EAST AFRICAN COMMUNITY
LAKE VICTORIA FISHERIES ORGANIZATION

A REPORT OF THE LAKE VICTORIA HYDRO-ACOUSTIC SURVEY

20^{th} October - 25^{th} November 2020

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December 2020

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DEUTSCHE ZUSAMMENARBEIT

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ACKNOWLEDGMENT

The hydroacoustic survey report of 2020 was written by the Hydroacoustic Regional Working Group of the Lake Victoria Fisheries Organization (LVFO), and would wish to acknowledge the captain (Mr. Edwin Sombe), engineer (Mr. Harith Kalima) and crew (Mr. Mr. Dustan Oswald Mpangala, Mr. Toto Mohamed, Mr. Boaz Jumbe Tukiko, Mr. Mzee Dioniz Sarungi, and Mr. Machuma Mumwisi Maneno) of RV Explorer for their effort to ensure that the survey is completed successfully. The technical support provided by Dr. Shigalla Mahongo, the Executive Secretary, Dr. Anthony Taabu-Munyaho, the Deputy Executive Secretary and Dr. Robert Kayanda, Director of Fisheries Resource Monitoring and Research from LVFO are highly appreciated. The financial support granted by Germany Federal Ministry for Economic Cooperation and Development (BMZ) through GIZ under the Responsible Fisheries Business Chains Project (RFBC) project that enabled the study to be conducted is highly valued.

EXECUTIVE SUMMARY

Hydro-acoustics surveys have been conducted in Lake Victoria since 1999 with the aim of determining and explaining quantities (biomass) and distribution of various fish groups. Herein results of the 23rd survey that was conducted from 20th October to 25th November 2020 are presented. Data were collected and analysed following standard operating procedures (SOPs) for hydro-acoustic surveys in Lake Victoria. The current methods (SOPs) are able to disaggregate and attribute acoustic measurements into four (4) fish groups, namely Nile perch, *dagaa*, haplochromines and other fish, and the freshwater prawn *Caridina nilotica*. Results of the current survey indicate that the lake had 3.47 million tons (t) of fish, including *Caridina,* which was a 29% increase from the previous year 2019 (2.68 million tons). Nile perch (30%), was the most dominant followed by *Caridina* (28%), *Dagaa* (27%) and haplochromines and others (15%) respectively. The following key observations were made:

- Nile perch was generally more abundant in the western part of the lake, consistent with findings from the previous survey.
- Nile perch biomass continued to expand, increasing by 25% compared to the 2019 survey. As in the previous survey (2019), the highest increase in biomass was observed in Uganda and Tanzania waters;
- The average size of Nile perch also improved slightly, increasing from 15.0 cm TL in 2019 to 18.39 cm in 2020, with the highest increase (of sizes above 50 cm TL), observed in the north-western parts of the lake (Uganda).
- The biomass of *dagaa* increased by 10% relative to 2019. The increase was only observed in Uganda and Kenya. Tanzania on the other hand recorded a decrease in *dagaa* biomass (36%). Unlike the previous survey, spatial differences were observed, with more *dagaa* concentrated in coastal and deep transects compared to inshore areas.
- Haplochromines and other fish, registered a 33% increase in biomass compared to the previous year. This group registered the highest average density (8 tons/km^2) since 2017.
- *Caridina* registered a 48% increase in biomass compared to the previous survey.
- The lake appeared to be undergoing stratification, with more pronounced thermally stratified waters occurring in the South Western, North Western, North Eastern parts of the lake, with instances of prominent anoxia and less fish at the bottom depths.

The observed stock status may be due to a combination of many factors, but mainly, the western side being relatively shallower, experiencing more mixing, coupled with the rising water levels, and the level of enforcement possibly being stronger in the western side than the eastern side. The decline in biomass of *dagaa* in the Tanzanian side may be not be a big concern given the high turnover rate of the species. From the findings and experiences of the present study we conclude and recommend that:

I. The current stocks are in good shape, and the current level of enforcement should be maintained and upscaled. This however, should be carried within an ecosystem approach to fisheries management (EAFM)
II. Annual hydro-acoustic surveys should be paired with stock assessment which was lastly done in 2016 to generate explicit management recommendations to support the current enforcement efforts.
III. There is need to re-analyze all the data from all the past surveys so as to improve reporting on the trends for all the monitored taxa cannot be overemphasized.

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1.0. INTRODUCTION

The management of fish stocks and any other aquatic organisms within a biological system requires information on their temporal and spatial distribution. Fisheries acoustic surveys are part of the routine stock assessment tools regularly used to measure the distribution and abundance of fish over large spatial areas (Simmonds and MacLennan, 2005). These surveys use active scientific echo-sounders, which transmit sound pulses (pings) and receive returning echoes from backscattering features (e.g. fish) within the water column at depths ranging from hundreds to thousands of meters. Fisheries acoustic surveys have an advantage of efficiently obtaining real time data over a large area with minimal physical contact with fish, thereby reducing the amount of resources needed to generate abundance estimates.

However, acoustics surveys have limitations including inability to differentiate among species and to detect fish close to the water surface and lake-bed bottom. The method also requires knowledge of species composition, length frequency distribution, and TS (for echo integration) for representative fish but these are not directly recorded. Therefore, acoustic methods are typically used in conjunction with traditional fishing gears (e.g bottom and pelagic trawls), and biases associated with gear selectivity are retained in acoustic estimates. The surveys are conducted following Standard Operating Procedures (SOPs) thereby providing consistent estimates of population changes. The estimates can then be incorporated into assessment models for prediction of sustainable yield.

At present, the biomass and distribution of Nile perch (≥10 cm total length), Dagaa, haplochromine cichlids, *Caridina nilotica* (a freshwater prawn) in Lake Victoria is estimated from annual lake-wide acoustic surveys conducted by the Hydro-acoustic Regional Working Group (HARWG) since February 1999. The surveys are conducted following standard designs that have evolved over years from systematic cross—lake (1999 – 2002) to radial (2005 - 2007), to parallel cross-lake (2007 -

2018). The 2019 and this year's (2020) survey used the radial design following the recommendations of the revised Lake Victoria acoustics SOPs (LVFO, 2018). Also, part of the recommendations of the new SOP implemented in this report include i) adoption of ‘standard’ echo-sounder calibration methods, ii) reporting biomass estimates with confidence limits, iii) re-analyzing data from previous surveys based on new analysis protocols, and iv) analyzing outcomes of single target detections (for Nile Perch) to determine if bias by depth or fish density is evident. However, some of the recommendations, including a move from the “third rule” to a school-based detection of dagaa, and determining more accurate target strength (TS) for haplochromine cichlids and Caridina have not been implemented in this survey.

The results and some recommendations of the 22nd Lake Victoria hydro-acoustics and environment survey conducted between 20th October and 24th November are presented in this report. The size structure of Nile perch is presented to guide the focus of fisheries (especially on slot size), although its biomass estimates were only compared with the re-analyzed data of 2015-2019. The catch composition, catch rates, and size structure from bottom trawl hauls are also reported to corroborate information from hydro-acoustics. Finally, information on bottom-type, physical, biological, and chemical attributes is gathered and compared with fish distribution.

2.0. MATERIALS AND METHODS

2.1. 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).

2.2. Organization of the cruise

This survey was conducted from 20^{th} October to 25^{th} November 2020. There were five days of preparations during which calibration of the echo-sounders and CTDs was done, and other research materials and equipment assembled and tested.

2.3. Calibration of echo-sounder

Two calibrations of the echo-sounders were performed. The first was conducted on 17^{th} October 2020 at the beginning of the survey in Mwanza gulf, and the second on 20^{th} November 2020 in off-Ukara island. Two Copper spheres of 32mm and 23 mm diameter were used in calibration of the 70kHz and 120 kHz transducers respectively.

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 average temperature at the calibration site was input into the EK80 system to predict the sound speed. 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 coefficient values.

2.4. 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.

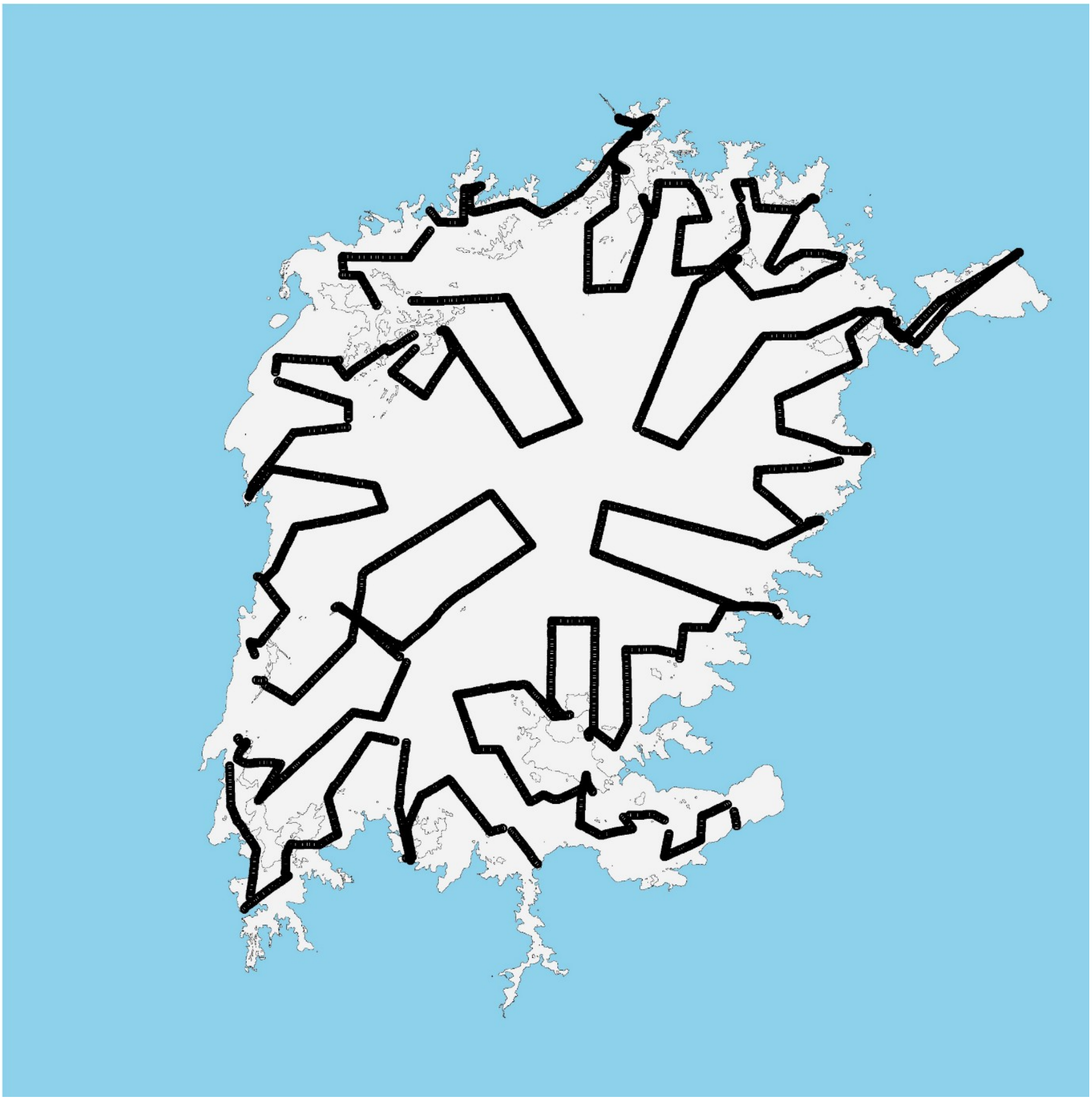

Figure 1.Map showing Survey cruise track.

The sampling and data collection were structured according to the type of activity taking place, these included;

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 an 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

2.5. Acoustic data acquisition, processing and analysis

2.5.1. Data logging and storage

At the beginning of each day, echo-sounder operation settings particularly the Data recording Range (which was set to 160 m) were thoroughly checked and recording directory set. Data were logged in files of length 1 GB and then transferred to three separate hard disks.

2.5.2. Acoustic data preparation

Each day's raw acoustic data files were loaded into Echoview (v. 8.0 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 echosounder was 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 and after the survey. Calibration settings were applied in an Echoview calibration file to update the calibration of all variables within each EV file.

