±0.83 Kg/haul in 2019 increases tremendous to 16.71±7.61 Kg/haul in overall catch rates, this is a good sign for the survival of Nile perch because, haplochromines are praying important role for the ecosystem of the lake and are most preferable feeds for Nile perch ad we need to protect them. However, Haplochromine CPUE behave in inversely correlation with Nile perch. In all the quadrants, Haplochromine increases, the highest increase is in the NW where by it raised tremendously from 0.42±0.18 Kg/haul (2020) to 34.18±27.83 Kg/haul in 2022. Dagaa catches from the last two surveys do not differ much except for the NW where the drop is higher from 5.39±3.33 Kg/haul in 2017 to 1.06±0.60 Kg/haul in 2019 then decreased slightly to 0.54±0.18 Kg/haul for 2021 survey. The Catch rates for other fish species combined as others shows to decreases progressively for the overall catch rates from 7.58±2.07 Kg/haul in 2017 to 2.35±0.65 Kg/haul in 2021, however, generally the same trend of declining observed in all other quadrant.

Dagaa decline from 2017 to 2019 by almost 33.73%. Although it is not alarming yet, but this should also be checked because of their importance as small pelagic fish species which ecological are also important. However, Dagaa is also coming up as an important prey in the diet of large Nile perch especially those above 40 cmTL. Data has shown also a decline in catch rate for the group of other fish species by 13.28% from 2020 to 2021 survey. The NW quadrant which for the three years 2017 to 2019 was increasing with highest catch rates for Nile perch, continue to decrease progressively from181.36±102.44 (2019) to 55.55±11.34 (2021) Table 3. This may be due to the current high fishing pressure targeting large Nile perch, this is stimulated by the current growth of fish maw business in East Africa and Asia due to fish maw value. Large fish maw has higher value and this drives most of the fishers to target large sized Nile perch. Another reason why there is decline in Nile perch composition by weight could be due to changes of our fisheries regulation by removing the upper limit of slot size which allows fishers to harvest lager Nile perch beyond the upper limit of slot size 85 cm TL, this stock of large Nile perch is the one considered as the brood-stock for the Nile perch. Removing the brood stock from the population will affect the size of the population.

Size of organisms is a central factor to key ecological processes, and changes in size distribution may have many causes, including environment-induced or genetic variability in life history characteristics predator-prey relationships or competitive interactions (Shin *et al.,* 2005). Most important in Lake Victoria, is that Nile perch fishing is selective, targeting large fish which are more valuable, modifies the size structure and functioning of fish assemblages, with consequences for productivity and resilience of some stocks especially the Nile perch. Although the catch rate for Nile perch declined, the overall mean size structure of Nile perch caught during the October-November 2021 survey observed to increases slightly from 18.46 cm TL (2020) to 20.86 cm TL (2021). However, the overall mean size for Nile perch still low compared to historical one of 25.17 cm TL recorded in the year 2018. The mean length for Nile perch observed to increases by 58.3% from 15.9 cm TL in 2017 to 25.17cm TL in 2018 before dropping to 18.46 cm TL in 2020. This time raised gradually to 20.86 cm TL. Moreover 96.87 % of the Nile perch caught were below the lower limit of slot size (50 cm TL). This means out of 14114 Nile perch caught only 423 equivalents to 2.99% by number were within the slot size of 50-85 cm TL. The mean size of Nile perch indicated that the population of Nile perch in the lake is dominated by the small sized Nile perch which is good if we will preserve this group to grow to recruitment. This could be attributed by the presence of many large individual Nile perch in 2020 which with high fecundity reproduces a quite number of offspring which letter on being caught during 2021 survey and rise arithmetic mean size of the Nile perch. Size characteristic of the Nile perch for different years and their frequency have been shown in table 3. The mean size of Nile perch can be applied as a key indicator within the Ecosystem Approach to Fisheries which required the use of size-based indicators for the assessment of fisheries trends in exploited aquatic ecosystem. Most life history traits are correlated with size, which acts as a constraint on metabolic rates and energy assimilation, so influencing the entire lives of animals including their growth, reproduction and survival (Shin *et al.,* 2005; Reiss 1989). Overall mode distribution for the 2021 length distribution pattern of the Nile perch observed at 12 cm TL This is the most frequent total length of Nile perch is also the largest mode for the seven consecutive sampling periods, normally the most frequent total length for Nile perch ranges from 7-9 cm TL, so when you compared to the previously modal value the increases is significant. The maximum and minimum length of *Lates niloticus* for the five consecutive years fluctuate but with no significant different in maximum size of Nile perch. The size ranges from 1 to 130 cm TL for the 2021 survey, however the 2020 survey had the highest maximus size of 150cm TL, while 2014 had the smallest maximum size of 95cm TL. Though, the population structure for Nile perch within the different sampled period has no differences Figure 2; Table 4, the population structure in all sampled period were dominated with juvenile fish (small sized fishes). Although the mode size during 2021 survey was 12 cm TL but it always ranges between 7.0 to 9.0 cm TL (Table 4). The current drop to130.0 cm TL may indicate that, we need to do something in our management to monitor and maintain the size of Nile perch stock.

A1. 4.3. Food and feeding for Nile perch

3.12 A1. 4.3.1. Food composition

In order to survive, grow and reproduce, fish need to feed on organic materials such as plants or other animals. Nile perch being predator fish feeds on a variety of prey organisms (Shin *et al.*, 2005). At early stage they feed on zooplankton subsequently shift to insect then to *Caridina niloticus* and finally they feed on fish (Hughes 1986, Ligtvoet & Mkumbo1992 and Oguto-Ohwayo1990). Since its introduction, there have been significant changes in the diet of Nile perch depending on the availability of its prey (Hughes 1986). Selection of prey is governed more by availability than preference for a particular species. When haplochromines were abundant, they dominated the diet of Nile perch, after the virtually complete disappearance of haplochromines the main diet of Nile perch was reported to be *Caridina niloticus*, dagaa and juveniles Nile perch (Mkumbo & Ligtvoet 1992). After resurgence of haplochromines Nile perch switched from shrimps to haplochromines as dominant prey (Kishe-Machumu et al 2011). The results from this survey show that shrimps and Haplochromines were the key prey of Nile perch. For the six consecutive years since 2016 to 2021 *Caridina niloticus* dominated in the diet of Nile perch with a contribution of approximately 44.09% to almost 70.00%. From the current survey results indicated *Caridina niloticus* continue to dominate in the stomach of juvenile Nile perch of ≤40cm TL while, Haplochromines dominated the food of large size class (≥ 60cm TL). This indicates that Haplochromines are the preferred prey of Nile perch that are large enough to feed on them. Food for the Nile perch of size range between 5.0 to 30 cm TL was dominated by Caridina but again for the size class between 31 to 39 cm TL there was no clear dominance prey for the Nile perch, the observed prey were Caridina, Haplochromine, Dagaa, unrecognized fish remains and Insects. Cannibalism observed in the size class between 60.0 cm TL. Cannibalism contribution to diet was a bit significant with (2.30%) compared to the one observed during 2018 survey (0.49%). Other studies show that cannibalism increased only when Haplochromines were depleted (Oguto-Ohwayo 1993). The preference of Nile perch for Haplochromines rather than of their own young reduces cannibalism (Kishe-Machumu *et al* (2011). Studies show that an increase in gill rakers spacing with size of fish prevent large Nile perch from being effective prawn predator (Hughes 1992).

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4.1 Appendix II: Detailed results from limnology

LAKE VICTORIA FISHERIES ORGANIZATION

EAST AFRICAN COMMUNITY PARTNERSHIP FUND/ GIZ

LIMNOLOGICAL REPORT

HYDROACOUSTIC SURVEY OF LAKE VICTORIA

FROM 26Th October TO 22Nd November 2021

Hydro-acoustic Survey Limnology and Environment Team

Email: collongore@gmail.com, congore@kmfri.co.ke

December 2021

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Abbreviations and Acronyms

µS/cm	Micro-Siemens per Centimetre
APHA	American Public Health Association
Chloro a	Chlorophyll-*a*
Cond	Conductivity
CTD	Conductivity Temperature Dissolved Oxygen
DO	Dissolved Oxygen
EP	Emin Persha
FTU	Formazin Turbidity Units
mg/L	Milligrams per Litre
NB	Net Bottom
NE	Northeast
NG	Nyanza Gulf
NTU	Nephelometric Turbidity Units
NW	Northwest
^{o}C	Degrees Celsius
ORP	Oxidation Reduction Potential
PCA	Principal Component Analysis
pH	$-\log_{10} [H^+]$ (Negative Log_{10} of Hydrogen Ions Concentration
SE	Southeast
SG	Speke Gulf
SI	Sesse Islands
SW	Southwest

TDS	Total Dissolved Solids
Temp	Temperature
YSI	Yellow Springs Instruments

SUMMARY

Limnological studies alongside the lake-wide acoustics surveys in Lake Victoria aim to characterize the aquatic environment by physical, chemical, biochemical, and ecological attributes that influence fish stocks. Limnological information explains the observed fish abundance trends at different spatial delimitations considered for the survey conducted in October-November 2021, with the objective of generating information on stock densities of commercially and ecologically important fish species. A priorly calibrated depth-profiling system; a submersible Seabird® SBE 19plus V2 SeaCAT was used for *insitu* logging of the vertical profile data of the water physical, chemical, and biochemical attributes. Observations across fifty-six (56) sampling points indicate shifts in thermal regimes and Dissolved Oxygen concentration patterns across the lake. The lake-wide mean temperature was 25.52±0.72 ºC, indicating an increase from the measurements of the previous year. Dissolved Oxygen (DO) recorded a lake-wide mean of 5.26±1.90 $mgL^{-1}mgL^{-1}$, a slight drop from the previous years. This study, therefore, observes notable shifts in spatial patterns in environmental conditions of the lake with notable occurrence of dramatic stratification patterns in most regions. More occurrence of fish within the pelagic zones is therefore highly predicted preceding a calamitous overturn event where widespread anoxia up the column may cause fish deaths. We recommend that efforts aimed at addressing deleterious catchment-based impacts, thus providing long term solutions to the eutrophication problems be implemented.

1. INTRODUCTION

1.1. Background

Lake Victoria (Fig. 1) is the second largest freshwater lake in the world and the largest lake in Africa (Jean-Pierre, 2006), with a surface area of 68,000 km^2 (Hamilton, 2017), shared among the three East African countries of Tanzania (51% of the area), Uganda (43%), and Kenya, (6%). Its catchment area of 193,000 km^2 (Hecky et al., 1992) is shared among five East African states of Tanzania at 44% (85,448 Km^2), Kenya at 22% (42,724 Km^2), Uganda at 16% (31,072 Km^2), Rwanda at 11% (21,362 Km^2)) and Burundi at 7% (13,594 Km^2) (LVBC, 2007). It has a long shoreline, which Hamilton, (2017), estimat4es to be 7360 km following high-resolution satellite data. The highly indented shoreline is characterized by bays and gulfs and demarcated by ecotone riparian wetlands, rocky cliffs, and open beaches, all providing access to ecosystem service seekers. A huge human population of about 42 million, and increasing at about 3.8% per annum, live in its basin, while depending on its resources for livelihoods (Nyamweya et al., 2020). The catchment also embraces the Nile Basin, which runs through Sudan and Egypt through the River Nile (Penn, 2001).