2.5.3. 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.

2.5.4. 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 analysed and standing stock estimated. For single target detections, analysis from each cell was exported by line and by region. To ensure that all the data was included, the option of All Classes was selected in Echoview - 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.

2.5.5. 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. Data was exported by lines and by regions (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:

Density=(*NTargets/VBeam*) (1)

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

Biomass = Density × Mean weight (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 determined by Kayanda et al 2012 (equations 3 and 4). They are

$TL=10^{((TS+84.14)/30.15)}$ (3)

Total weight = 0.0042 x TL3.26 (4)

2.5.6. 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.

2.5.7. 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:

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

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.

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

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:

$$ABC\ Nile\ perch = 10^{((Sv\ Nile\ perch)/10)} \qquad (7)$$

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:

$ABC\ dagaa = ABC_{dagaarange} - ABC_{Nileperchdagaarange}$ (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)

2.5.8. 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 70kHz and 120 kHz SQ1 telegram echograms. Integration was done between the dagaa line and checked bottom in the 70kHz and 120 kHz echograms and exported by line and by region. 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:

Caridina density = 1000 ^ ((Sv – TS)/10) (10)

2.5.9. 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-taxa = ABC other-taxa-range – ABC Nile-perch-other-taxa-range (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:-

Haplochromines and other taxa density = 1000 *10^ ((Sv – TS)/10) (12)

2.5.10. 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 through bootstrapping in the R statistical package, version 4.0.2 (R Development Core Team, 2020). 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.

2.5.11. 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 in 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 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 re-calculated from the map grid squares (Table 2). The rest of the strata were analyzed by country and by quadrant.

Table 1. Area of Lake Surface (km^2) 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**

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)
NE		1,082 (Ke)	1,763 (Ke)	
TOTAL	**23,367**	**21,038**	**14,028**	**8,760**

Tz =Tanzania, Ug = Uganda and Ke = Kenya

2.6. Biological and environmental data acquisition

2.6.1. 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 catches were all sorted into 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 subsampled. The catch was mixed thoroughly and a subsample was taken for recording length and weight. The results were raised by 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).

2.6.2. Environmental data

Location of the sites (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 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.

Measurement of water environmental attributes followed published standard methods for aquatic environmental studies (APHA, 2012). 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 ®, 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.

Sampling stations locations (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 statements and referred to for data analysis and interpretation.

All data were 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 was done on QGIS. The GIS base maps were obtained from Hamilton (2017).

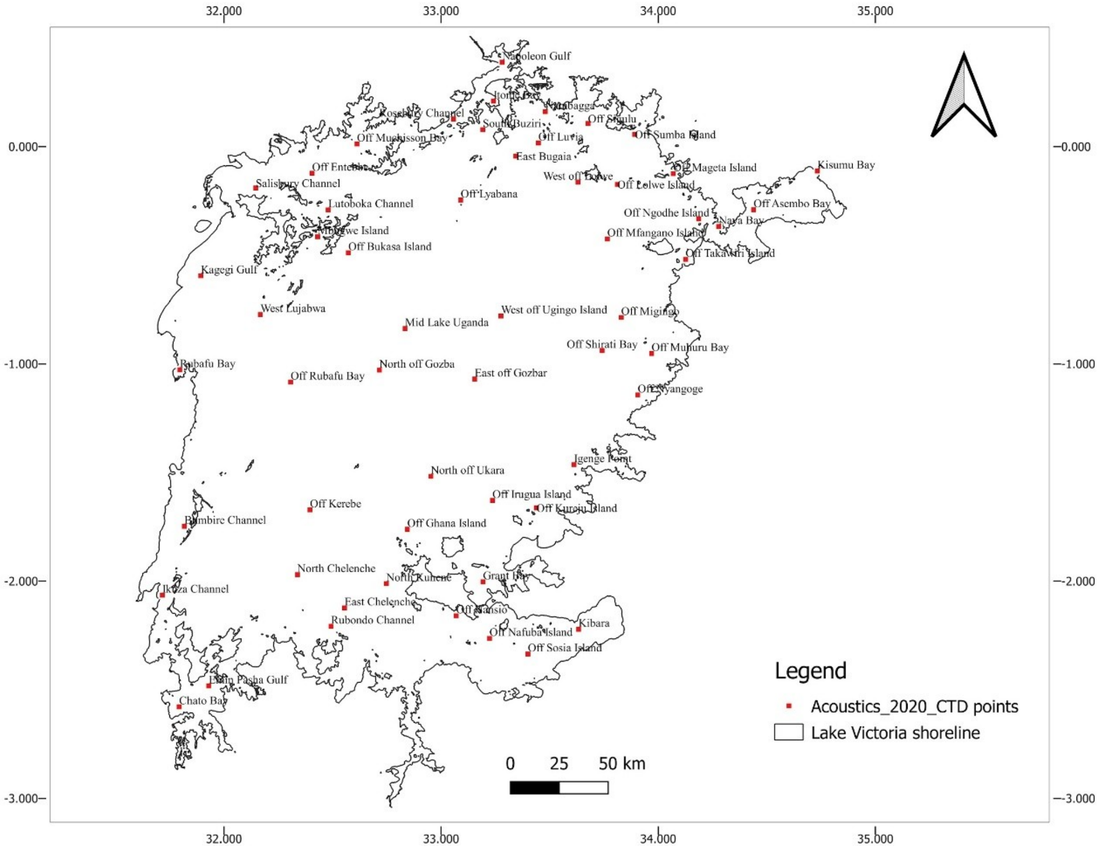

Figure 2. Map of Lake Victoria showing the CTD stations, October-November 2020

2.6.3. Bottom classification

Bottom Substrate Acoustic Data Analysis

The acoustic data was collected by a split beam echosounder operating at 70kHz and 120 kHz, and recorded by using the EK 80 software.

Echoview 8.0 software was subsequently used to process, analyse and export raw acoustic backscatter data into CSV formats for spatial distribution analysis and classification of bottom substrate. Data collected by the 70 kHz frequency was used to analyse bottom classification. Background noise level was subsequently removed by estimating the noise and subtracting it (Anderson et al 2007; De Robertis and Higginbottom, 2007). The lakebed was then obtained using the *best bottom candidate* algorithm and a back step of 0.0 m. Within the 70 kHz Sv echogram, the lakebed (bottom line) line was manually edited to ensure the line was continuous without containing any signal from fish. The bottom line and the echoes (E1 and E2) below the line were applied in Echoview to carry out the seabed classification algorithm (BioSonics, 2008; Ostrovsky and Tegowski, 2010).

Depth normalization

Due to variations in depth brought about mainly by lakebed morphological features, the pulse length around the off-axis part of the beam travels a distance greater than $C\tau/2$. Depth normalization was therefore necessary in order to account for variations in pulse length with depth. The expression used is as follows:

Depth normalization coefficient = off axis pulse length (ref)*Actual value/ off-axis pulse length (actual).

Where, off-axis pulse length (ref) is off-axis pulse length where the normal incidence start depth is specified by the reference depth, off-axis pulse length (actual) is the off-axis pulse length of the first echo where the normal incidence start depth is given by actual depth for the ping. Echoview determined one seabed point per feature extraction interval. The lakebed point data includes time, latitude, longitude, depth, and seabed features. The best value for the reference depth was the average depth of the seabed and in this study 40 m was used.

Lakebed roughness and lakebed hardness

The two key features in bottom classification analysis are bottom roughness (E1) and bottom hardness (E2) parameters, Energy feature from the first acoustic lakebed is related to bottom roughness parameters while the second echo is related to the bottom hardness parameters.

The start point for calculation of bottom roughness is therefore given by bottom line depth plus the distance of cτ/2 plus the off-axis angle offset. The E1 value was processed using the threshold range from -30.0dB to 0 dB. The second lakebed echo started at twice the depth of the first lakebed echo and the whole second lakebed echo is used for calculation of lakebed hardness (Anderson et al., 2007). Assuming that the total acoustic pressure reflection coefficient was the best descriptor of seabed hardness and that the second seabed echo reflected up and down twice from the surface is proportional to the 4th power (rather than the 2nd) of the acoustic pressure coefficient, integration of the whole second echo is used to provide an estimate of lakebed hardness (Rodríguez-Pérez et al., 2014). Acoustically different seabed types can be discriminated by clustering the backscatter signals by these two parameters E1 and E2. Siwabessy et al. (1999) determined E1 and E2 values using the equation below:

$$Bottom\_hardness_{DepthNormalized\ i,j} = \left(\frac{OffAxisPulseLength_{Ref}}{OffAxisPulseLength_{Actual,i,j}}\right) Bottom\_hardness_{Actual,i,j}$$

$$Bottom\_hardness_{Actual\ i,j} = E2 = log_{10}\left(E_{SecondEcho\ i,j}\right)$$

$$E_{SecondEcho\ i,j} = 4\pi(1852)^2 \frac{\sum_{i=1}^{n}\left(\sum_{k=1}^{m} s_{v(i,k)}\right)}{n}$$

Where sv (i, k) is the linear value for Sv for sample k in ping i

The ratio of the second part of the first bottom echo and second bottom echo (E1/E2) has been used to classify different types of sediments (Chiverset al., 1990). In addition to these energy-based measures, the shape and structure of the bottom echo also contains information about the sediment properties (Van Walree et al.,2005).

Principal Component Analysis

The next processing stage was to calculate the normal deviate for lakebed features in the echogram data. Statistical features values were processed by the statistical procedure of Principal Component Analysis (PCA) followed by K-Means clustering in echoview. PCA aimed to compress or simplify datasets by reducing the number of dimensions without much loss of information. PCA was a linear transformation from the axes representing the original variables into a new set of axes called principal components (Pcs), such that greatest variance by projection of the dataset came to lie on the first axis (then called the first principal component), the second greatest variance on the second axis, (Amiri-Simkooei et al., 2011). Under lakebed classification, PCA determined principal component as cluster seabed features of dataset. In this study, PCA was used to figure out a relationship between acoustic data and physical substrate parameters thought to provide an overview of seabed characteristics. Echoview 8.0 was used cluster dimensions to characterize each seabed point in cluster dimension space. At this stage, lakebed point data includes depth, first bottom skewness, second bottom length normalized, first bottom rise time normalized, bottom roughness normalized, and bottom hardness normalized.

Seabed classification using Cluster Analysis

Seabed classification is the process of partitioning acoustic seabed returns into discrete classes for substrate and seabed types. The classification of the sampled values was performed using clustering analysis. Clustering could be interpreted as process of grouping objects that explains the relationship between objects to maximize the similarity of members in one class and to minimize similarities between classes/clusters. The well-known K-means clustering algorithm was used in this study. Generally, the K-means algorithm aimed to partition n observations into k clusters in which each observation belongs with the cluster with the nearest mean. The result was a set of clusters that were as compact and well-separated as possible (Legendre et al.,2002). The set of cluster was exported to generate a seabed classified map in QGIS 2.18.8

3.0. RESULTS AND DISCUSSION

Results of the current survey indicate that the lake had 3.47 million tons (t) of fish, including Caridina, which was a 29% increase from the previous year. Nile perch (30%), was the most dominant followed by *Caridina* (28%), *Dagaa* (27%) and haplochromines and others (15%) respectively.

3.1. Standing stock of Nile perch and size structure

Table 3 shows the densities and biomass of Nile perch estimated in different regions of the lake. Both values of density and biomass are presented as means with 95% confidence intervals (CI), showing the lower and upper possible limits, for each quadrant and depth strata, and for each country. The estimated mean biomass for the whole lake was 1,024,623 tons, representing a 25% increase compared to the survey of 2019. The lower and upper limits of CI were 871,315 and 1,206,202 tons, respectively. In terms of relative abundance, Nile perch constituted about 30% of the total fish biomass in the whole lake. At country level, Nile perch was, on average, more abundant (high biomass per unit of habitat area) in Uganda (16.0 tons/km^2) and least abundant (8.5 tons/km^2) in Kenya. Spatial differences in biomass were observed at strata level, where Nile perch was generally more abundant in coastal and deep waters compared to inshore and Gulfs (Table 3; Figure 3a).

Table 3: Density and biomass estimates of Nile perch greater than 10 cm TL, in Lake Victoria by country and stratum

Region Parameters			**Densities (t/km²)**			**Biomass (tons)**		
Quadrant	**Stratum**	**Areas (Sq.km)**	**Tanzania**					
			low	high	mean	Low	High	Mean
SE	Deep	6166	7.77	10.41	9.03	47,887	64,163	55,705
SE	Coastal	5786	12.30	27.18	17.96	71,149	157,254	103,921
SE	Inshore	2003	13.75	18.47	16.01	27,541	36,989	32,074
SE	SpekeGulf	2909	11.81	15.42	13.60	34,369	44,862	39,564
SW	Inshore	3181	12.17	15.40	13.73	38,719	48,999	43,669
SW	Coastal	6601	18.18	23.20	20.57	120,003	153,124	135,754
SW	EminPasha	2022	4.41	7.82	6.01	8,911	15,809	12,142
SW	Deep	6251	16.01	20.75	18.34	100,098	129,725	114,650
Subtotal						**448,677**	**650,925**	**537,479**
Uganda								
NW	Deep	6226	16.40	20.69	18.51	102,131	128,843	115,232
NW	Coastal	4865	14.12	17.01	15.58	68,697	82,764	75,795
NW	Inshore	3115	14.69	18.72	16.65	45,769	58,324	51,855
NW	Sesse	2494	17.74	24.96	21.23	44,241	62,242	52,948
NE	Deep	4724	17.57	22.56	19.96	83,013	106,564	94,307
NE	Coastal	2704	12.27	14.93	13.57	33,175	40,360	36,688
NE	Inshore	3966	5.43	8.38	6.84	21,517	33,247	27,132
Subtotal						**398,542**	**512,342**	**453,958**
			Kenya					

NE	Coastal	1082	14.41	19.88	17.10	15,596	21,506	18,502
NE	Inshore	1763	4.72	11.66	8.04	8,316	20,550	14,179
NE	NG	1335	0.14	0.66	0.38	184	879	506
Subtotal						**24,096**	**42,935**	**33,187**
Total		**67,193**				**871,315**	**1,206,202**	**1,024,623**

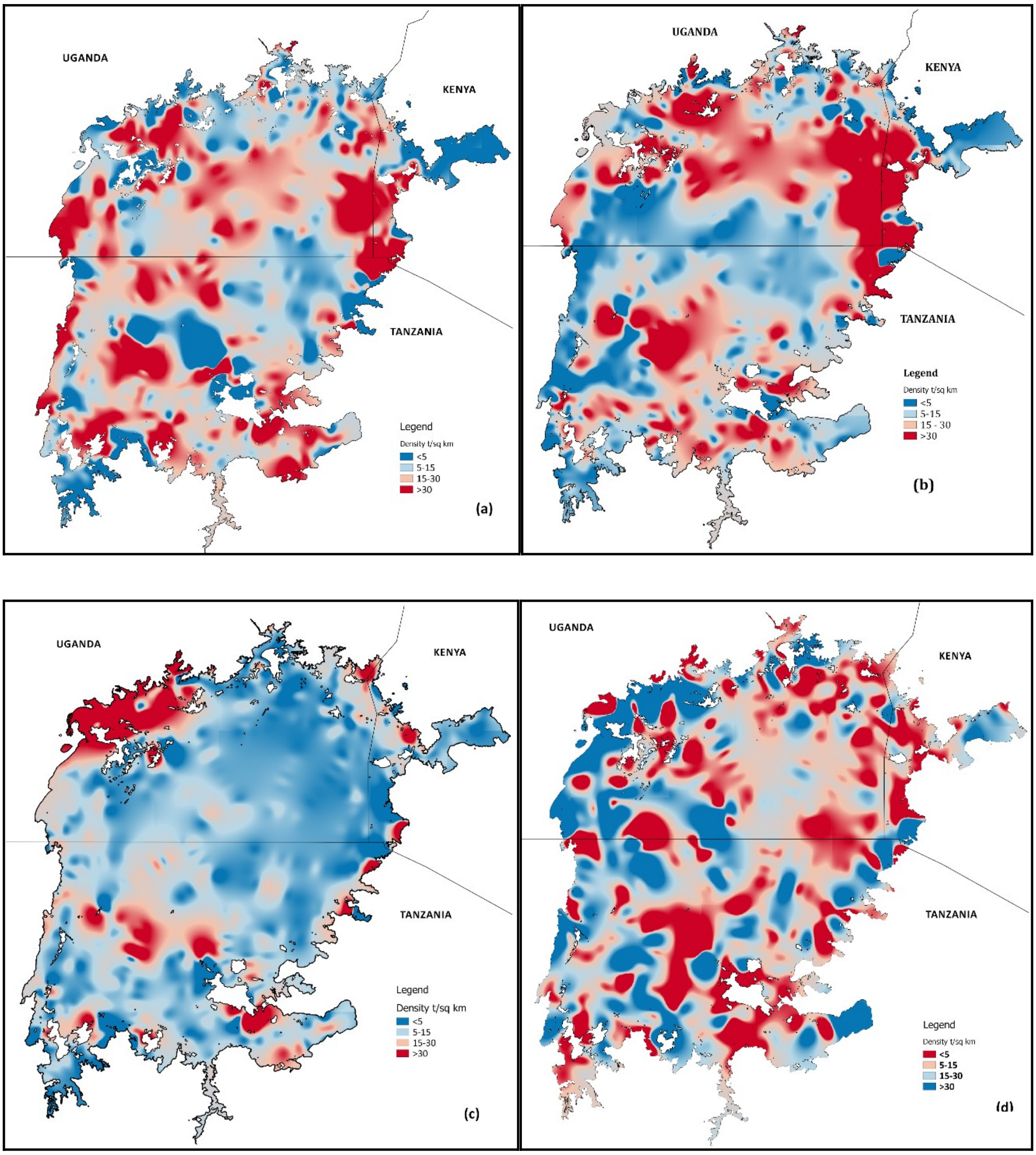

Figure 3. Spatial distribution of major fish groups and caridina in Lake Victoria during the 2020 hydro-acoustic survey. (a) Nile perch, (b) *Dagaa*, (c) Haplochromines and others, and (d) and *Caridina nilotica*.

The length frequency distribution of Nile perch above 10 cm total length (TL) is shown in Figure 4. 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). However, the North-western portion of the lake (Uganda) had a higher proportion of fish above 50 cm than other parts of the lake, a trend that has been consistent since 2018, which can be attributed to the enforcement by the Fisheries Protection Unit (FPU). However, the results may also suggest that enforcement is possibly concentrated on the western side than in the Eastern side.

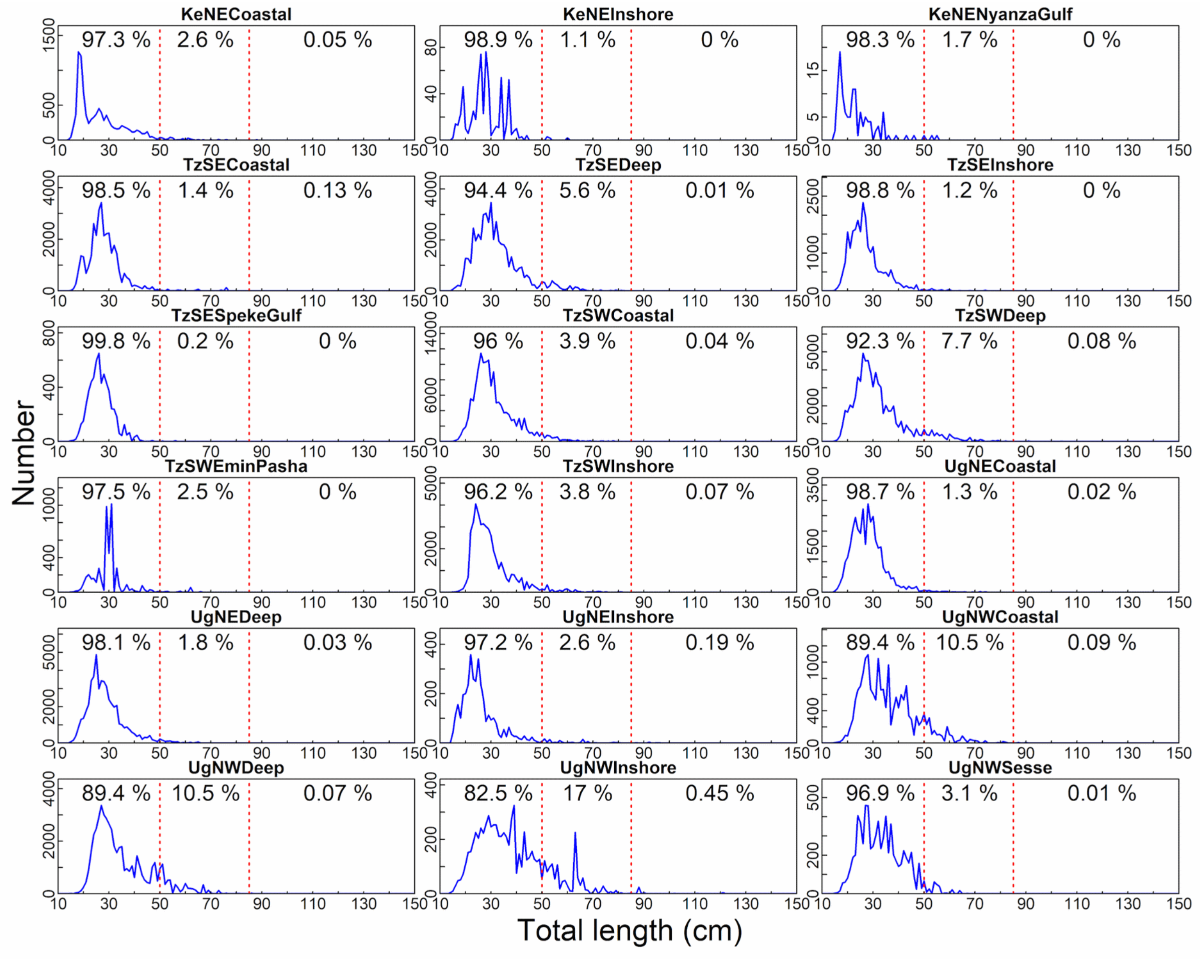

Figure 4. Length frequency distribution of Nile perch determined from acoustic single target detections during the September 2019 survey.

3.2. Standing stock of dagaa

Table 4 shows the estimated densities and biomass of *dagaa* in different regions of the lake. The lake-wide estimated mean standing stock was 950,714 tons, representing about 10% increase compared to biomass in the previous year (2019). However, the increase was only observed in Uganda and Kenya; for Tanzania, the species' biomass decreased. The lower and upper limits of the 95% CI were 791,832 and 1,125,529, respectively. At country level, biomass per unit of habitat area was high in Kenya, with an average density of 20.56 t/km^2, followed by Uganda (16.13 t/km^2), and lowest in Tanzania (12.02 t/km^2). Generally, *dagaa* was more abundant in coastal and deep transects compared to inshore transects (Figure 3b).

Table 4: Density and biomass estimates of dagaa in Lake Victoria by country and stratum.

Region parameters			**Densities (t/ km^2)**			**Biomass (tons)**		
Quadrant	**Stratum**	**Areas (Sq.km)**	**Tanzania**					
			low	high	mean	Low	High	Mean
SW	Inshore	3181	6.31	8.82	7.52	20,065	28,066	23,909
SW	Coastal	6601	12.37	16.97	14.50	81,622	112,019	95,687
SW	Emin pasha	2022	5.04	8.42	6.64	10,190	17,026	13,423
SW	Deep	6251	11.23	17.30	14.10	70,197	108,166	88,129
SE	Inshore	2003	14.09	18.15	16.06	28,225	36,356	32,163
SE	Coastal	5786	13.96	20.93	17.26	80,780	121,074	99,892
SE	Speke Gulf	2909	11.76	17.32	14.40	34,195	50,377	41,895
SE	Deep	6166	4.98	6.54	5.72	30,684	40,342	35,263
Subtotal						**355,959**	**513,426**	**430,359**
			Uganda					
NW	Inshore	3115	10.41	13.74	12.01	32,430	42,814	37,413
NW	Coastal	4865	3.36	5.23	4.24	16,339	25,442	20,618
NW	Sesse	2494	16.31	22.50	19.35	40,670	56,106	48,268
NW	Deep	6226	11.68	16.55	14.05	72,730	103,049	87,488

NE	Inshore	3966	7.93	10.36	9.08	31,447	41,082	35,995
NE	Coastal	2704	18.67	24.29	21.39	50,485	65,688	57,830
Ne	Deep	4724	27.47	38.39	32.77	129,756	181,355	154,804
Subtotal						**373,856**	**515,535**	**442,417**
			Kenya					
NE	Inshore	1763	10.16	19.33	14.18	17,912	34,076	24,994
NE	Nyanza Gulf	1335	4.64	7.72	6.12	6,198	10,304	8,175
NE	Coastal	1082	35.03	48.23	41.38	37,906	52,189	44,770
Subtotal						**62,016**	**96,568**	**77,938**
Total		**67,193**				**791,832**	**1,125,529**	**950,714**

3.3. Standing stock of Haplochromines and others

Table 5 shows the densities and biomass of haplochromines and other species estimated in different regions of the lake. The estimated mean biomass for the whole lake was 517,850 tons, representing about 15% of the total fish biomass in the lake. This estimate represents a 42% increase compared to the previous survey of 2019. The lower limit of the 95% CI was 427,996 tons, while the upper limit was 617,439 and tons. There was no significant difference in abundance (biomass per unit of habitat area) between the three countries, with the biomass averaging between 8 and 8.6 t/km^2.