Changes fostered by local direct human impacts and global trends in climate change have caused phenomenal changes to the lake environment within the past century (Nyamweya et al., 2020). For instance, the mixing pattern has been disrupted and no longer predictable with observed increases in surface temperatures (Hecky, 1993), often deviating from its earlier classification of oligotrophic monomictic type. According to neolimnological data (Graham, 1929), the thermocline, often occurred at 30-40 m depth, with periodic partial thermal mixing between the epilimnion and hypolimnion (Payne, 1986), and complete annual mixing between June to August. In recent observations, the lake experiences very different thermal regimes, characterized by increasing physical thermal stability and shallower mixing depths, potentially affecting fish productivity (Sitoki et al., 2010). Nyamweya et al., (2020) illustrates scenes in the life of this lake within the past century and observes that changes have occurred in the lacustrine environment and fisheries which are characterized and influenced by enhanced fishing pressure, biomanipulation and catchment processes.

The ecosystem stressors to this lake have been shown to emanate from main and distinct geographical realms; the lake itself, the littoral zone, within the basin, and outside the basin. Stressors from these sources work synergistically degrade the lake, reducing its resiliency (Mugidde, 2001, Kolding et al. 2008, Hecky et al. 1996). Such stressors, most of which are anthropogenically sustained and of such complex nature, have been noted to be driven by the ever-changing physical infrastructure around the lake, human population explosion and advances in fishing efficiency (Balirwa et al., 2003; Goudswaard et al., 2011; Goldschmidt et al., 1993; Nyamweya et al., 2016). Human population explosion on the other hand, has been shown to lead to nutrient-enrichment of the lake waters through nutrient streams from domestic waste and intense agricultural practices (Verschuren et al., 2002).

The aim of limnological studies which are integrated into the acoustics surveys in Lake Victoria is to characterize the lake-wide aquatic environment by physical, chemical, biochemical, and ecological attributes that influence fish stocks. The environmental conditions of a water body directly affect the fish stocks by influencing the abundance, species composition, stability, productivity, and their physiological conditions (APHA, 1985). Measurements of such attributes within the acoustics transects, not only provides a clear understanding of habitat quality and its Spatio-temporal variations, but also gives an insight into how such parameters influence the fish stocks (Laevastu and Hayes, 1981, Laevastu, 1993). This leads to a better knowledge of the ecosystem processes of the aquatic system, which translates to improved management approaches to the lake and its fisheries resources (Santoso and Toruan, 2020).

Thus, the hydro-acoustics studies on Lake Victoria, whose objective is to generate information on stock densities of commercially important fish species, particularly Nile Perch and the pelagic groups (Dagaa and the haplochromine cichlids), rely on limnological information to explain the observed fish biomass and abundance trends at different transects, strata and other spatial delimitations considered. This approach provides a holistic ecosystem perspective of the fisheries and an enhanced understanding of the performance of the acoustics equipment and ensuing data.

1.1 Objective

- To is to characterize the lake-wide aquatic environment by physical, chemical, biochemical, and ecological attributes that influence fish stocks and their spatial-temporal trends.

2. MATERIALS AND METHODS

The location of the sampling points (CTD stations) for measurements of water physical and chemical attributes followed the provisions in the Standard Operating Procedures (SOPs) for Lake Victoria Hydro Acoustics Surveys. The fifty-six (56) points were purposively and subjectively selected by stratified strategy to ensure even distribution and representation of all the strata, special regions, countries, and quadrants, while logically coinciding with the bottom trawl (NB) sampling points. Hence, the sites occurred systematically and intermittently between acoustics cruise transects covering the entire lake and followed closely, the CTD stations for the previous surveys, with minor logistical deviations occasioned following local prevailing conditions like the weather and time of day. Figure 1 shows the spatial positions of the CTD stations. More detailed descriptions of the CTD stations are presented in Annex 4.

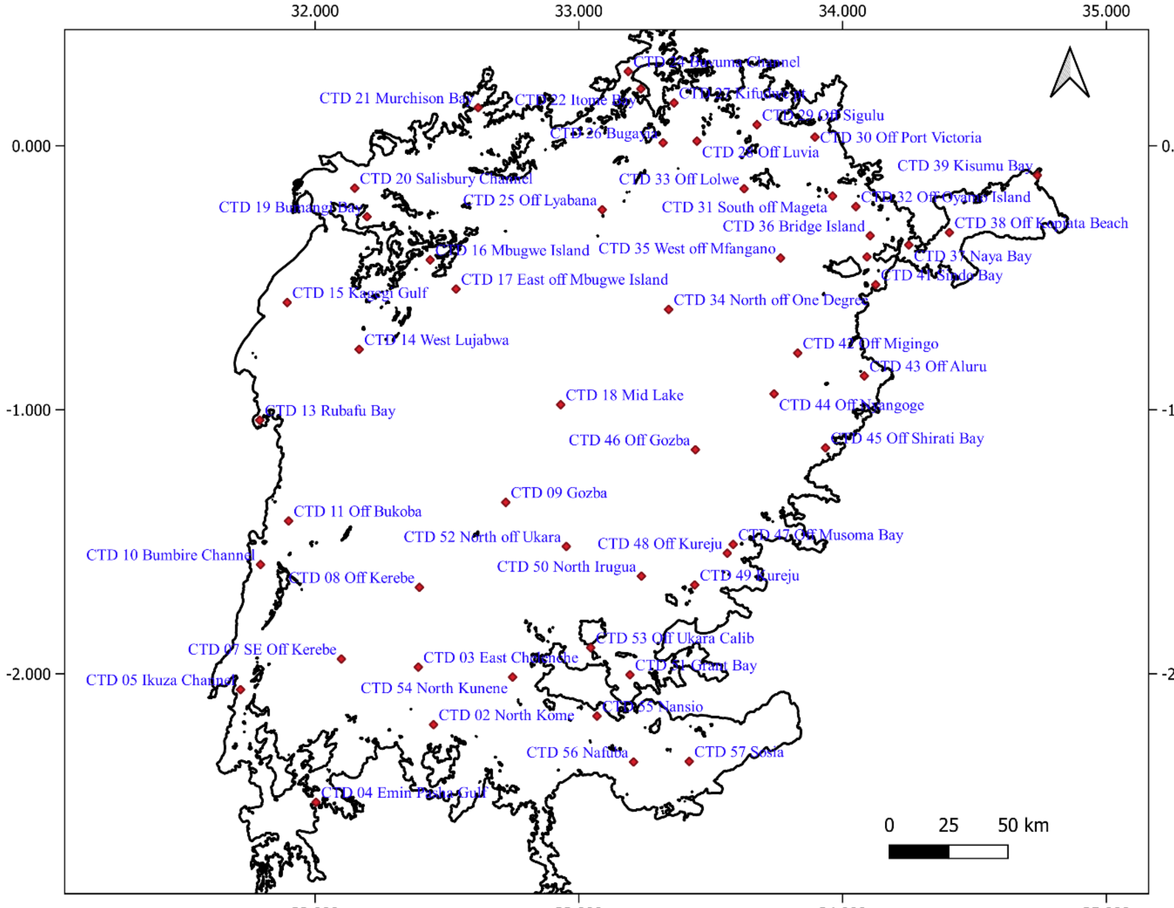


Fig. AII.**1.** Map of Lake Victoria showing the CTD stations, October- November 2021

Measurement of water environmental attributes followed published standard methods for aquatic environmental studies (APHA, 2012). In a depth-profiling system; a submersible was used to log the vertical profile data of the water physical and chemical parameters. Calibration of the probe was performed ahead of the survey by running analytical tests on sample waters for pH, DO and turbidity and comparing with sensor logged values. Corrective calibration was then done accordingly. Calibration for temperature measurements was done by comparing with readings of different thermometric instruments the of same samples of water and mean deviation of temperature values noted for onward correction of field measured data. Periodically the instrument was serviced by clearing off clogging debris from the conduits and pump orifices to prevent instrument malfunction.

Water transparency was determined as Secchi depth using a standard Secchi disc and measured following standard procedures. Complimentary chlorophyll-*a* measurements were taken using Algal Torch®, a LED based algal reflectance meter, which was lowered to log data on total algae counts and chlorophyll a concentration down up to 5 metres.

Locations of CTD stations (GPS Coordinates) were logged on to a smartphone application-based GGPS Maps. Me and collated with those displayed on the RV *Explorer* on boardonboard the echo-sounder system.

The habitat characteristics and weather conditions at the CTD stations were noted in a detailed descriptive statement and referred to for data analysis and interpretation.

All data was compiled in comprehensive electronic datasheets, the main summaries, and statistical computing done using the R statistical package (R Core Team 2018) while GIS mapping and spatial visualization were done on QGIS. The GIS base maps were obtained from Hamilton, (2017).

3. AII. RESULTS AND DISCUSSION

The results are hereby presented in tables and figures which summarize all data points for each electronically logged parameter by quadrants, strata, and special regions and the depth strata and country boundary derived acoustics regions of the lake while focusing on the sites with salient physical, chemical and biochemical and characteristics.

3.1. Overall limnological conditions of the lake

Observations across fifty-six (56) CTD stations indicate widespread active thermal stratification patterns, most prominently in the North-western and the North-eastern sectors. This showed further in the dissolved oxygen (DO) profiles with instances of anoxia or below critical levels of DO occurring at the bottom depth zones being pervasive. Under such conditions, it would be expected that fish would avoid the lake bottom.

Generally, most CTD stations exhibited dissolved oxygen levels of above 5 mgL^{-1} throughout the water column but with drastic shifts in concentrations down the column, occasioned by the apparent stratification. The lake-wide mean temperature was 25.30±0.90 ºC (Table 1), which is an increase from the mean temperatures recorded in the previous year of 24.98±1.07 ºC. Dissolved Oxygen (DO) recorded a lake-wide mean of 5.26±1.90 mgL^{-1}., a slight reduction compared to the previous year's 5.44±1.97 mgL^{-1}.

3.2. Spatial variations in temperature by quadrant and strata

The warmest sector among the four quadrants was the Southeast (SE) with a mean (± SD) temperature of 25.52±0.72 compared to the previous year's mean temperature of 25.03±0.47 ºC (Table 2). The Northeast (NE) which had previously remained the ever-warmest quadrant recorded a mean of 25.29±1.06 ºC, compared to the previous year's 25.21±0.62 ºC and becoming the second warmest. In the Southwest (SE) the total meantemperatures was 25.18±0.42 ºC compared to the previous year's mean of 25.03±0.47 ºC. The Northwest became the coldest at 25.09±1.25 ºC with a drop from 25.11±0.59 ºC.

In a comparison between the depth delineated strata and the special ecological areas, the latter wethe re warmest with Nyanza gulf retaining the warmest conditions and stable temperatures at 26.80±0.72 ºC compared to the previous year's temperatures of 26.8±0.51 ºC. Unlike in the previous year, the Sesse Islands became warmer than the Speke Gulf at 24.68±0.05 ºC. Emin Persha (EP) and Speke Gulf (SG) recorded mean temperatures of 25.48±0.43 ºC and 26.14±0.50 ºC respectively. In the previous survey the Emin Persha had recorded a mean of 25.17±0.11 ºC while the Speke Gulf had 25.7±0.28 ºC

Among the water depth delineated strata, the Inshore areas were warmest with mean temperatures of 25.73±1.08 compared to the previous year's 25.08±1.08 ºC which is consistent with the logical expectation that coldest waters are expected more at greater depths. The Coastal strata had the coldest waters at 24.91±0.59 ^{o}C which shows a slight increase since the previous year (24.8±1.2 ^{o}C) while the deep recorded 25.32±0.92 ^{o}C.