Table 5: Estimated standing stock of Haplochromine cichlids and other unidentified fish species in Lake Victoria by country and by strata

Regions parameters			**Densities (t/km^2)**			**Biomass (tons)**		
Quadrant	**Stratum**	**Areas (Sq. km)**	**Tanzania**					
			Low	**High**	**Mean**	**Low**	**High**	**Mean**
SW	Inshore	3181	5.49	7.12	6.27	17,465	22,649	19,960
SW	Coastal	6601	7.29	9.97	8.50	48,152	65,828	56,095
SW	EP	2022	4.92	7.31	5.99	9,945	14,779	12,107
SW	Deep	6251	8.56	11.12	9.81	53,478	69,525	61,348
SE	Inshore	2003	8.53	14.59	11.28	17,093	29,222	22,602
SE	Coastal	5786	7.55	12.07	9.72	43,690	69,857	56,216
SE	SG	2909	7.13	9.97	8.45	20,736	28,990	24,589
SE	Deep	6166	4.02	5.22	4.60	24,766	32,199	28,367
Subtotal						**235,324**	**333,048**	**281,283**
			Uganda					
NW	Inshore	3115	16.13	23.66	19.82	50,254	73,715	61,751
NW	Coastal	4865	4.59	5.73	5.14	22,353	27,857	25,019
NW	SI	2494	11.07	22.27	16.39	27,612	55,542	40,876
NW	Deep	6226	4.64	5.68	5.14	28,870	35,350	31,984
NE	Inshore	3966	3.66	5.23	4.39	14,529	20,729	17,400
NE	Coastal	2704	2.89	3.66	3.25	7,809	9,901	8,793
NE	Deep	4724	2.28	2.82	2.54	10,787	13,325	12,006
Subtota						**162,2**	**236,4**	**197,8**

l						**14**	**19**	**29**
			Kenya					
NE	Inshore	1763	11.30	18.77	14.86	19,923	33,092	26,194
NE	NG	1335	2.62	3.08	2.84	3,496	4,114	3,788
NE	Coastal	1082	6.51	9.95	8.09	7,039	10,765	8,756
Subtotal						**30,458**	**47,971**	**38,738**
Total		**67193**				**427,996**	**617,439**	**517,850**

3.4. Standing stock of *Caridina nilotica*

The densities and biomass of *Caridina nilotica* estimated for the different regions/quadrant and depth strata are shown in Table 6. The mean biomass for *C. nilotica* was 972,726, tons representing about 28% of the total biomass in the lake. The lower limit of the 95% CI was 661,906 tons, while the upper limit was 1,353,323 tons. Biomass per unit area was highest (15.0 tons/km^2) in Uganda and lowest (11.7 tons/km^2) in Tanzania, respectively. Spatial variations in biomass were observed. In Tanzania, high densities were observed in Southwest Coastal and deep areas. In Uganda, high densities were observed in North-west inshore areas, while in Kenya Nyanza gulf had high density.

Table 6: Density and biomass estimates of *Caridina nilotica* in Lake Victoria by country and stratum

Region parameters			**Densities (t/km^2)**			**Biomass (tons)**		
Quadrant	**Stratum**	**Areas (Sq. km)**	**Tanzania**					
			Low	**High**	**mean**	**Low**	**High**	**Mean**
SW	Inshore	3181	11.37	18.97	14.82	36,156	60,357	47,149
SW	Coastal	6601	13.91	21.54	17.48	91,819	142,207	115,411
SW	EP	2022	4.32	18.97	10.89	8,743	38,356	22,013
SW	Deep	6251	13.90	26.01	19.68	86,906	162,569	123,016
SE	Inshore	2003	4.55	10.61	6.96	9,110	21,253	13,938
SE	Coastal	5786	7.88	19.34	12.68	45,568	111,878	73,347
SE	SG	2909	3.41	29.15	14.07	9,913	84,788	40,932
SE	Deep	6166	10.58	17.29	13.73	65,236	106,582	84,671
Subtotal						**353,451**	**727,991**	**520,477**
			Uganda					
NW	Inshore	3115	31.60	58.91	44.20	98,427	183,508	137,680
NW	Coastal	4865	11.78	24.23	17.45	57,320	117,860	84,886
NW	SI	2494	4.92	14.08	8.82	12,266	35,113	22,008
NW	Deep	6226	6.08	15.93	10.45	37,827	99,207	65,083
NE	Inshore	3966	6.35	13.14	9.51	25,174	52,102	37,704
NE	Coastal	2704	4.76	8.00	6.18	12,881	21,622	16,710

NE	Deep	4724	7.26	9.73	8.42	34,300	45,950	39,786
Subtotal						**278,195**	**555,361**	**403,855**
			Kenya					
NE	Inshore	1763	3.68	15.27	9.03	6,479	26,916	15,916
NE	NG	1335	12.79	20.95	16.72	17,071	27,966	22,325
NE	Coastal	1082	6.20	13.95	9.38	6,710	15,090	10,153
Subtotal						**30,260**	**69,972**	**48,394**
Total		**67,193**				**661,906**	**1,353,323**	**972,726**

3.5. Temporal changes in abundance of fish and *Caridina nilotica* in Lake Victoria

Generally, the biomass of fish groups, except haplochromines and 'others' have continued to expand since 2017 (Figure 5), except *dagaa*, which decreased in Tanzania between 2019 and 2020 (Figure 6). Nile perch and *dagaa* biomass have almost doubled, while *C. nilotica* has increased by three-folds; however, the increase, especially for Nile perch, is more pronounced in Uganda and Tanzania, which is consistent with the level of enforcement by the FPU and multi-sectoral task force in Uganda and Tanzania, respectively. Whereas haplochromines and 'others' do not show similar trend, the down-ward trend was halted after 2017, currently fluctuating between 6 and 8 tons/km^2, given that its abundance is much controlled by predators (Nile perch).

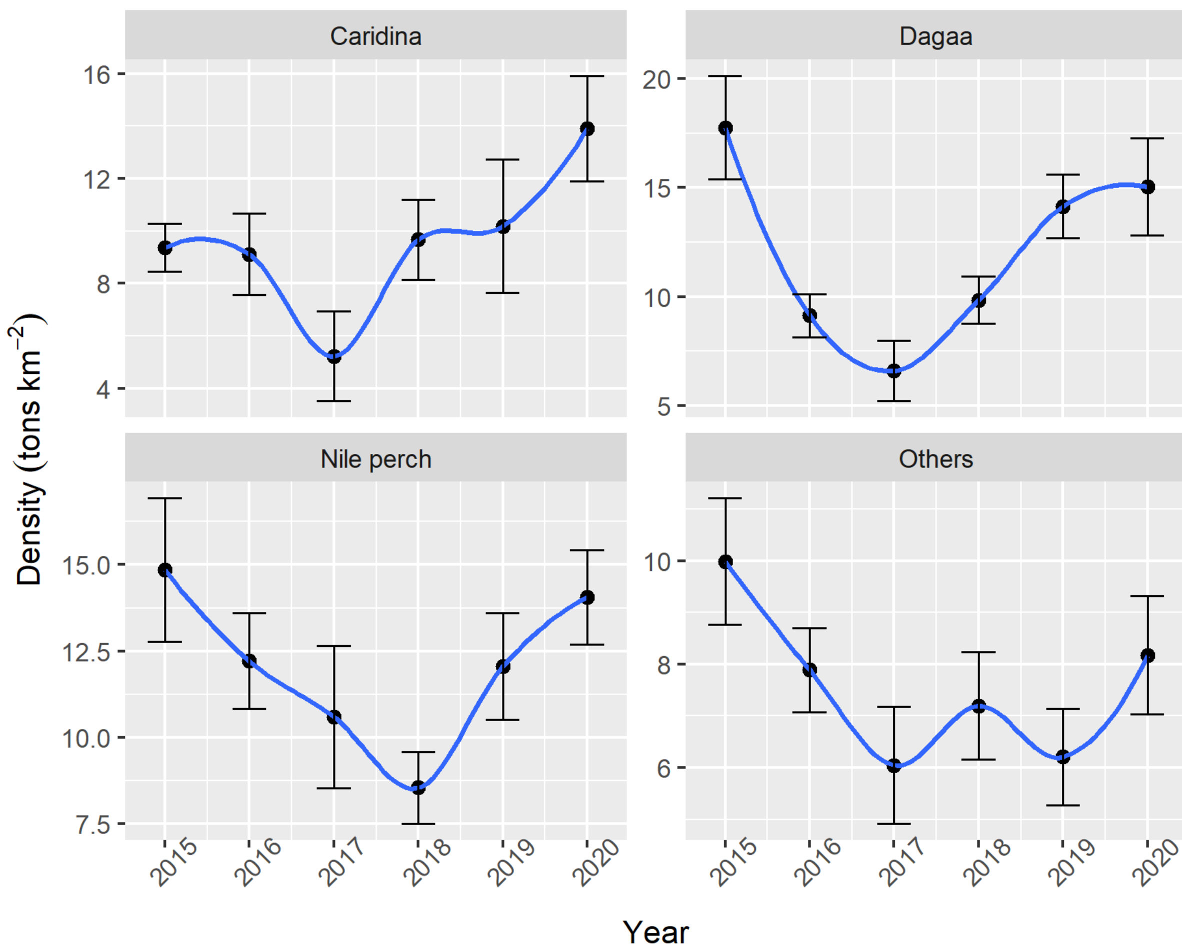

Figure 5: Changes in abundance (biomass per unit of habitat area) of fish and shrimp (*Caridina nilotica*) estimated through acoustic surveys over years

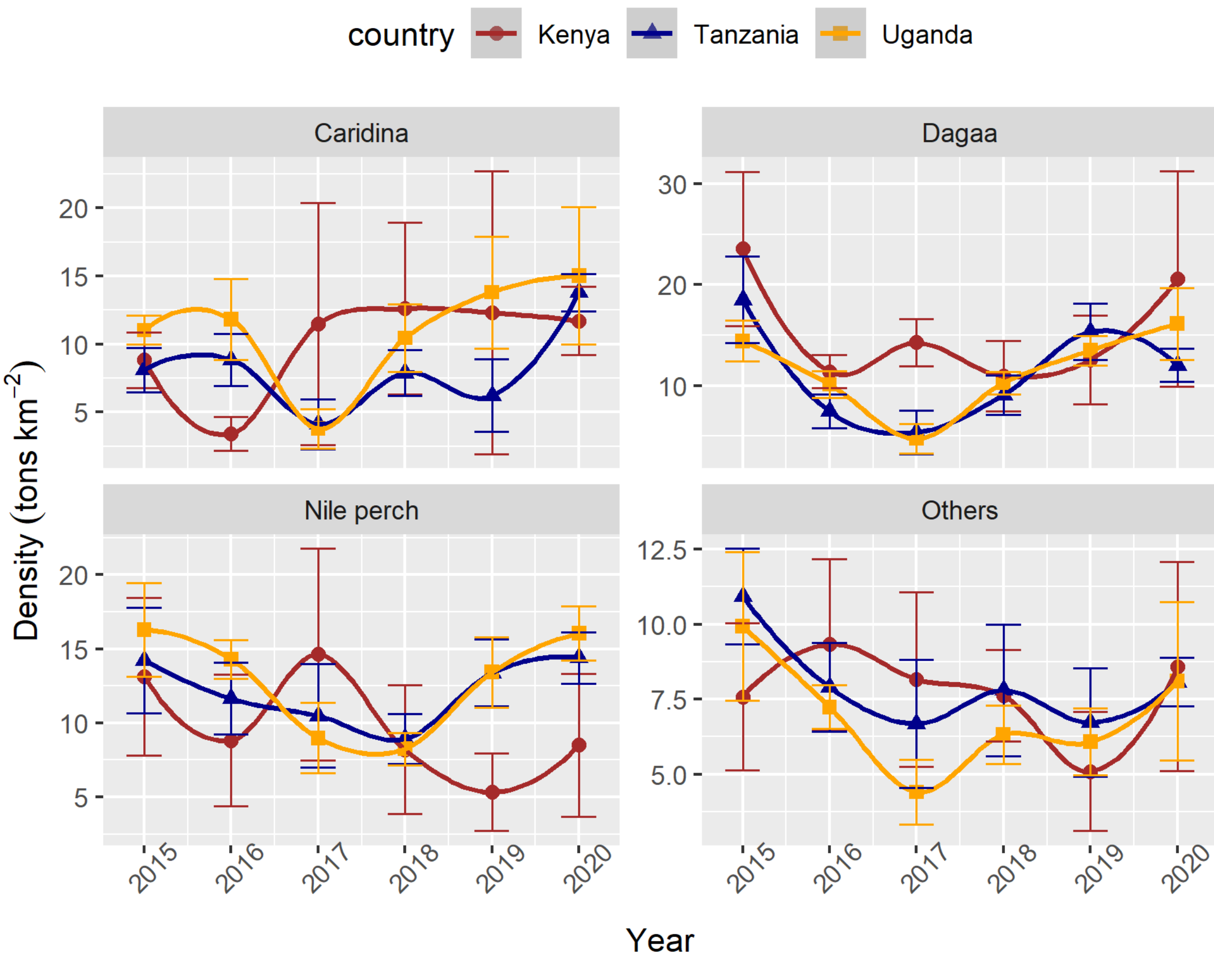

Figure 6: Changes in abundance (biomass per unit of habitat area) of fish and shrimp (*Caridina nilotica*) by country

3.6. Relationship between fish biomass from acoustics and catch rates from bottom trawl hauls

Figure 7 shows results of multiple correlations between biomass estimates from acoustics and catch rates from bottom trawl hauls. Unlike the previous survey, where Nile perch biomass from acoustics was strongly correlated with catch rates, the correlation during this survey was negative. This trend can be attributed to stratification, with incidences of anoxia, especially in the northern parts of the lake. This was also evident from the echograms, where fish was most concentrated in the pelagic zone, with most of the bottom trawls coming out empty.

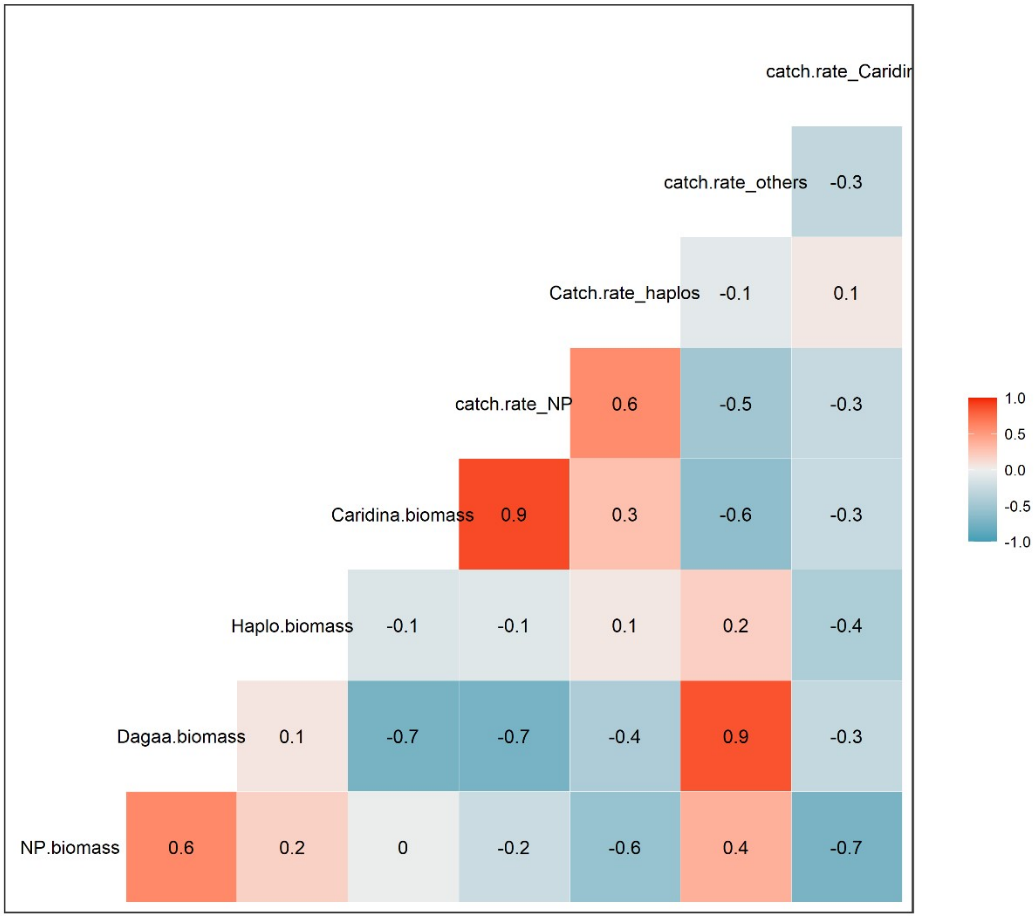

Figure 7 Relationship between spatial fish biomass trends and catch rates from net bottom hauls. NP stands for Nile perch, haplos stands for haplochromines

3.7. Relationship between fish distribution and environmental parameters

Observations across fifty-six (56) sampling points and 3035 data-points for each parameter indicated widespread thermal stratification patterns, with more pronounced thermally stratified waters occurring in the South Western North Western, North Eastern sectors. Dissolved oxygen (DO) profiles showed instances of prominent anoxia or below critical levels of DO occurring at the bottom depth zones, consistent with low fish catch rates from bottom trawls. Otherwise, environmental conditions of the lake remained within the normally recorded ranges. The lake-wide mean temperature was 24.98±1.07 ºC which compares with the mean temperatures recorded in the previous year. Dissolved Oxygen (DO) recorded a lake-wide mean of 5.44±1.97 mgL-1. The relationship between fish abundance (biomass) and limnological parameters is shown in Figure 8. With the exception of dissolved oxygen, Nile perch appeared to be negatively correlated with all environmental variables (turbidity, chlorophyll a, conductivity, and temperature), which were generally high in inshore and special areas (most prominently Nyanza Gulf).

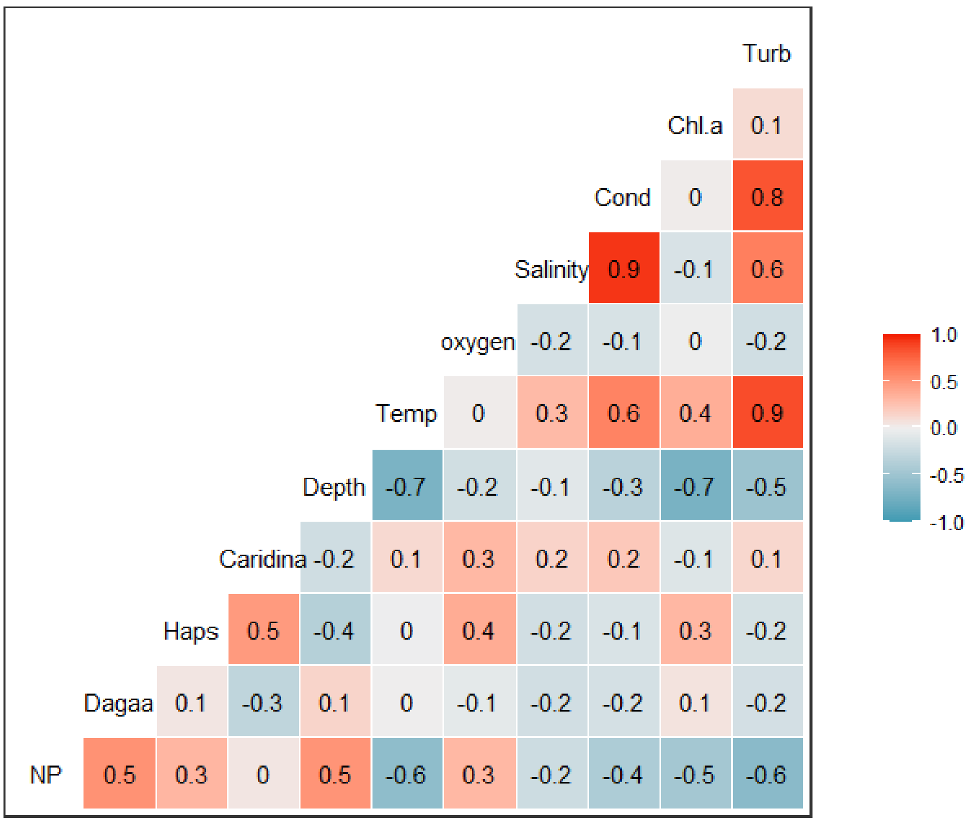

Figure 8: Relationship between biomass densities and environmental parameters under different regions.

3.8. Bottom classification results and analysis

The Bottom surface backscattering strength (BSBS) distribution classes as shown in Figure 9 demonstrates the sediment distribution along Lake Victoria. High BSBS are associated with coarse sediments whereas low values infer to softer and fine sediments, as shown in Table 7 (Siwabessy etal., 2004; Anderson et al., 2011; Snellen et al., 2011; Coasta et al., 2013).

Table 7. Sediment characteristics in relation to BSBS classes

BSBS class	**Classification according to Shepard's triangular diagram**	**Corresponding colors on the acoustic map**
0 to -10 dB	Gravel, silty gravel, sandy gravel, sand silt gravel, gravelly sand	Red
-10 to -15 dB	Gravel silt, sandy silt, silty sand, sand	Yellow
-15 to -20 dB	Sandy silt, silt	Green
<-20 dB	Silt, Mud	Blue

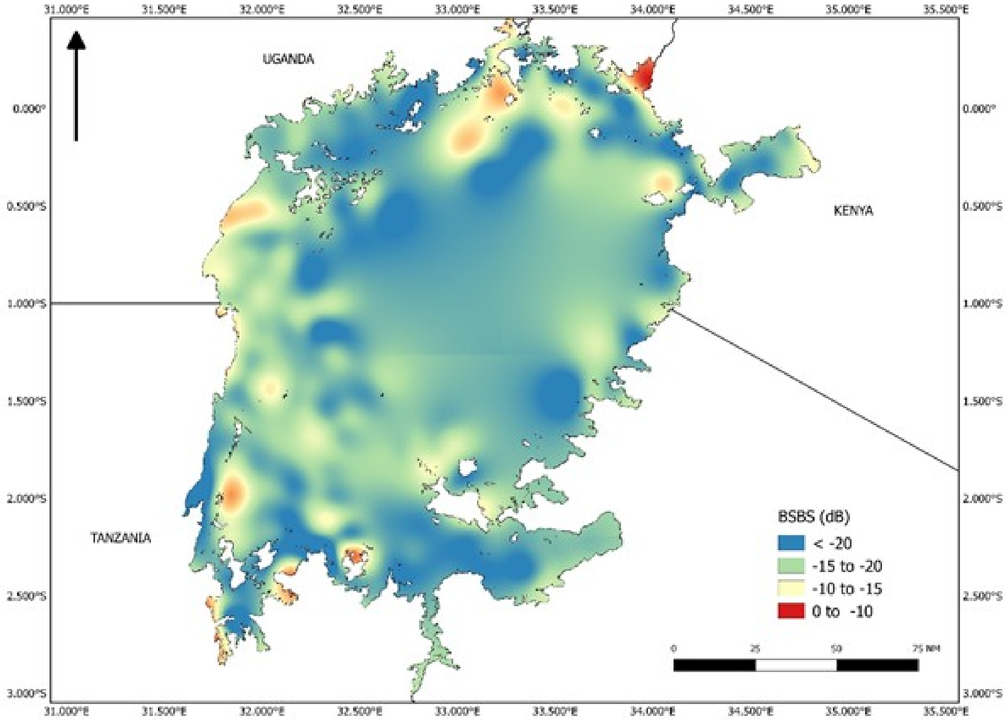

Figure 9: Seabed Acoustic Map generated by surface interpolation of BSBS (Bottom surface backscattering strength) values