3.3. Spatial variations in dissolved oxygen (DO) by quadrants and strata

This year recorded a further oxygen fluctuation with the lake-wide mean Dissolved Oxygen (DO) of 5.26±1.90 mgL^{-1} compared to the previous year's 5.44±1.97 mgL^{-1}. The oxygen depletion was more pronounced at the profundal depths thereby causing the Deep transects to register the lowest column mean DO of 4.64±2.16 mgL^{-1} (Table 3).

A comparison of the spatial trends by quadrants reveals that the Northwest recorded the highest DO levels with a mean of 6.51±0.80 mgL^{-1}, followed by the Southwest with 5.7±1.22 mgL^{-1}, the 5.02±2.05 mgL$^{-1,}$ and the Southeast at 4.9±1.08 mgL^{-1} (Table 1).

The mean (±SD) DO as recorded within the depth strata and special regions in descending order were; Ssese Island (6.74±1.25 mgL^{-1}), Speke gulf (6.66±0.71 mgL^{-1}), Emin Pasha (5.73±0.69 mgL^{-1}), Inshore (5.44±2.18 mgL^{-1}), Coastal (5.39±1.87 mgL^{-1}), Deep (5.01±2.29 mgL^{-1}) and Nyanza gulf (4.88±0.52 mgL^{-1}), against the lake-wide mean of 5.44±1.97 mgL^{-1}). This indicates that the Deep strata were the most oxygen-deprived parts of the lake after the Nyanza gulf (Table 3).

The gulfs and special regions recorded higher DO concentrations at 6.41±0.94 mgL^{-1}, 5.79±1.80 mgL^{-1}, 5.67±1.07 mgL^{-1}, 5.42±1.19 mgL^{-1}, for Nyanza Gulf, Emin Persha, Speke Gulf and Sesse Islands, respectively. However, the Inshore strata had the highest concentrations of DO of 5.89±1.19, while the Coastal strata recorded a mean DO of 5.29±1.94.

Table AII.1. Mean (±SD) physical, chemical and biochemical attributes of water column compared among regions (strata defined by quadrants and countries)

Region	**Temp (ºC)**	**DO (mgL^{-1})**	**Cond (μScm^{-1})**	**Turb (NTU)**	**Chlorophyll (ugL^{-1})**	**Salinity (ppt)**	**Secchi depth (m)**	**Total depth (m)**
KeNECoastal	25.22±0.67	4.07±2.65	100.16±5.99	2.56±1.06	2.38±1.24	0.05±0.00	1.55±0.23	30.40±9.81
KeNENyanzaGulf	26.80±0.72	6.41±0.94	158.31±6.04	14.37±8.32	8.73±5.51	0.08±0.00	0.83±0.53	8.50±4.95
TzSECoastal	25.63±0.58	5.46±1.73	95.59±2.87	1.08±0.86	1.29±1.04	0.05±0.00	2.53±0.84	34.33±17.90
TzSEDeep	25.06±0.71	4.60±2.31	95.37±2.49	1.06±1.27	1.26±0.56	0.05±0.00	2.80±1.45	56.00±29.46
TzSEInshore	25.94±0.56	6.00±1.62	98.89±3.37	5.08±1.70	2.75±0.27	0.05±0.00	1.35±0.21	32.00±2.83
TzSESpekeGulf	26.14±0.50	5.67±1.07	99.01±0.89	2.02±0.02	2.58±0.42	0.05±0.00	1.40±0.00	24.00±5.66
TzSWCoastal	25.10±0.39	6.13±1.32	97.51±3.44	0.56±0.03	0.67±0.11	0.05±0.00	3.35±0.40	56.70±4.96
TzSWDeep	25.06±0.31	6.37±0.56	96.50±0.64	0.48±0.00	0.46±0.00	0.05±0.00	4.40±0.00	69.00±0.00
TzSWEminPasha	25.48±0.43	5.79±1.80	99.68±1.72	2.49±1.27	3.17±2.36	0.05±0.00	1.37±0.35	17.33±8.50
TzSWInshore	25.24±0.42	6.32±0.71	97.87±2.01	0.84±0.56	1.69±2.05	0.05±0.00	2.50±1.16	29.90±16.77
UgNECoastal	25.49±1.33	1.88`	99.55±11.26	1.07±0.39	1.43±0.59	0.05±0.00	2.21±0.96	41.26±18.60
UgNEDeep	24.83±0.54	4.46±1.97	96.49±1.35	0.61±0.03	0.99±0.09	0.05±0.00	2.56±0.59	54.25±26.29
UgNEInshore	25.75±0.49	5.48±1.28	99.72±2.19	2.72±0.64	2.38±0.49	0.07±0.02	2.10±0.99	19.50±0.71
UgNWCoastal	24.62±0.16	5.06±1.37	97.89±10.05	0.56±0.17	0.78±0.29	0.05±0.00	3.15±0.21	44.00±11.31
UgNWDeep	24.66±0.42	3.84±2.40	98.50±12.43	0.54±0.00	0.78±0.00	0.05±0.01	3.80±0.00	67.00±0.00
UgNWInshore	26.10±1.85	5.29±0.82	102.03±6.36	2.98±0.60	4.38±1.65	0.05±0.00	1.08±0.24	13.78±3.81
UgNWSesse	24.68±0.05	5.42±1.19	95.38±1.27	24.29±0.00	5.07±0.01	0.05±0.00	2.80±0.00	33.00±0.00
Lakewide	**25.30±0.90**	**5.26±1.90**	**98.20±7.52**	**1.69±3.13**	**1.62±1.47**	**0.05±0.01**	**2.18±1.02**	**35.34±20.40**

The water column profiles of dissolved oxygen are visualized alongside those of temperatures in the figures (Fig. 2-8).

The water salinity of Lake Victoria remained generally unchanged with a lake-wide mean of 0.05±0.01ppt. physical-chemical parameters like conductivity, turbidity, Secchi depth, and Chlorophyll-*a* followed such sporadic patterns.

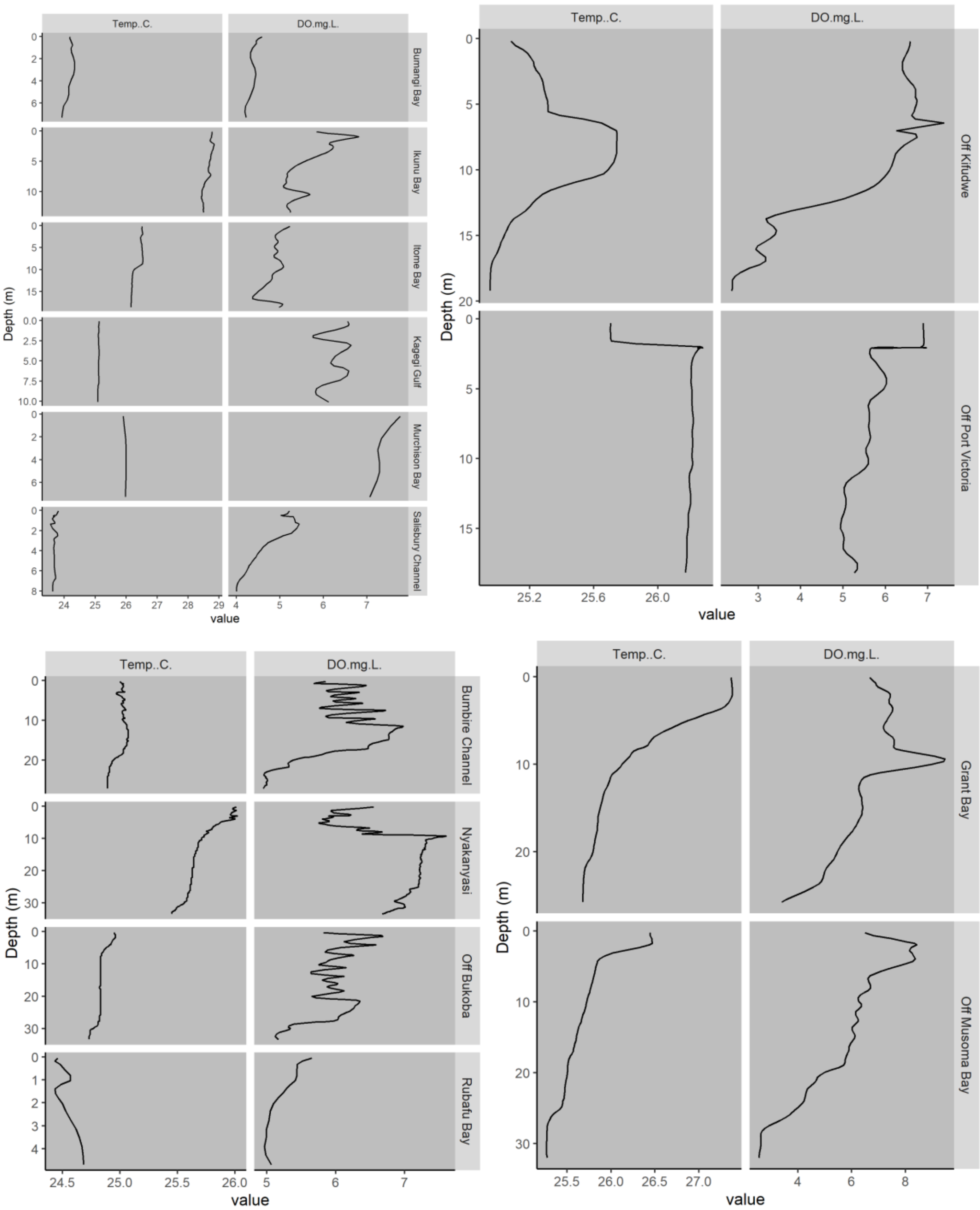


Fig. AII.2. Temperature and Dissolved oxygen (DO) profiles within the Inshore CTD stations