The spatial distribution of the BSBS, as shown in Figure 9, demonstrates that a series of high bottom reflectivity of greater than -10 dB are located along most of the shallow inshore regions of the lake ranging from 0 to 20 m deep. This high bottom reflectivity is most likely attributed to the sediment influx of coarser and heavier sediments from rivers discharging into the lake and presence of islands. There seems to be a direct relationship between high bottom reflectivity and the location of the river mouths of R. Sio, R. Nile , R. Kagera, R. Biharamulo as well as islands. Bottoms with intermediate reflectivity values of -10dB and -20 dB predominate most of the coastal regions of the lake ranging from 20 to 40 m deep, which is represented in yellow and green. This pattern could be associated with sandy sediments. Deeper areas of the lake, which are represented in blue, are associated with low acoustic reflectivity values ranging above -20 dB and are associated with soft mud and clay sediments. These characteristics could be attributed to riverine dynamics and sediment dynamics of the lake whereby softer and lighter sediments travel furthest from the point of river discharge. It would, therefore, be important to further investigate the hydrodynamics of Lake Victoria and what role it plays in the dynamics of sediments and its distribution within the lake. Lake bottom hardness was negatively correlated with fish densities (Figure 10). This was especially so for Nile perch and *dagaa* whose abundance was higher in regions where the lake-bed was relatively soft. Further investigations are warranted to help explain the observed relationships.

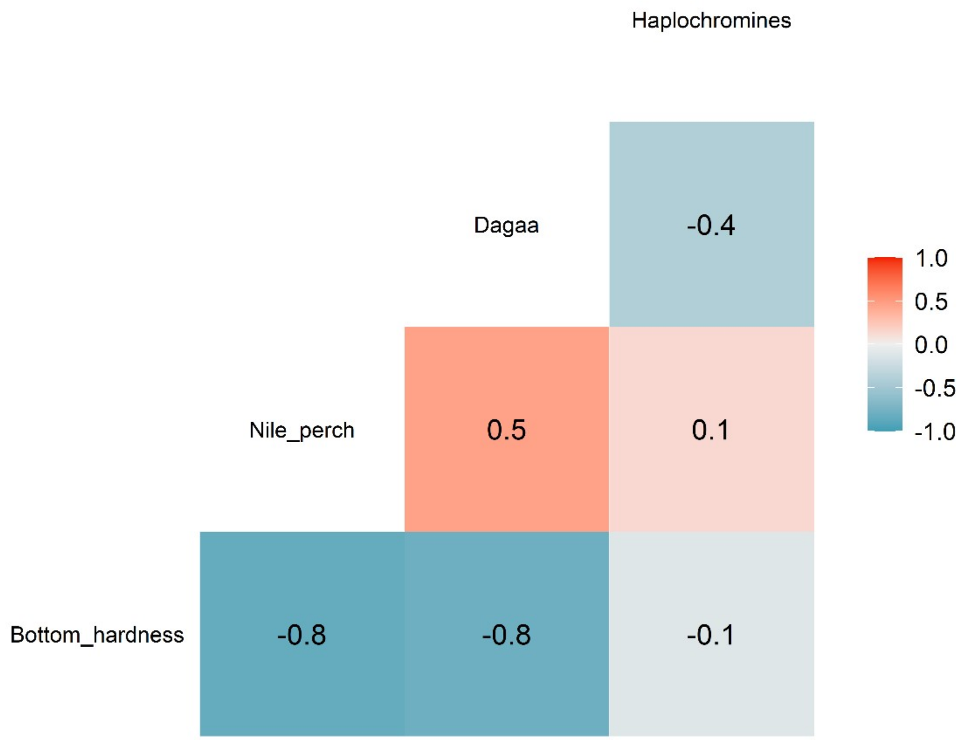

Figure 10: Relationship between fish densities and Bottom surface backscattering strength (BSBS)

4.0. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this survey was to estimate the standing sock of major commercial fish species (Nile perch, *daga*a, haplochromines, and freshwater prawn) in Lake Victoria using acoustic methods. The methods of data analysis were the same as in previous surveys, except that SIMRAD EK 80 echosounder was used in acoustic measurements instead of EK 60. Generally, the results showed an increase in biomass of all fish groups and *C. nilotica*, lakewide, except for *dagaa* which decreased in Tanzania. The increase in biomass, especially for Nile perch, was more apparent in the western side of the lake compared to the eastern side, a trend that has been consistent since 2018. The observed stock status may be due to a combination of many factors, but mainly, the western side being relatively shallower, experiencing more mixing, coupled with the rising water levels, and the level of enforcement possibly being stronger in the western side than the eastern side. The decline in biomass of *dagaa* in the Tanzanian side may be not be a big concern given the high turnover rate of the species. We conclude that the current stocks are in good shape, and the current level of enforcement should be maintained. We recommend that annual hydro-acoustic surveys should be paired with stock assessment, for which there is already capacity in the working group, to generate explicit management recommendations. Consequently, the need to re-analyze all the data from all the past surveys so as to improve reporting on the trends for all the monitored taxa cannot be overemphasized, except that this will need logistical support from LVFO. We further recommend addition of two scientists to the group, with a bias in Fish Biology and Limnology, respectively, to boost the two sections as currently each section is having one scientist each who are overwhelmed.

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APPENDICES

Appendix I: Detailed results from net bottom hauls

A.1.1. Catch composition

During October November 2020 surveys, a total of eleven fish taxa were recorded through 24 net hauls, which were two less compared to the September 2019 survey. During the current survey, *Lates niloticus*, with 89.93%, dominated the catch by weight, followed by Haplochromines (3.56%). Nile perch was less abundant from bottom trawls compared to the previous survey as the lake was stratified with pronounced incidences of anoxia at the bottom. Haplochromines, on the other hand, showed an improvement from 1.95% (2019) 3.56% (2020). The rest was contributed by other fish species (Figure A.1.1).

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

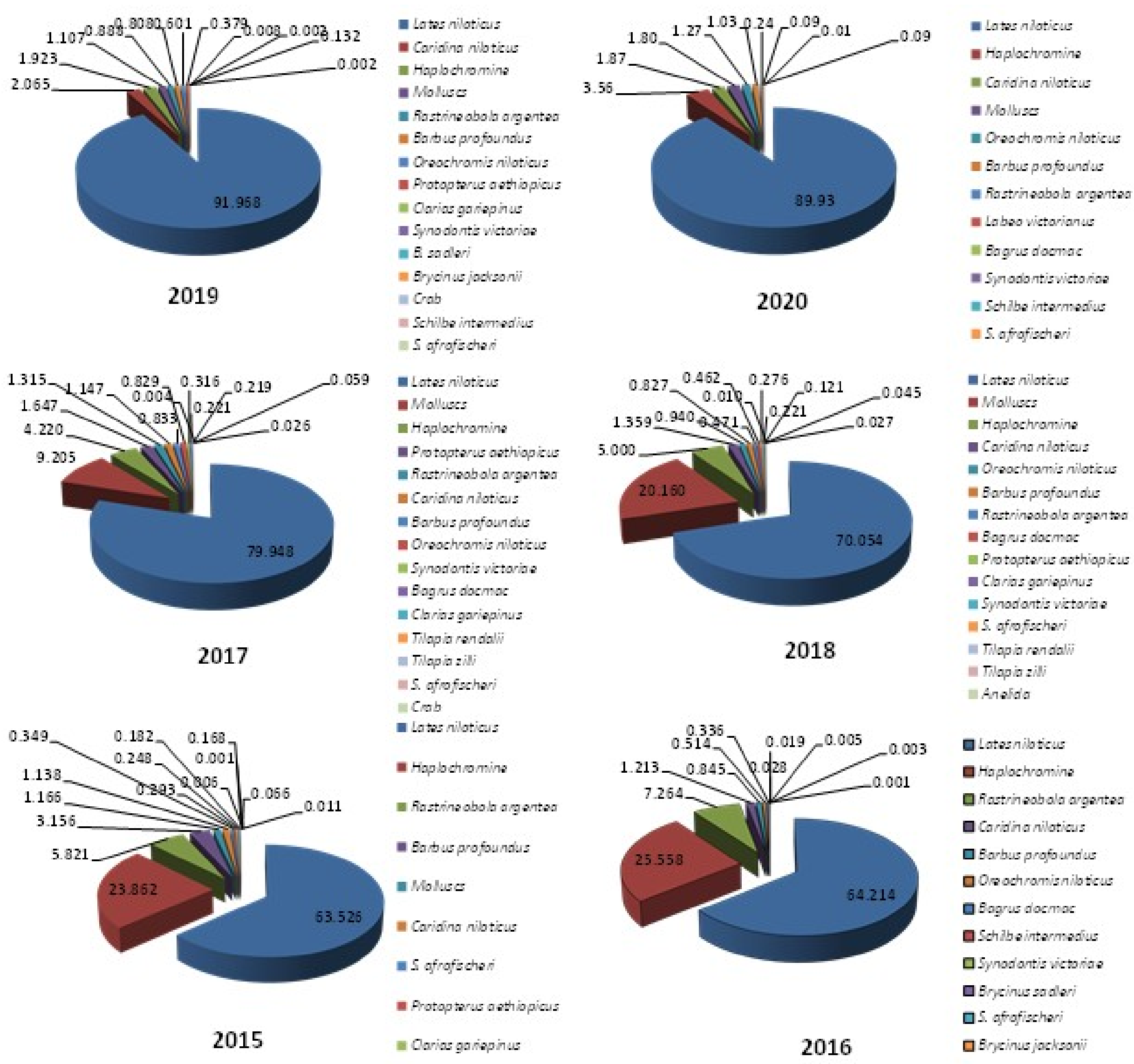

Figure A.1.1: *Catch composition for the survey period of 2015-2019*

Table A.1.1: Changes in % catch composition by weight in Lake Victoria

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

A.1.2. Catch per Unit Effort as an index of Relative abundance

Catch per Unit Effort (CPUE) by quadrant and depth strata are shown in Table A.1.2, while temporal changes for six consecutive years expressed as Kg/haul are shown in Table A.1.2 for the Nile perch, Haplochromines, Dagaa and other fish species combined as ‘others’. Nile perch and haplochromine biomass was higher inshore and coastal areas, consistent with the acoustic data, except that low catch rates in deep areas, especially in the northern part of the lake (Table A.2.4), could have been due to stratification, where most of the fish, as evident on the echograms, was in the middle pelagic zone. This could also explain the decrease in CPUE for Nile perch in 2020. The rest fish species combined as others are seen to be stable since the 2015, although there was a significant increase in 2017.

Table A.1.2: Catch rates per Country per quadrant per stratum in (Kghaul^{-1})

Strata	**Nile perch**	**Haplochromines**	**Others**	**Caridina**
TzSEDeep				
TzSECoastal	115.52±47.32	8.55±6.47	1.86±0.56	2.49±1.96
TzSEInshore	154±0.00	19.44±0.00	0.68±0.00	0.00±0.00
TzSESpekeGulf				
TzSWDeep	3.30±3.30	0.00±0.00	0.00±0.00	0.00±0.00
TzSWCoastal	241.72±19.53	3.09±2.34	1.67±1.67	0.00±0.00
TzSWInshore	197.03±195.6			
TzSWEminPasha	307.43±85.24	5.60±0.18	1.67±1.67	0.00±0.00
UgNWDeep				
UgNWCoastal	151.12±48.12	0.325±0.275	0.50±0.05	0.00±0.00
UgNWInshore	43.76±7.63	0.48±0.27	3.19±3.17	

UgNWSesse				
UgNEDeep	0.00±0.00	0.015±0.015	0.057±0.057	0.00±0.00
UgNECoastal	0.00±0.00	0.055±0.00	0.42±0.00	0.003±0.000
UgNEInshore	0.588±0.00	2.52±0.00	0.476±0.00	31.399±0.00
KeNECoastal	31.74±7.08	4.07±0.345	10.802±7.809	2.40±2.40
KeNEInshore	0.588±0.00	2.52±0.00	0.476	0.00±0.00
KeNENyanzaGulf				

Table A.1.3: Changes in CPUE (Kg/haul) (Kg ± SE) since 2015 to 2020

Period	n	Nile perch	Haplochromines	Dagaa	Other sp
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

A.1.3.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 four successive years expressed as Kg/haul in both quadrants is shown in Table A.1.4. The Overall CPEU for Nile perch, which observed to increase from 79.88±21.40 Kg/haul (2018) to 116.36±29.69Kg/haul (2019), decreased to 85.67±21.71Kg/haul. Nile perch fluctuates in all the quadrant except for SE where it maintains a higher catch rate more than 100 Kg/haul. However, Haplochromine CPUE is inversely related to that Nile perch. In quadrants where there is an increase in Nile perch catch rate, Haplochromine decreases and where there is decreases in Nile perch the haplochromine increases except for NW quadrant where both Nile perch and Haplochromine decreased. The Catch rates for other fish species combined as others show a decrease in the overall catch rates.