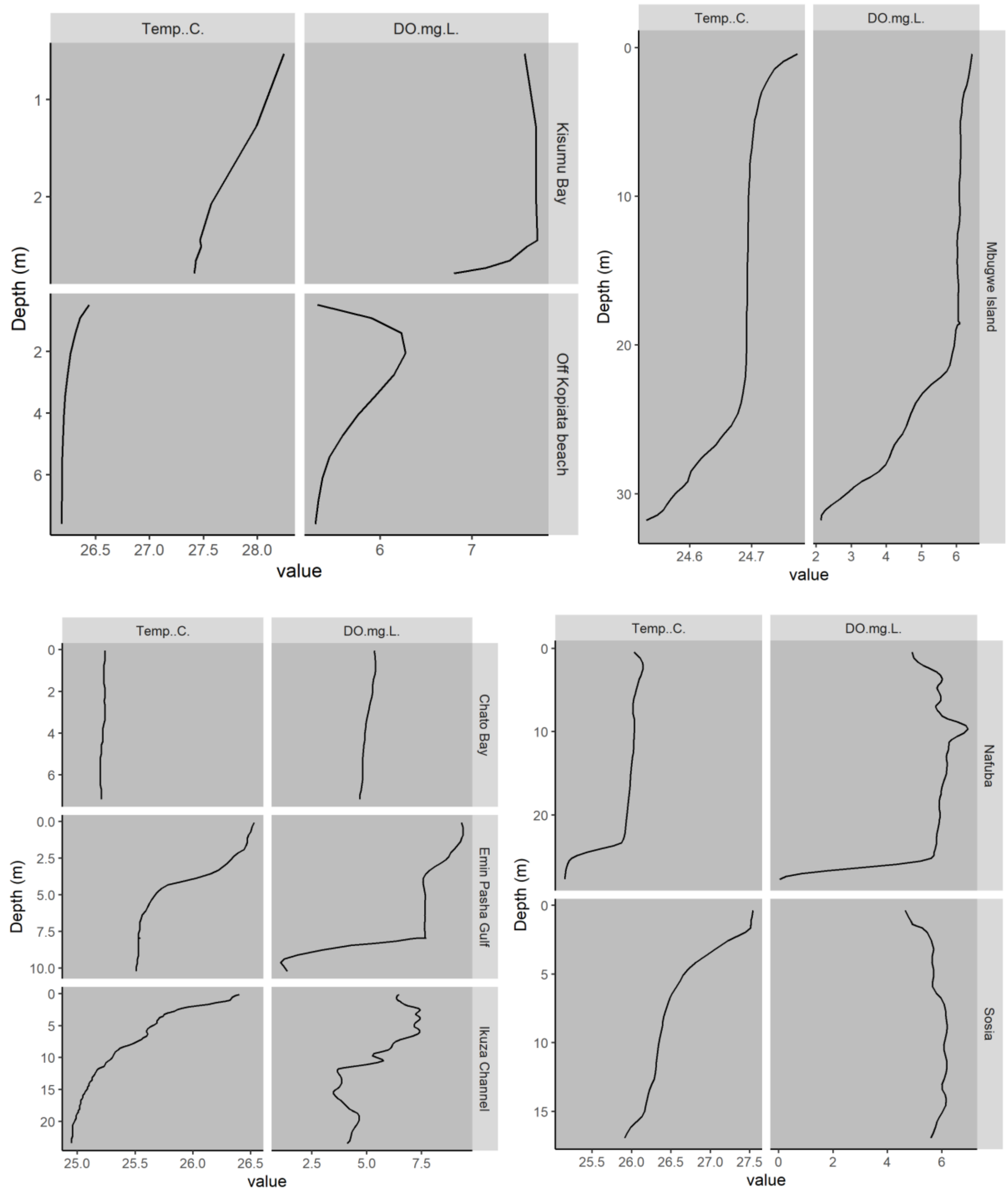
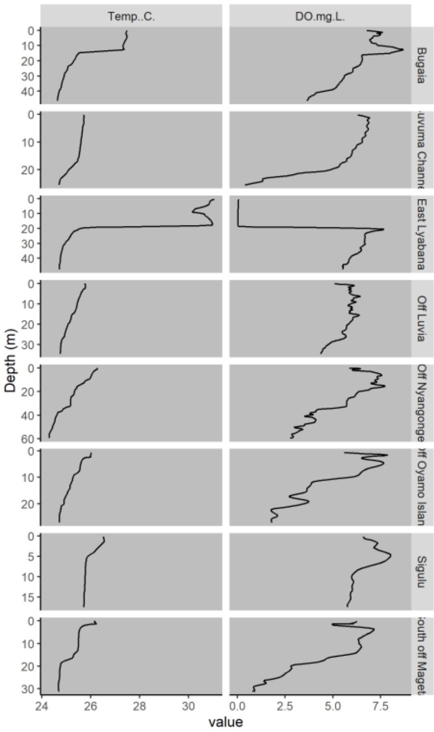
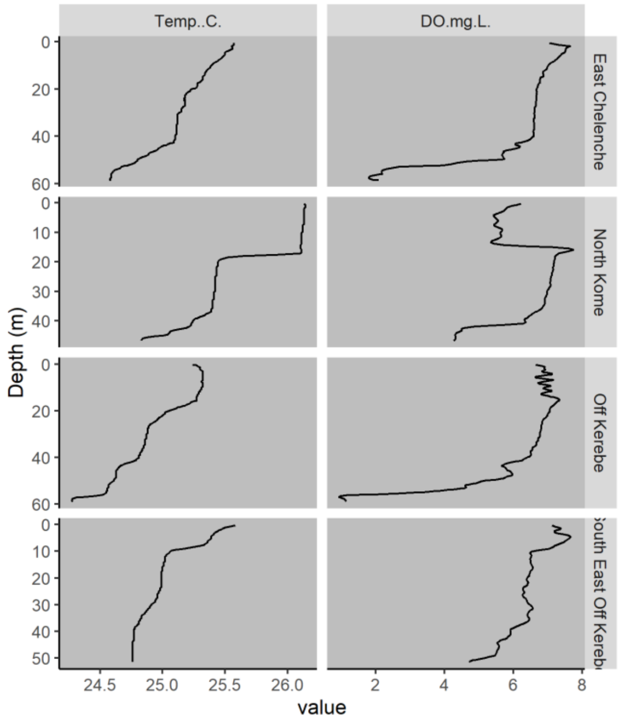
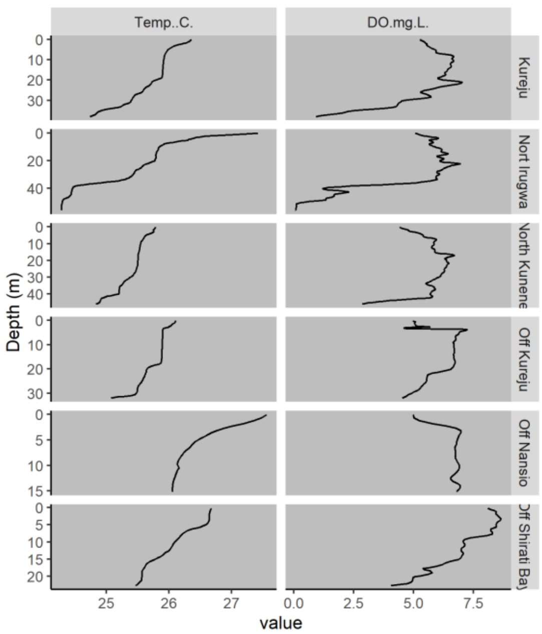
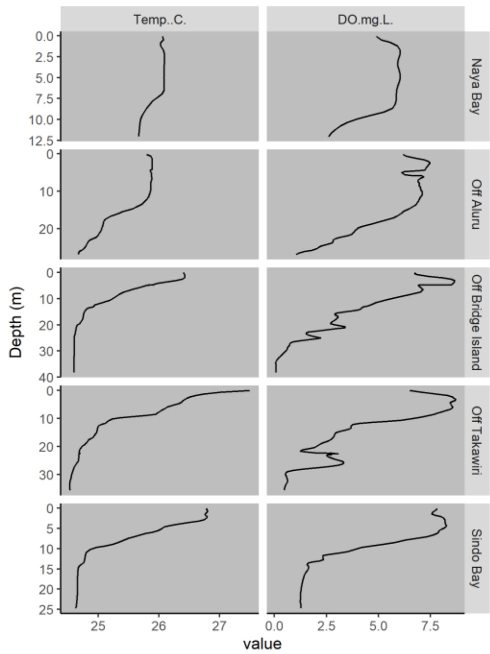


Fig. AII.3. Temperature and Dissolved oxygen (DO) profiles within the Gulfs and special regions CTD stations


Temp..C.
DO.mg.L.
Bugaia
uvuma Channe
East Lyabana
Off Luvia
Off Nyangonge
ff Oyamo Islan
Sigulu
outh off Maget
Depth (m)
value


Temp..C.
DO.mg.L.
East Chelenche
North Kome
Off Kerebe
outh East Off Kereb
Depth (m)
value


Temp..C.
DO.mg.L.
Kureju
Nort Irugwa
North Kunene
Off Kureju
Off Nansio
Off Shirati Bay
Depth (m)
value


Temp..C.
DO.mg.L.
Naya Bay
Off Aluru
Off Bridge Island
Off Takawiri
Sindo Bay
Depth (m)
value

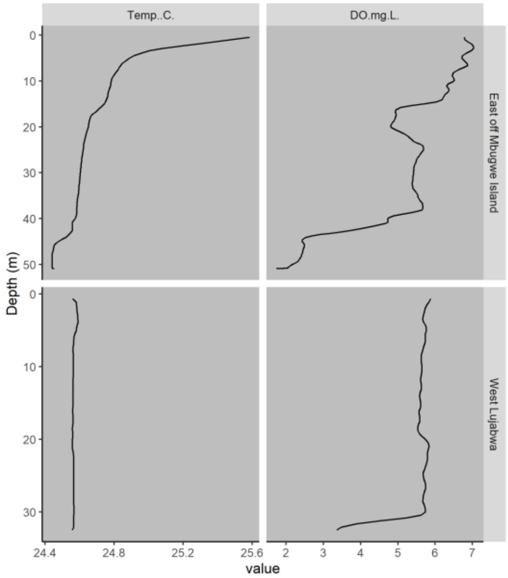


Fig. AII.4. Temperature and Dissolved oxygen (DO) profiles within the Coastal CTD stations

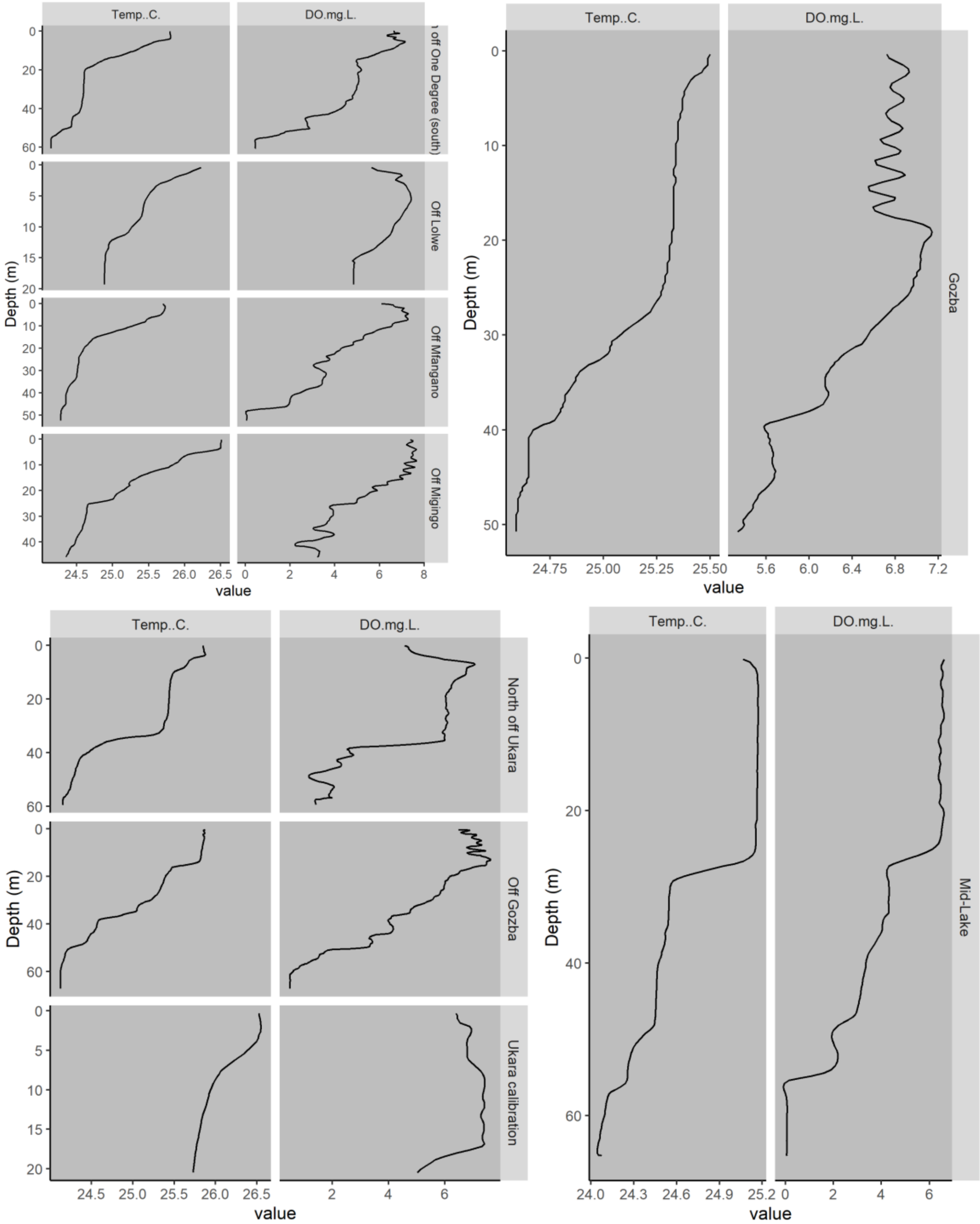


Fig. AII.5. Temperature and Dissolved Oxygen (DO) profiles within Deep CTD stations.

Following the evidence of widespread thermal stratification and the attendant occurrence of oxygen-depleted waters within the deeper waters, it is expected that most of the pelagic fish and crustaceans would be found high above the lake bottom (pelagic zone). Moreover, the regions of the lake which recorded low to near anoxia would largely have lower fish abundances. Such conditions could have arisen due to sustained anthropogenic input of oxygen depleting and generally toxic compounds into the water like agriculturally derived nutrient over-enrichment.

Evidence of such eutrophication was also noted within the Ugandan waters around Napoleon Gulf, Ssese islands, Murchison Bay, and further to the Northeastern end around Sigulu and Sumba Islands. Other equally impacted areas were the Nyanza gulf and areas around Mfangano islands which also exhibited dense algal blooms exacerbating the stratification-driven anoxia. The occurrence of eutrophic conditions within the Rusinga Channel and elsewhere around the Mfangano island could easily be associated with the existence and drastic growth of caged fish farms around the area.

Table AII.1. Mean (±SD) physical, chemical and biochemical attributes of water column compared among quadrants

Quadrant	Temp (°C)	DO (mgL^{-1})	Cond (µScm^{-1})	Turb (NTU)	Chlorophyll (ugL^{-1})	Salinity (ppt)	Secchi depth (m)	Total depth (m)
NE	25.29±1.06	4.80±2.10	99.44±10.19	1.47±1.79	1.63±1.24	0.05±0.01	1.98±0.85	35.96±20.82
NW	25.09±1.25	4.85±1.70	99.05±9.48	4.01±7.37	2.38±2.10	0.05±0.00	1.94±1.15	27.07±19.61
SE	25.52±0.72	5.27±1.95	96.25±3.05	1.68±1.74	1.58±0.98	0.05±0.00	2.24±1.01	37.38±20.18
SW	25.18±0.42	6.17±1.20	97.78±2.80	0.88±0.83	1.26±1.64	0.05±0.00	2.66±1.16	38.95±21.22
Lakewide	**25.30±0.90**	**5.26±1.90**	**98.20±7.52**	**1.69±3.13**	**1.62±1.47**	**0.05±0.01**	**2.18±1.02**	**35.34±20.40**

Table AII.2. Mean (±SD) physical and chemical attributes of water column compared among countries

Country	Temp (°C)	DO (mgL^{-1})	Cond (µScm^{-1})	Turb (FTU)	Chlorophyll (ugL^{-1})	Salinity (ppt)	Secchi depth (m)	Total depth (m)
Ke	25.29±0.71	4.24±2.56	102.24±12.86	2.83±3.09	2.58±2.01	0.05±0.01	1.38±0.43	12.53
Tz	25.35±0.61	5.73±1.67	97.03±3.02	1.27±1.41	1.42±1.37	0.05±0.00	2.44±1.08	38.14±20.27
Ug	25.23±1.18	4.94±1.84	98.70±9.15	1.94±4.31	1.64±1.35	0.05±0.01	2.17±0.98	36.10±22.12
Lakewide	**25.30±0.90**	**5.26±1.90**	**98.20±7.52**	**1.69±3.13**	**1.62±1.47**	**0.05±0.01**	**2.18±1.02**	**35.34±20.40**

Table AII.3. Mean (±SD) physical, chemical and biochemical attributes of water column compared among strata

Strata	Temp (°C)	DO (mgL^{-1})	Cond (µScm^{-1})	Turb (FTU)	Chlorophyll (ugL^{-1})	Salinity (ppt)	Secchi depth (m)	Total depth (m)
C	25.32±0.92	5.29±1.94	98.21±7.96	1.13±0.87	1.31±0.92	0.05±0.00	2.41±0.90	40.12±16.36
D	24.91±0.59	4.64±2.16	96.41±5.01	0.73±0.76	0.99±0.41	0.05±0.00	2.98±1.05	57.89±22.58

EP	25.48±0.43	5.79±1.80	99.68±1.72	2.49±1.27	3.17±2.36	0.05±0.00	1.37±0.35	17.33±8.50
I	25.73±1.08	5.89±1.19	99.68±4.19	2.62±1.83	2.69±2.02	0.05±0.01	1.52±0.75	21.27±12.04
NG	26.80±0.72	6.41±0.94	158.31±6.04	14.37±8.32	8.73±5.51	0.08±0.00	0.83±0.53	8.50±4.95
SG	26.14±0.50	5.67±1.07	99.01±0.89	2.02±0.02	2.58±0.42	0.05±0.00	1.40±0.00	24.00±5.66
SI	24.68±0.05	5.42±1.19	95.38±1.27	24.29±0.00	5.07±0.01	0.05±0.00	2.80±0.00	33.00±0.00
Lakewide	**25.30±0.90**	**5.26±1.90**	**98.20±7.52**	**1.69±3.13**	**1.62±1.47**	**0.05±0.01**	**2.18±1.02**	**35.34±20.40**

4. AII. CONCLUSIONION AND RECOMMENDATIONS

This study, therefore, observes notable shifts in spatial patterns in environmental conditions of the lake with the notable occurrence of dramatic stratification patterns in most regions. More occurrence of fish within the pelagic zones is therefore highly predicted preceding a calamitous overturn event where widespread anoxia up the column may cause fish deaths. Deliberate efforts aimed at addressing deleterious catchment-based impacts, thus providing long term solutions to the eutrophication problems should be implemented.

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Annex AII.1. Temporal trends in quadrants by means

Mean water column (± standard deviation) Physico-chemical in the various quadrants of Lake Victoria, (For the years 2008 and 2009 ± refer to standard errors).

	Strata/Year	NE	NW	SE	SW	Overall
Temp (°C)	2008	25.8 ± 0.27	25.3 ± 0.21	25.1 ± 0.12	25.0 ± 0.21	25.2 ± 0.11
	2009	25.27 ± 0.02	25.17 ± 0.01	25.08 ± 0.01	24.9 ± 0.01	25.09 ± 0.01
	2011	25.04 ± 0.67	24.38 ± 0.25	24.71 ± 0.47	24.14 ± 0.23	24.58 ± 0.60
	2014	24.7±0.5	24.4±0.33	24.9±0.49	24.6±0.43	24.7±0.49
	2015	24.54±0.82	23.86±0.74	24.22±0.74	23.70±0.83	24.12±0.84
	2016	24.93±1.57	24.73±1.46	24.55±1.69	24.58±1.73	24.67±1.61
	2017	23.33±0.58	22.90±0.40	23.06±0.42	22.72±0.24	
	2018	25.07±0.92	24.67±0.53	24.28±0.64	24.43±0.38	24.66±0.77
	2019	25.07±0.66	24.84±0.46	25.18±0.76	24.78±0.34	24.98±0.66
	2020	25.21±0.62	25.11±0.59	25.03±0.47	24.54±0.89	**24.98±1.07**
	2021	25.29±1.06	25.09±1.25	25.52±0.72	25.18±0.42	25.30±0.90
DO (mg L-1)	2008	7.5 ± 0.22	8.0 ± 0.25	7.7 ± 0.20	8.0 ± 0.33	7.8 ± 0.13
	2009	8.0 ± 0.07	8.5 ± 0.04	7.8 ± 0.04	9.1 ± 0.03	8.3 ± 0.02
	2011	7.72 ± 1.9	8.07 ± 1.2	8.56 ± 1.2	7.54 ± 1.0	7.88 ± 1.5
	2014	5.9±1.87	6.3±1.49	6.4±2.07	7.1±0.95	6.5±1.75
	2015	6.97±3.85	4.08±0.91	6.58±2.12	6.06±2.27	6.06±2.77
	2016	6.94±13.58	6.85±3.90	7.27±8.27	7.54±6.94	7.19±8.86
	2017	7.97±2.77	9.08±1.71	8.87±2.24	6.40±1.70	

	2018	7.43±1.75	7.37±1.52	7.31±2.12	8.02±1.67	7.54±1.82
	2019	6.79±1.6	6.11±1.62	7.2±1.47	7.61±1.11	
	2020	5.02±2.05	6.51±0.80	4.9±1.08	5.7±1.22	**5.44±1.97**
	2021	4.80±2.10	4.85±1.70	5.27±1.95	6.17±1.20	5.26±1.90
Secchi (m)	2008	1.8 ± 0.34	2.7 ± 0.56	3.6 ± 0.54	3.3 ± 0.54	2.9 ± 0.27
	2009	2.0 ± 0.32	3.0 ± 0.49	2.8 ± 0.37	3.5 ± 0.47	2.8 ± 0.21
	2011	2.0 ± 1.2	2.9 ± 1.6	2.7 ± 1.7	3.1 ± 1.8	2.7 ± 1.6
	2014	2.2±0.98	2.8±0.77	2.6±1.25	3.3±1.38	2.7±1.19
	2015	1.97±1.24	3.33±1.46	3.68±1.72	3.89±1.42	1.8±0.3
	2016	2.14±0.43	2.87±0.32	2.98±0.31	3.35±0.20	2.82±0.35
	2017	2.07±1.11	2.70±1.32	2.66±0.97	3.07±1.50	2.64±1.27
	2018	1.81±1.12	2.26±1.34	2.19±1.46	3±1.09	2.29±1.23
	2019	2.03±2.51	2.12±1.08	2.22±0.68	2.62±1.42	
	2020	1.84±0.95	2.03±0.92	2.66±0.94	2.95±1.43	**2.32±1.15**
	2021	1.98±0.85	1.94±1.15	2.24±1.01	2.66±1.16	2.18±1.02

Annex AII.2. Temporal trends in special areas by means

Mean water column (± standard deviation) temperature (Temp.), dissolved oxygen (DO), and Secchi depth (Secchi), in selected areas of Lake Victoria, (For the years 2008 & 2009 ± refer to standard errors).