Table A.2.4: Changes in CPUE (Kg/haul) (Kg ± SE) based on Quadrants

Quadrant	YEAR	Nile perch	Haplochromine	Dagaa	Other sp
Overall	2020	85.67±21.71	3.39±1.35	0.23±0.11	2.71±1.10
	2019	116.36±29.6	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±14.7	6.29±1.40	1.69±0.71	7.58±2.07
SW	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	2020	86.70±30.67	0.42±0.18		1.93±1.90
	2019	181.36±102.4	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	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±16.6	6.43±4.76	0.92±0.55	3.88±2.7

		2			6
	2017	59.67±19.99	6.45±2.48	0.71±0.59	4.19±2.03
SE	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

A.1.4. Length frequency distribution of Nile perch

The size structure of Nile perch caught during the October-November 2020 surveys ranged from 1cm TL to 150 cm TL, compared 1cm TL to 103 cm Tl for 2019 survey, while total mean length shows slightly increase from 15.0 cm TL in 2019 to 18.39 cm TL. However the overall mean size for Nile perch is still low compared to 25.17 cm TL for the year 2018. The mean length for Nile perch was observed to increase by 58.3% from 15.9 cm TL in 2017 to 25.17cm TL in 2018. This time raised gradually to 18.39 cm TL. Furthermore 97.03 % of the Nile perch caught were below the lower limit of slot size (50 cm TL). This means out of 22,686 Nile perch caught only 674 equivalents to 2.97% by number were within the slot size of 50-85 cm TL.

Overall length distribution pattern of the Nile perch in 2020 differ from that of 2018 survey results (Figure A.1.2). The 2018 distribution had bimodal distribution with modes at 9 and 24 cm TL, while the current 2019 had mode at 7 cm TL. Although there is some decline in mean size of the *Lates niloticus*, when you compare the two modes, the decline is not substantial.

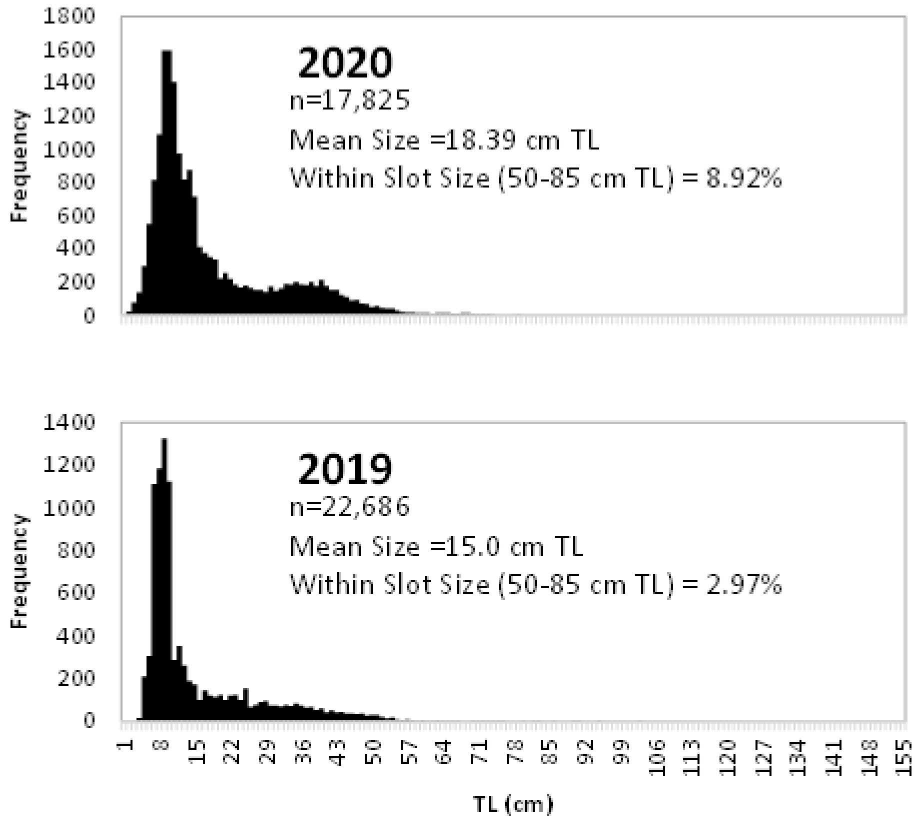

Figure A.1.2: Overall population structure of *Lates niloticus* for two consecutive surveys.

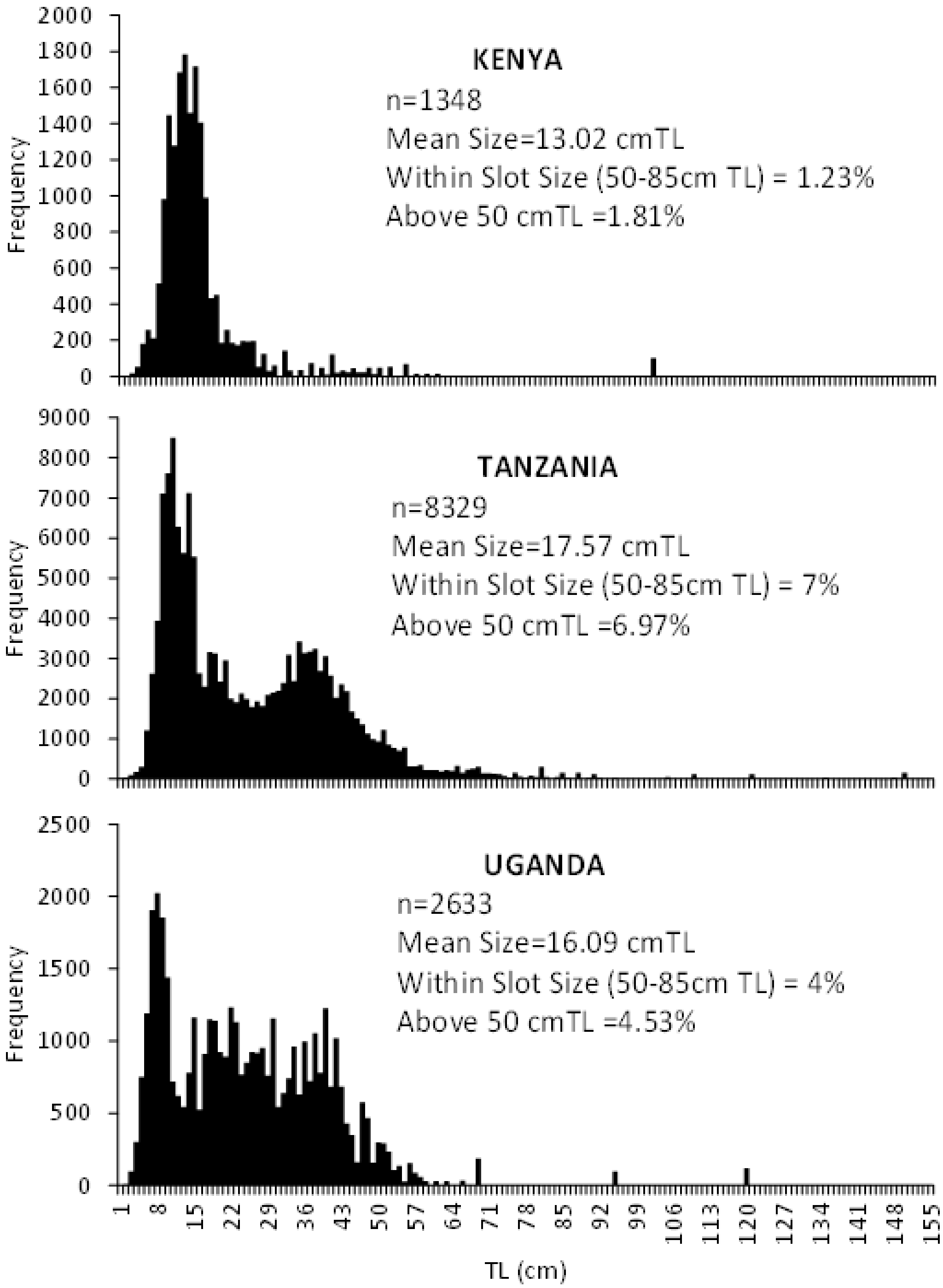

Figure A.1.3: Population structure of *Lates niloticus* in partner states for the 2020 survey.

Length frequency distribution of *Lates niloticus* by quadrants is given in Figure A.1.3. Small sized fish dominated in the four quadrants as well as into the overall population structure. The lowest mean length was recorded in the SW quadrant and the highest in NW quadrant. The lowest and highest percentages of fish of 50 cm TL and above were found in NE and SW quadrants respectively (Table A.1.5).

Table A.1.3: Size characteristics of Nile perch by quadrants in Lake Victoria

Quadrant	**Year**	**Mean TL (cm)**	**n**	**%>50.0 cm TL**
SW	**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
	2015	12.6	5801	0.99
NW	**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
	2015	17.39	624	0.64
NE	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
	2015	12.12	1327	0.08
SE	**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
	2015	10.84	4255	0.35

A.1.5. Size characteristics of Nile perch in relation to their weight for different year

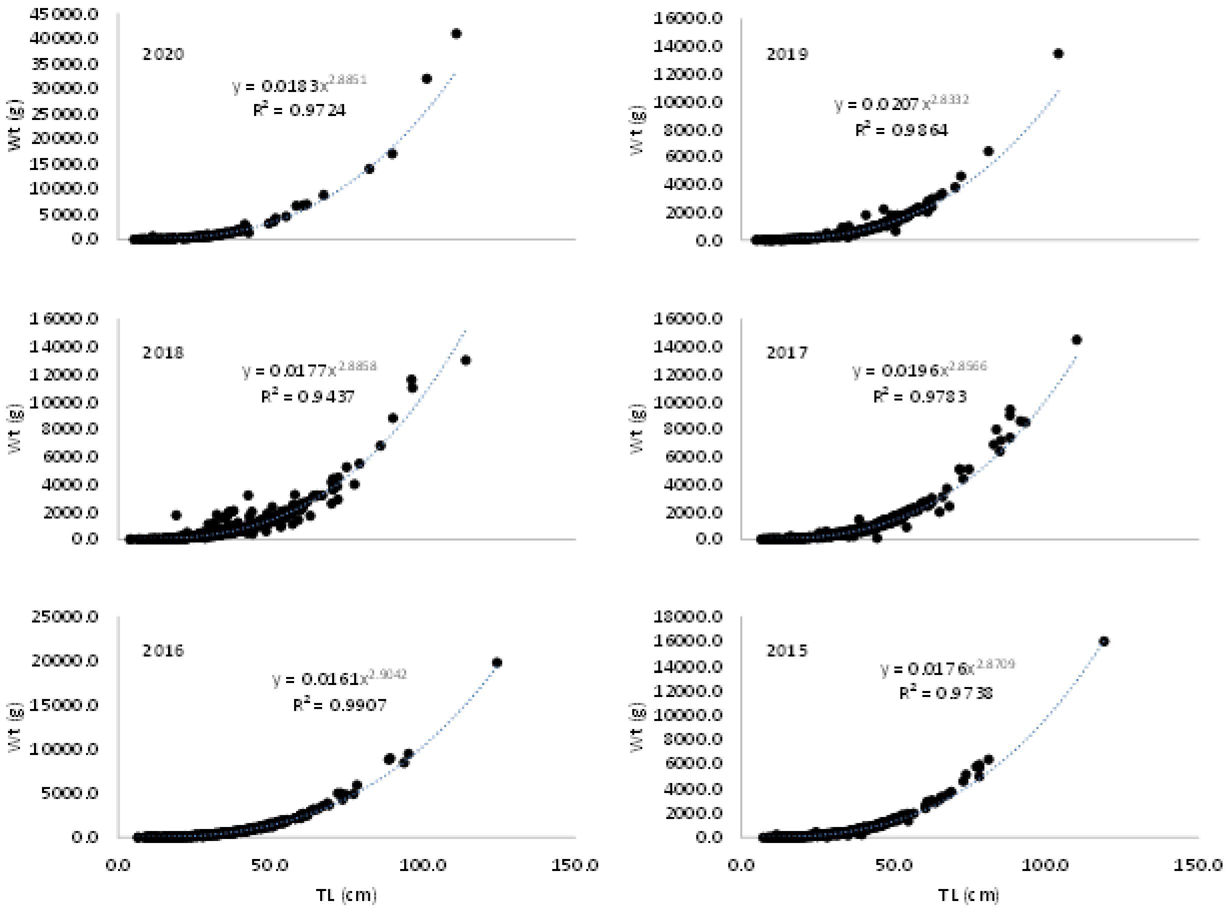

Figure A.1.4: Length Weight Relationship of Nile perch

Size characteristic of Nile perch has been shown in figure 2, 3, & 4 above and in quadrants in Table 3 above.