Special area	Year	Emin Pasha	Sesse Is.	Nyanza Gulf	Speke Gulf
Temp (ºC)	2008	25.0 ± 0.46	25.2 ± 0.13	27.1 ± 0.54	24.7 ± 0.12
	2009	24.8 ± 0.01	25.3 ± 0.02	25.2 ± 0.04	24.7 ± 0.04
	2011	24.7 ± 0.02	24.4 ± 0.26	25.7 ± 0.18	24.6 ± 0.02
	2014	25.1±0.44	24.5±0.23	25.4±0.01	25.0±0.20
	2015	22.8±1.3	23.7±0.7	24.7±0.6	24.1±0.6
	2016	24.63±0.22	24.65±0.27	24.85±0.58	23.92±0.32
	2017	22.57±0.01	23.54±0.41	24.09±0.49	23.33±0.42
	2018	24.64±0.43	24.65±0.4	25.77±0.58	24.68±0.3
	2019	25.17±0.56	24.95±0.41	26.46±0.84	24.82±0.23
	2020	25.17±0.11	25.05±0.4	26.8±0.51	25.7±0.28
	2121	25.48±0.43	24.68±0.05	26.80±0.72	26.14±0.50
DO (mg L-1)	2008	8.1 ± 0.67	8.1 ± 0.38	7.6 ± 1.36	7.0 ±0.09
	2009	9.8 ± 0.04	8.7 ± 0.06	6.6 ± 0.04	7.7 ±0.07
	2011	8.0 ± 0.15	7.2 ± 1.21	9.1 ± 1.06	8.1 ±0.37
	2014	7.8±0.81	5.7±0.84	6.2±0.07	6.9±0.24
	2015	8.5±2.1	3.6±0.4	8.1±0.5	6.3±0.3
	2016	8.19±0.44	6.96±0.54	8.56±0.86	7.40±0.47
	2017	4.13±0.39	9.77±2.66	8.62±4.06	10.99±0.50
	2018	8.28±1.12	7.53±0.98	6.81±0.94	8.91±0.86
	2019	8.82±1.17	4.91±1.73	8.78±1.06	7.53±0.62
	2020	5.73±0.69	6.74±1.25	4.88±0.52	6.66±0.71
	2021	5.79±1.80	5.42±1.19	6.41±0.94	5.67±1.07
Secchi (M)	2008	1.7 ± 0.82	3.1 ± 1.2	0.6 ± 0.10	3.0 ± 0.25
	2009	1.4 ± 0.27	2.2 ± 0.21	0.6 ± 0.20	1.5 ± 0.71
	2011	0.9	1.8	0.5 ± 0.07	1.9 ± 0.07
	2014	1.4±0.21	2.9±	0.4±	2.1±0.28
	2015	0.9±0.0.1	3.1±0.4	0.5±0.1	1.8±0.3
	2016	1.20±	3.05±0.07	0.73±0.75	1.93±0.40
	2017	1.40±0.00	2.60±0.00	0.70±0.14	1.77±0.40
	2018	2.275±1.39	1.9±0.57	0.53±0.40	2.75±0.07
	2019	1.20±0.46	1.35±0.78	0.40±0.14	2.07±0.32
	2020	1.53±0.40	1.45±0.21	0.35±0.07	1.6±0.40
	2021	1.37±0.35	2.80±0.00	0.83±0.53	1.40±0.00

Annex AII.3. Temporal trends in strata by means

Mean water column (± standard deviation) temperature (Temp.), dissolved oxygen (DO), and Secchi depth (Secchi), in the various strata of Lake Victoria, August/September 2016. (For the years 2008 & 2009 ± refer to standard errors)

	Strata/ Year	Deep	Coastal	Inshore
Temp (ºC)	2008	24.9 ±0.16	25.1 ±0.15	25.5 ± 0.15
	2009	25.0±0.01	25.0 ±0.01	25.3 ±0.01
	2011	24.4 ± 0.19	24.5 ±0.46	24.8 ±0.82
	2014	24.5±0.32	24.7±0.43	25.0±0.58
	2015	23.98±0.41	24.02±0.81	24.47±0.89
	2016	24.6±0.19	24.6±0.25	24.9±0.44
	2017	22.83±0.29	22.86±0.39	23.08±0.48
	2018	24.34±0.55	24.51±0.75	25.21±0.85
	2019	25.15±0.7	24.92±0.58	24.64±0.1
	2020	24.92±0.52	24.8± 1.21	25.08±1.08
	2021	24.91±0.59	25.32±0.92	25.73±1.08
DO (mg L-1)	2008	8.1 ±0.57	7.5 ±0.13	8.0 ±0.21
	2009	9.0 ±0.06	8.4 ±0.04	8.0 ±0.04
	2011	7.0 ±0.06	7.8 ±0.04	8.4 ±0.04
	2014	6.4±1.16	6.3±1.87	6.7±2.24
	2015	4.27±1.02	6.88±3.54	6.43±2.08
	2016	7.00±0.93	7.16±0.99	7.36±1.26
	2017	8.35±1.84	8.07±2.29	7.31±2.39
	2018	7.49±2.16	7.46±1.96	7.33±1.49
	2019	6.4±1.55	6.95±1.4	6.89±0.28
	2020	5.01±2.29	5.39±1.87	5.44±2.18
	2021	4.64±2.16	5.29±1.94	5.89±1.19
Secchi (m)	2008	4.7 ±1.01	4.0 ±0.45	2.0 ±0.26
	2009	4.9 ± 0.49	4.0 ±0.27	1.9 ± 0.16
	2011	4.7 ± 1.71	3.8 ± 1.23	2.0 ±1.03
	2014	3.7±0.89	3.3±1.07	2.0±0.79
	2015	4.95±1.21	3.57±1.12	1.73±0.88
	2016	5.06±0.57	3.88±1.18	1.74±0.75
	2017	4.13±1.07	3.18±1.00	2.08±0.94
	2018	3.98±1.52	2.375±1.078	1.55±0.70
	2019	4.97±3.78	1.91±0.99	2.13±0.82
	2020	3.34±0.55	2.69±1.10	1.98±1.02
	2021	2.98±1.05	2.41±0.90	1.52±0.75

Annex AII.4. Summary descriptions of CTD stations

Station	CTD No.	X	Y	Quadrant	Strata	Country	Timestamp
Nyakanyasi	1	32.78727	-2.30808	SW	I	Tz	26/10/2021 11:12
North Kome	2	32.44918	-2.19281	SW	C	Tz	26/10/2021 12:36
East Chelenche	3	32.39137	-1.97506	SW	C	Tz	27/10/2021 07:05
Emin Pasha Gulf	4	32.00343	-2.48678	SW	EP	Tz	27/10/2021 13:28
Chato Bay	5	31.80988	-2.56382	SW	EP	Tz	28/10/2021 08:02
Ikuza Channel	6	31.7172	-2.0602	SW	EP	Tz	28/10/2021 09:03
South East Off Kerebe	7	32.09957	-1.9442	SW	C	Tz	29/10/2021 07:18
Off Kerebe	8	32.39551	-1.67271	SW	C	Tz	29/10/2021 10:57
Gozba	9	32.72274	-1.35099	SW	D	Tz	30/10/2021 07:52
Bumbire Channel	10	31.79307	-1.5865	SW	I	Tz	31/10/2021 08:13
Off Bukoba	11	31.89959	-1.42127	SW	I	Tz	31/10/2021 11:21
Rubafu Bay	13	31.78996	-1.03984	SW	I	Tz	02/11/2021 14:19
West Lujabwa	14	32.1671	-0.7716	NW	C	Ug	03/11/2021 07:07
Kagegi Gulf	15	31.89419	-0.59383	NW	I	Ug	03/11/2021 10:49
Mbugwe Island	16	32.43621	-0.43271	NW	SI	Ug	04/11/2021 06:37
East off Mbugwe Island	17	32.53442	-0.5428	NW	C	Ug	04/11/2021 12:03
Mid-Lake	18	32.93111	-0.98098	NW	D	Ug	05/11/2021 07:09
Bumangi Bay	19	32.19684	-0.26901	NW	I	Ug	06/11/2021 04:51
Salisbury Channel	20	32.15029	-0.16095	NW	I	Ug	06/11/2021 06:46
Murchison Bay	21	32.61819	0.144102	NW	I	Ug	06/11/2021 11:53
Itome Bay	22	33.23514	0.215404	NW	I	Ug	07/11/2021 07:15
Ikunu Bay	23	33.33083	0.334167	NW	I	Ug	07/11/2021 13:06
Buvuma Channel	24	33.18752	0.281173	NE	C	Ug	09/11/2021 06:57
East Lyabana	25	33.08863	-0.24241	NE	C	Ug	09/11/2021 11:05
Bugaia	26	33.31943	0.010982	NE	C	Ug	09/11/2021 14:11
Off Kifudwe	27	33.36089	0.162019	NE	I	Ug	10/11/2021 04:40
Off Luvia	28	33.44779	0.017493	NE	C	Ug	10/11/2021 07:23
Sigulu	29	33.6753	0.079257	NE	C	Ug	10/11/2021 12:07
Off Port Victoria	30	33.89513	0.032855	NE	I	Ug	11/11/2021 04:52
South off Mageta	31	33.96208	-0.19099	NE	C	Ug	11/11/2021 08:30
Off Oyamo Island	32	34.05038	-0.2307	NE	C	Ke	11/11/2021 10:05
Off Lolwe	33	33.62659	-0.16311	NE	D	Ug	11/11/2021 13:40
Noth off One Degree (south) UG	34	33.34058	-0.62033	NE	D	Ug	12/11/2021 05:21
Off Mfangano	35	33.76499	-0.4255	NE	D	Ug	12/11/2021 09:57
Off Bridge Island	36	34.1045	-0.34097	NE	C	Ke	12/11/2021 12:40
Naya Bay	37	34.25106	-0.37587	NE	C	Ke	13/11/2021 04:54
Off Kopiata beach	38	34.40502	-0.3288	NE	NG	Ke	13/11/2021 07:33
Kisumu Bay	39	34.73834	-0.11197	NE	NG	Ke	13/11/2021 10:35
Off Takawiri	40	34.09219	-0.42119	NE	C	Ke	15/11/2021 10:09
Sindo Bay	41	34.12546	-0.52648	NE	C	Ke	15/11/2021 11:02
Off Migingo	42	33.82987	-0.78555	NE	D	Ug	15/11/2021 14:08
Off Aluru	43	34.08246	-0.87215	NE	C	Ke	16/11/2021 05:50
Off Nyangonge	44	33.74026	-0.9401	NE	C	Ug	16/11/2021 08:35
Off Shirati Bay	45	33.93533	-1.1444	SE	C	Tz	16/11/2021 11:39
Off Gozba	46	33.44178	-1.15142	SE	D	Tz	17/11/2021 07:05
Off Musoma Bay	47	33.58506	-1.51019	SE	I	Tz	17/11/2021 11:15
Off Kureju	48	33.56289	-1.54377	SE	C	Tz	19/11/2021 06:45
Kureju	49	33.43945	-1.66361	SE	C	Tz	19/11/2021 08:30
Nort Irugwa	50	33.2373	-1.63036	SE	C	Tz	19/11/2021 10:48
Grant Bay	51	33.1936	-2.00404	SE	I	Tz	19/11/2021 13:39
North off Ukara	52	32.95237	-1.51797	SE	D	Tz	20/11/2021 07:28
Ukara calibration	53	33.04485	-1.90144	SE	D	Tz	20/11/2021 13:33
North Kunene	54	32.74887	-2.01271	SE	C	Tz	21/11/2021 08:59
Off Nansio	55	33.06886	-2.16053	SE	C	Tz	21/11/2021 12:58
Nafuba	56	33.20742	-2.33432	SE	SG	Tz	22/11/2021 07:35
Sosia	57	33.41849	-2.3323	SE	SG	Tz	22/11/2021 10:56

Appendix III: Echo-sounder Calibration output files

70 kHz Calibration   (26 October 2022)

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SourceCal T1(70 kHz)

Absorption Depth = 10.000 # (meters) [0.000..10000.000]

Acidity = 8.000 # (pH) [0.000..14.000]

Effective Pulse Duration = 0.256 # (milliseconds) [0.001..50.000]

Frequency = 70.00 # (kilohertz) [0.01..10000.00]

Major Axis 3-db BeamAngle = 6.74 # (degrees) [0.00..359.99]

Major Axis Angle Offset = -0.03 # (degrees) [-9.99..9.99]

Major Axis Angle Sensitivity = 23.000000 # [0.100000..100.000000]

Minor Axis 3-db BeamAngle = 6.88 # (degrees) [0.00..359.99]

Minor Axis Angle Offset = -0.02 # (degrees) [-9.99..9.99]

Minor Axis Angle Sensitivity = 23.000000 # [0.100000..100.000000]

Pulse Duration = 0.256 # (milliseconds) [0.001..50.000]

Sa Correction Factor = -0.7600 # (decibels) [-99.9900..99.9900]

Salinity = 0.000 # (parts per thousand) [0.000..50.000]

Sampling Frequency = 15.6250000 # (kilohertz) [0.0100000..1000.0000000]

Sound Speed = 1498.80 # (meters per second) [1400.00..1700.00]

Temperature = 25.800 # (degrees celsius) [-3.000..100.000]

Transceiver Impedance = 1000.0 # (ohms) [0.0..1000000.0]

Transducer Gain = 26.3100 # (decibels) [1.0000..99.0000]

Transmitted Power = 225.00000 # (watts) [1.00000..30000.00000]

Tvg Range Correction = SimradEK80 # [None, BySamples, SimradEx500, SimradEx60, BioSonics, Kaijo, PulseLength, Ex500Forced, SimradEK80, Standard]

Two-Way Beam Angle = -20.700000 # (decibels re 1 steradian) [-99.000000..-1.000000]

#==#

LOCALCAL SETTINGS

#==#

120 kHz Calibration (26th October 2022)

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SourceCal T2 (120 kHz)

Absorption Depth = 10.000 # (meters) [0.000..10000.000]

Acidity = 8.000 # (pH) [0.000..14.000]

Effective Pulse Duration = 0.256 # (milliseconds) [0.001..50.000]

Frequency = 120.00 # (kilohertz) [0.01..10000.00]

Major Axis 3-db Beam Angle = 6.84 # (degrees) [0.00..359.99]

Major Axis Angle Offset = 0.07 # (degrees) [-9.99..9.99]

Major Axis Angle Sensitivity = 23.000000 # [0.100000..100.000000]

Minor Axis 3-db Beam Angle = 6.77 # (degrees) [0.00..359.99]

Minor Axis Angle Offset = 0.02 # (degrees) [-9.99..9.99]

Minor Axis Angle Sensitivity = 23.000000 # [0.100000..100.000000]

Pulse Duration = 0.256 # (milliseconds) [0.001..50.000]

Sa Correction Factor = -0.5600 # (decibels) [-99.9900..99.9900]

Salinity = 0.000 # (parts per thousand) [0.000..50.000]

Sampling Frequency = 15.6250000 # (kilohertz) [0.0100000..1000.0000000]

Sound Speed = 1498.80 # (meters per second) [1400.00..1700.00]

Temperature = 25.800 # (degrees celsius) [-3.000..100.000]

Transceiver Impedance = 1000.0 # (ohms) [0.0..1000000.0]

Transducer Gain = 25.3300 # (decibels) [1.0000..99.0000]

Transmitted Power = 200.00000 # (watts) [1.00000..30000.00000]

Tvg Range Correction = SimradEK80 # [None, BySamples, SimradEx500, SimradEx60, BioSonics, Kaijo, PulseLength, Ex500Forced, SimradEK80, Standard]

Two Way Beam Angle = -20.700000 # (decibels re 1 steradian) [-99.000000..-1.000000]

#==#

LOCALCAL SETTINGS

#==#

5.1 Appendix IV: October-November 2021 Acoustic Survey Event Log-sheet

26/10/2021	1	DH	1		SW	I	Tz	0646	0808	Left Mwanza
	2	CTD		1	SW	I	Tz	0808	0824	
	3	NB		1	SW	I	TZ	0837	0910	
	4	TI	2		SW	I	Tz	0925	0944	
	5	DH	3		SW	D	Tz	0944	1133	
	6	TC	4		SW	C	Tz	1133	1225	
	7	CTD		2	SW	C	Tz	1225	1237	
	8	DH	5		SW	C	Tz	1237	1335	
	9	TC	6		SW	C	Tz	1335	1418	
	10	TI	7		SW	I	Tz	1418	1438	End of Day Nyakaliro
27/10/2021	11	TI	9		SW	I	Tz	0338	0502	Left Nyakaliro
	12	TC	10		SW	C	Tz	0502	0655	
	13	CTD		3	SW	C	Tz	0655	0703	
	14	NB		2	SW	C	Tz			Not done due to late departure from Nyakaliro
	15	DH	11		SW	C	Tz	0708	0807	
	16	TC	12		SW	C	Tz	0807	1008	
	17	TI	13		SW	I	Tz	1008	1109	
	18	DH	14		SW	I	Tz	1109	1143	
	19	TI	15		SW	I	Tz	1143	1230	
	20	TI	16		SW	I	Tz	1230	1250	
	21	TI	17		SW	EP	Tz	1250	1317	
		CTD		4	SW	EP	Tz	1318	1326	
	22	TI	18		SW	EP	Tz	1326	1359	
	23	TI	19		SW	EP	Tz	1359	1509	End of Day Chato
28/10/2022	24	DH	20		SW	EP	Tz	0347	0402	Left Chato
	25	NB		3	SW	EP	Tz	0414	0445	Big Nile tilapia caught
	26	CTD		5	SW	EP	Tz	0500	0515	
	27	TI	21		SW	EP	Tz	0515	0620	
	28	TI	22		SW	EP	Tz	0620	0743	
	29	TI	23		SW	EP	Tz	0743	0850	
	30	CTD		6	SW	EP	Tz	0852	0857	
	31	NB		4	SW	EP	Tz	0903	0933	
	32	NB			SW	EP	Tz	1005	1200	
	33	DH	24		SW	EP	Tz	1254	1320	End of Day Kimoyomoyo
29/10/2021	33	DH	25		SW	C	Tz	0311	0513	Left Kimoyomoyo, data was not recorded
	34	TC	26		SW	C	Tz	0542	0617	Started recording at 0842
	35	NB		5	SW	C	Tz	0625	0655	Fished to verify signals
	36	CTD		7	SW	C	Tz	0713	0719	

	37	TC	27		SW	C	Tz	0719	0812	
	38	DH	28		SW	I	Tz	0812	0901	
	39	TC	29		SW	I	Tz	0901	1047	
	40	CTD		8	SW	C	Tz	1047	1035	
	41	NB		6	SW	C	Tz	1102	1135	
	42	DH	30		SW	I	Tz	1156	1359	
	43	TC	31		SW	C	Tz	1359	1407	End of Day Kerebe Is
30/10/2021	47	DH	32		SW	C	Tz	0148	0304	Left Kerebe Is
		TD	33		SW	D	Tz	0304	0544	Transect shortened
	46	DH	34		SW	D	Tz	0544	0741	
	47	CTD		9	SW	D	Tz	0741	0749	
	48	TD	35		SW	D	Tz	0750	0917	Transect shortened(Off Gozbar Is)
	49	TD	36		SW	D	Tz	0917	1207	
	50	TC	37		SW	C	Tz	1207	1427	
	51	DH	38		SW	I	Tz	1427	1524	End of day Bumbire111
31/10/2021	51	DH	39		SW	I	Tz	0400	0410	Left Bumbire
	52	NB		7	SW	I	Tz	0418	0629	Witch got mechanical breakdown at start of net haul (0929), restarted to retrieve at 1040
	53	CTD		10	SW	I	Tz	0808	0816	
	54	DH	40					0821	0837	
	55	TI	41		SW	I	Tz	0837	0940	
	56	NB		8	SW	I	Tz	0946	1052	
	57	CTD		11	SW	I	Tz	1113	1120	
	58	DH	42		SW	C	Tz	1123	1207	End of day Bukoba
	59	TI	43		SW	I	Tz			
	60	TI	44		SW	I	Tz			
	61	DH	45		SW	I	Tz			
01/11/2021										Rest day Bukoba
02/11/2021	59	DH	46		SW	I	Tz	0400	0435	Left Bukoba
	60	TI	47		SW	I	Tz	0435	0551	
	61	TC	48		SW	C	Tz	0551	0908	Speed slowed due stormy weather
	62	CTD		12	SW	C	Tz	0908	0908	Speed slowed due stormy weather and CTD missed out
	63	TC	48a		SW	C	Tz	0908	1128	
	64	TC	48b		NW	C	Ug	1128	1236	
	65	DH	49a		NW	I	Ug	1236	1317	
	66	DH	49b		SW	I	Tz	1317	1325	
	67	NB		8	SW	I	Tz	1335	1405	

	68	CTD		13	SW	I	Tz	1405	1421	End of Day Rubafu
03/11/2021	69	TI	50a		SW	I	Tz	0326	0327	Left Rubafu
	70	TI	50b		NW	I	Ug	0327	0533	
	71	TC	51		NW	NW	C	0533	0658	
	72	CTD		14	NW	C	Ug	0658	0710	
	73	NB		9	NW	C	Ug	0714	0801	
	74	DH	52		NW	C	Ug	0818	0836	
	75	TI	53		NW	I	Ug	0836	1042	
	76	CTD		15	NW	I	Ug	1042	1051	
	77	NB		10	NW	I	Ug	1051	1125	
	78	DH	54		NW	I	Ug	1139	1206	
	79	TI	55		NW	I	Ug	1206	1349	End of Day Nakatiba landing site
04/11/2021	80	DH	56		NW	I	Ug	0320	0358	Left Nakatiba
	81	TI	57		NW	I	Ug	0358	0520	Speed lowered due encountered under water island at 0420
	82	DH	58		NW	SI	Ug	0520	0527	
	83	TI	59		NW	SI	Ug	0527	0619	
	84	DH	60		NW	SI	Ug	0619	0627	
	85	CTD		16	NW	SI	Ug	0627	0634	
	86	NB		11	NW	SI	Ug	0634	0741	
	86	TC	61		NW	SI	Ug	0800	0851	
	87	DH	62		NW	C	Ug	0851	0958	
	88	TC	63		NW	C	Ug	0958	1028	
	89	CTD		17	NW	C	Ug			
	90	NB		12	NW	C	Ug	1034	1137	
	91	TC	64		NW	C	Ug	1203	1230	
	92	DH	65		NW	SI	Ug	1230	1308	
	93	DH	66		NW	SI	Ug	1308	1314	End of the day- Mpata Bay
05/11/2021	94	DH	67		NW	SI	Ug	0156	204	Left Mpata Bay
	95	TD	68		NW	D	Ug	0204	0701	
	96	CTD		18	NW	D	Ug	0701	0718	
	97	DH	69		NW	D	Ug	0718	0848	
	98	TD	70		NW	D	Ug	0848	1315	
	99	TC	71		NW	C	Ug	1315	1525	
	100	TI	72		NW	SI	Ug	1525	1654	End of day Kalangala
06/11/2021	101	TI	73		NW	SI	Ug	0332	0419	Left Kalangala
	102	NB		13	NW	I	Ug	0423	0437	Stopped fishing due to hard bottom
	103	CTD		19	NW	I	Ug	0437	0455	
	103	TI	74		NW	I	Ug	0455	0532	
	104	TI	75		NW	I	Ug	0532	0603	
	105	NB		14	NW	I	Ug	0610	0640	
	106	CTD		20	NW	I	Ug	0642	0658	

	107	DH	76		NW		Ug	0658	0713	
	108	TI	77		NW	I	Ug	0713	0902	
	109	TI	78		NW	I	Ug	0902	1050	
	110	TI	79		NW	I	Ug	1050	1145	
	111	CTD		21	NW	I	Ug	1145	1153	
	112	TI	80		NW	I	Ug	1153	1204	
	113	DH	81		NW	I	Ug	1204	1239	
	114	DH	82		NW	I	Ug	1239	1357	
	115	TI	83		NW	I	Ug	1357	1437	
	116	TI	84		NW	I	Ug	1437	1523	End of the day Muvo Bukafu bay
07/11/2021	117	DH	85		NW	I	Ug	0330	0357	Left Muvo Bukafu bay
	118	TI	86		NW	I	Ug	0357	0509	
	119	TI	87		NW	I	Ug	0509	0542	
	120	NB	88		NW	I	Ug	0557	0608	Abandoned because of rough ground at 0559
	121	DH	89		NW	I	Ug	0608	0624	
	122	NB		15	NW	I	Ug	0630	0701	
	123	CTD		22	NW	I	Ug	0701	0711	
	124	TI	90		NW	I	Ug	0711	0857	
	125	NB		16	NW	I	Ug	0900	1003	
	126	CTD		23	NW	I	Ug	1003	1021	
	127	DH	91		NW	I	Ug	1021	1125	End of the day Jinja pier
08/11/2021										Rest day
09/11/2021	129	DH	92		NE	I	Ug	0406	0417	Left Jinja
	130	DH	93		NE	I	Ug	0417	0430	Turned back to the pier
	131	TI	94		NE	I	Ug	0432	0529	Left Jinja
	132	TI	95		NE	I	Ug	0529	0650	
	133	CTD		24	NE	C	Ug	0650	0659	
	134	DH	96		NE	C	Ug	0659	0823	
	135	TC	97		NE	C	Ug	0823	0915	
	136	TC	98		NE	C	Ug	0915	1059	
	137	CTD		25	NE	C	Ug	1059	1105	
	138	DH	99		NE	D	Ug	1107	1211	
	140	TC	100		NE	C	Ug	1211	1405	
	141	CTD		26	NE	C	Ug	1405	1416	
	142	DH	101		NE	C	Ug	1416	1459	End of the day Koja Bay
10/11/2021	144	DH	102		NE	I	Ug	0305	0337	Left Koja Bay
	145	TI	103		NE	I	Ug	0337	0430	
	146	CTD		27	NE	I	Ug	0430	0440	
	147	DH	104		NE	I	Ug	0440	0531	
	149	TI	105		NE	I	Ug	0531	0719	
	151	CTD		28	NE	C	Ug	0719	0727	
	152	TC	107		NE	C	Ug	0727	0848	
	153	TC	108		NE	C	Ug	0849	0951	

	154	DH	109		NE	C	Ug	0951	1105	
	155	TC	110		NE	C	Ug	1105	1204	
	156	CTD		29	NE	C	Ug	1204	1211	
	157	NB		17	NE	C	Ug	1216	1246	
	158	TI	111		NE	I	Ug	1258	1324	
	159	DH	112		NE	I	Ug	1324	1354	
	160	TI	11 3		NE	I	Ug	1354	1438	
	161	DHa	114a		NE	I	Ug	1438	1542	
	162	DHb	114b		NE	I	Ke	1542	1619	End of day, Port Victoria
11/11/2021	163	DHa	115a		NE	I	Ke	0328	0356	Left Port Victoria
	164	DHb	115b		NE	I	Ug	0356	0408	
	166	NB		18	NE	I	Ug	0408	0438	
	165	CTD		30	NE	I	Ug	0438	0447	
	167	TC	116		NE	C	Ug	0448	0627	
	168	DH	117		NE	C	Ug	0627	0640	
	166	TC	118		NE	C	Ug	0640	0656	Speed slowed due to under water hill encountered at 0656, Abandoned transect
	168	TC	119a		NE	C	Ug	0708	0822	
	168	CTD		31	NE	C	Ug	0822	0902	
	169	TC	119b		NE	C	Ke	0902	0935	
	170	DH	120		NE	C	Ke	0935	0949	Cross check time with echogram
	172	NB		19	NE	C	Ke	0949	1003	
	171	CTD		32	NE	C	Ke	1003	1005	
	173	TC	121a		NE	C	Ke	1006	1051	
	174	TC	121b		NE	C	Ug	1051	1123	
	175	TC	122		NE	C	Ug	1123	1234	
	176	TC	123		NE	C	Ug	1234	1334	
	178	CTD		33	NE	D	Ug	1334	1340	
	179	DH	124		NE	D	Ug	1340	1407	End of day Lolwe
12/11/2021	180	DH	125		NE	D	Ug	0100	0220	Leaving Lolwe
	178	TD	126		NE	D	Ug	0220	0520	
	179	CTD		34		D	Ug	0520	0529	
	181	DH	127		NE	D	Ug	0529	0703	
	182	TD	128		NE	D	Ug	0703	0953	GPT went off shortily at 0907 due to cable power failure
	183	CTD		35	NE	D	Ug	0953	1002	
	184	TC	129a		NE	C	Ug	1002	1111	
	185	TC	129b		NE	C	Ke	1111	1236	
	186	CTD		36		C	Ke	1236	1244	
	186	DH	130		NE	C	Ke	1244	1337	

	187	TI	131		NE	C	Ke	1337	1409	End of day Luanda Kotieno
13/11/2021	188	NB		20	NE	I	Ke	0346	0444	Left Lwanda Kotieno
	189	CTD		37	NE	C	Ke	0448	0502	
	190	TI	132		NE	I	Ke	0502	0532	
	191	TI	133		NE	NG	Ke	0532	0614	
	192	NB		21	NE	NG	Ke	0616	0721	
	192	CTD		38	NE	NG	Ke	0730	0737	
	193	TI	134		NE	NG	Ke	0740	1036	
	194	CTD		39				1036	1043	End of day Kisumu
	196									Rest day Kisumu
15/11/2021	197	DH	135		NE	NG	Ke	0351	0621	Left Kisumu Pier
	198	TI	136		NE	NG	Ke	0621	0711	
	199	DH	137		NE	NG	Ke	0711	0823	
	200	DH	138		NE	NG	Ke	0823	0845	
	201	DH	139		NE	C	Ke	0845	0906	
	202	DH	140		NE	C	Ke	0906	1002	
	203	CTD		40	NE	C	Ke	1002	1010	
	204	TC	141		NE	C	Ke	1010	1058	
	205	CTD		41	NE	C	Ke	1058	1105	
	206	TD	142a		NE	D	Ke	1105	1256	
	207	TD	142b		NE	D	Ug	1256	1403	
	208	CTD		42	NE	D	Ug	1403	1408	
	209	TD	143a		NE	D	Ug	1408	1448	
	210	TD	143b		NE	D	Ke	1448	1619	Reduced speed due to stormy weather around Sori
	211	DH	145		NE	C	Ke	1619	1653	End day at Sori
16/11/2021	212	DH	146		NE	C	Ke	0416	0425	Left Sori
	213	NB		22	NE	C	Ke	0425	0537	
	215	CTD		43	NE	C	Ke	0540	0555	
	216	DH	147		NE	C	Ke	0555	0612	
	217	TC	148a		NE	C	Ke	0612	0717	
		TC	148b		NE	C	Ug	0717	0831	
	219	CTD		44	NE	C	Ug	0831	0838	
	220	DH	149		NE	C	Ug	0838	0905	
	221	TC	150		SE	C	Tz	0905	1035	Stopped temporarily at 0919 by Kenyan security agents. Restarted at 0927
	222	NB		23	SE	C	Tz	1040	1140	
	223	CTD		45	SE	C	Tz	1140	1144	
	224	DH	151		SE	C	Tz	1144	1211	End of Day, Shirati
17/11/2021	225	DH	152		SE	D	Tz	0258	0435	Left Shirati
	226	TD	153		SE	D	Tz	0435	0657	
	227	CTD		46	SE	D	Tz	0659	0705	

	228	DH	154		SE	D	Tz	0706	0848	
	229	TD	155		SE	D	Tz	0848	1107	
	230	CTD		47	SE	I	Tz	1108	1114	
	231	NBa		24	SE	I	Tz	1120	1222	
	232	NBb		25	SE	I	Tz	1252	1339	
	232	DH	156		SE	C	Tz	1403	1531	End of day Musoma
18/11/2021										Rest day
19/11/2021	233	DH	157		SE	I	Tz	0415	0430	Left Musoma
	234	TI	158		SE	I	Tz	0430	0546	
	235	TC	159		SE	C	Tz	0546	0640	
	236	CTD	160	48	SE	C	Tz	0641	0647	
	237	TC	161		SE	C	Tz	0647	0732	
	238	TC	162		SE	C	Tz	0732	0826	
	239	CTD		49	SE	C	Tz	0826	0832	
	240	NB		24	SE	C	Tz	0839	0909	
	241	TC	163		SE	C	Tz	0917	0953	
	242	DH	164		SE	C	Tz	0953	1042	
	243	CTD		50	SE	C	Tz	1043	1051	
	244	TC	165		SE	C	Tz	1051	1249	
	245	TI	166		SE	I	Tz	1249	1314	
	246	CTD		51	SE	I	Tz	1314	1320	
	247	DH	167		SE	I	Tz	1320	1429	End of day Irondo bay (Ukerewe Island)
20/11/2021	248	TI	168		SE	I	Tz	0306	0615	Left Irondo bay (Ukerewe Island)
	247	TD	169		SE	I	Tz	0615	0727	
	248	CTD		52	SE	D	Tz	0727	0731	
	249	TD	170		SE	D	Tz	0731	0950	
	250	TD	171		SE	D	Tz	0950	1043	
	252	CTD		53	SE	D	Tz	1044	1047	End of Transect
					SE	I	Tz			Calibration failed due bad weather and strong underwater currents, End of day Ukara (Bwisya)
21/11/2021	254	DH	173		SE	I	Tz	0317	0447	Left Ukara (Bwisya)
	255	DH	174		SE	C	Tz	0447	0640	Slowed down due to rock outcrops at 0536 to 0538
	256	TC	175		SE	C	Tz	0640	0814	
	257	TC	176		SE	C	Tz	0814	0852	
	258	CTD		54	SE	C	Tz	0853	0859	
	259	NB		25	SE	C	Tz	0859	0938	
	260	TC	177		SE	C	Tz	0954	1121	
	261	TI	178		SE	I	Tz	1121	1252	
	263	CTD		55	SE	C	Tz	1252	1258	

	264	NB		26	SE	C	Tz	1300	1404	
	265	DH	179		SE	D	Tz	1419	1455	End of day Nansio
22/11/2021	266	DH	180		SE	SG	Tz	0317	0346	Left Nansio
	267	TI	181		SE	SG	Tz	0346	0452	
	268	TI	182		SE	SG	Tz	0452	0602	
	269	DH	183		SE	SG	Tz	0602	0612	
	270	NB		27	SE	SG	Tz	0624	0720	
	271	CTD		56	SE	SG	Tz	0729	0739	
	272	DH	184		SE	SG	Tz	0739	0748	
	273	DH	185		SE	SG	Tz	0748	0911	
	274	NB		28	SE	SG	Tz	0914	1045	
	275	CTD		57	SE	SG	Tz	1053	1102	
	276	TI	186		SE	SG	Tz	1103	1140	
	277	DH	187		SE	SG	Tz	1140	1208	
	278	TI	188		SE	SG	Tz	1208	1325	
	279	NB		29	SE	SG	Tz	1325	1422	
	280	DH	189	58	SE	SG	Tz	1431	1500	End of day and survey at Nyamikoma
23/11/2021										Travel to TAFIRI pier, Mwanza