A.1.5. Food and feeding for Nile perch

A total of 164 Nile perch stomachs were gutted compared to 457 and 502 stomachs for the 2019 and 2018 survey, respectively, out of which only 71 equivalents to (43.56%) stomachs contained food items with different fullness. Four stomachs were empty stomach and 88 stomachs were extruded due to pressure difference caused by depth effects during net hauling. Out of 163 gutted stomachs with prey, 47 were full stomach, 6 were three quarters stomach, 8 were half stomach, and 10 were quarter stomach. The diet of Nile perch was dominated by *Caridina niloticus* 64.65%, Haplochromines 34.67% and followed by Dagaa 0.38%. 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 A.1.5). However, a change in diet of Nile perch with size was observed (Figure A.1.6). *Caridina niloticus* formed an important food item for the diet of young *L. niloticus* especially the fishes below 40 cm TL contributing to more than 50% of their diet, while haplochromines dominated in the diet of Nile perch above 60 cm TL.

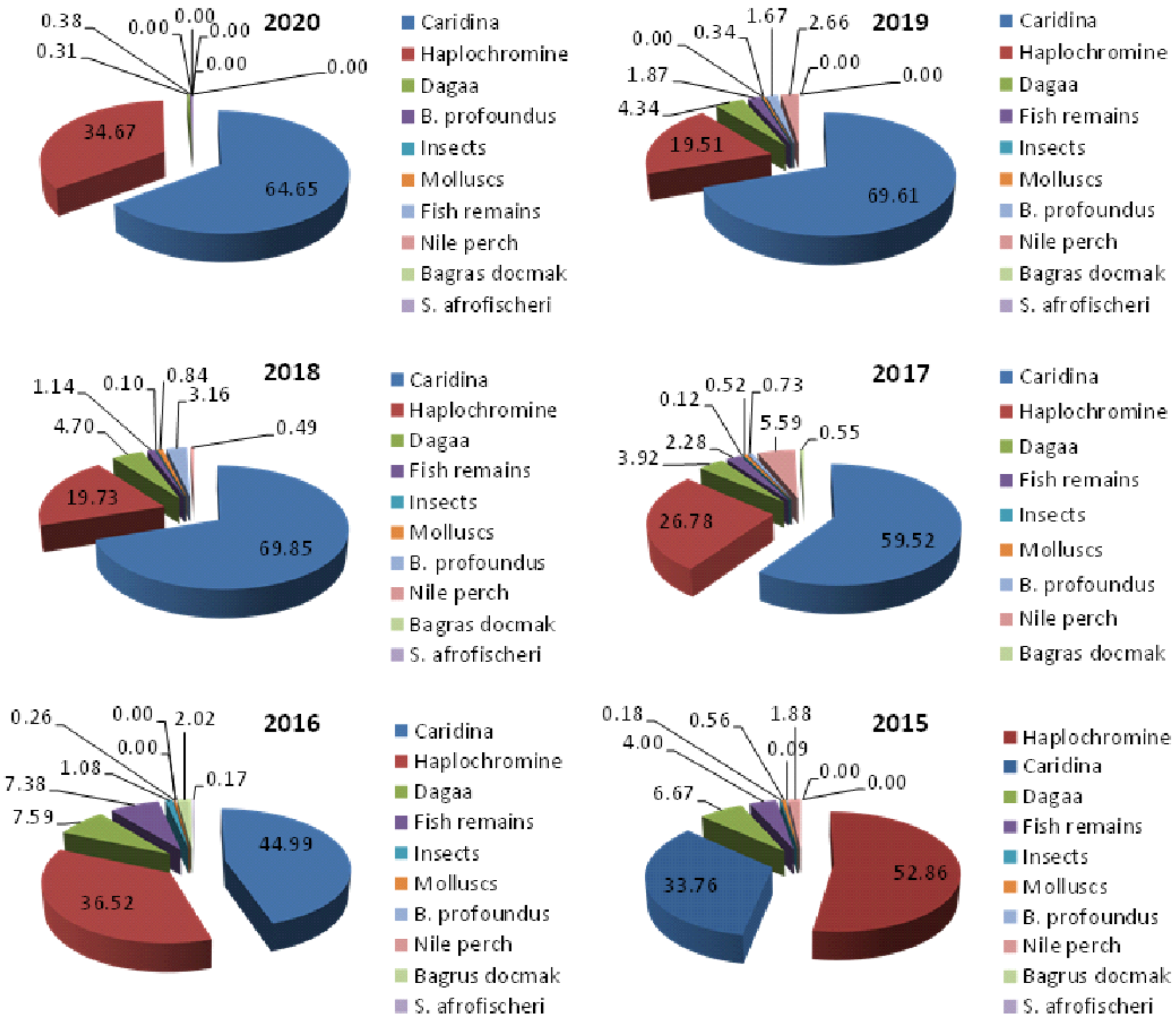

Figure A.1.5: Percentage contribution of different prey items to the diet of *Lates niloticus*

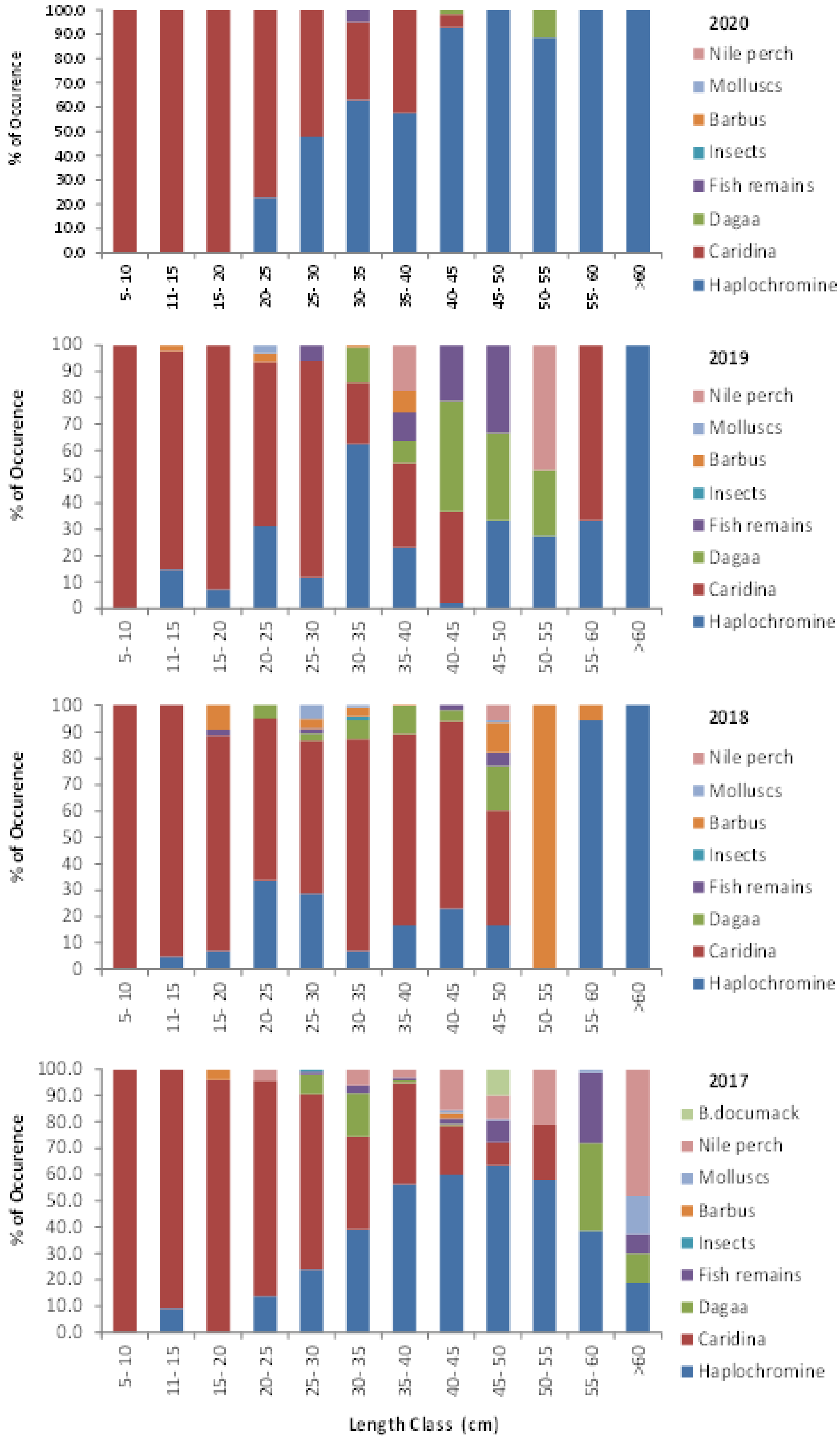

Figure A.1.6: The ontogenetic shift of *Lates niloticus* for its prey

A.1.6. References

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Appendix II: Detailed results for limnological parameters

A.2.1. Overall limnological conditions of the lake

Observations across fifty-six (56) sampling points and 3035 datapoints indicate widespread active thermal stratification patterns, most prominently in the North Western, South 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 dramatic drastic shifts in concentrations down the column, occasioned by the apparent stratification. The lake-wide mean temperature was 24.98±1.07 ºC which compares with the mean temperatures recorded in the previous year. Dissolved Oxygen (DO) recorded a lake-wide mean of 5.44±1.97 mgL^{-1}.

A.2.2. Spatial variations in temperature by quadrant and strata

The North East remained the warmest of all quadrants at a mean (± SD) temperature of 25.21±0.62 ºC compared to the North West at 25.11±0.59 ºC, the South East at 25.03±0.47 ºC, the coldest South west at 24.54±0.89 ºC and the whole lake mean of 24.98±1.07 ºC (Table 1). The Kenyan waters of appeared warmest and the main contributor to the warmth of the North Eastern Sector (Tables 2 & 4). However, a comparison of the magnitude of stratification among the sectors by CTD stations (Fig. 2-8) do not seem to conform to the order of degree of warmth.

Among the depth strata and special ecological areas, the special areas were warmest with Nyanza gulf retaining the warmest conditions at 26.8±0.51 ºC ahead of Speke gulf at 25.7±0.28 ºC and Emin Pasha at

25.17±0.11 °C. The Inshore areas were warmest with mean temperatures of 25.08±1.08 while the Coastal strata had the coldest waters at 24.8±1.2 °C. Temperatures recorded at the Deep transects had a mean of 24.92±0.52 °C. Coldest waters are expected more at greater depths. However, these observations indicate that the deeper transects might have had warmest waters within the column, inferring more pronounced stratification in these areas.

A.2.3. Spatial variations in dissolved oxygen (DO) by quadrants and strata

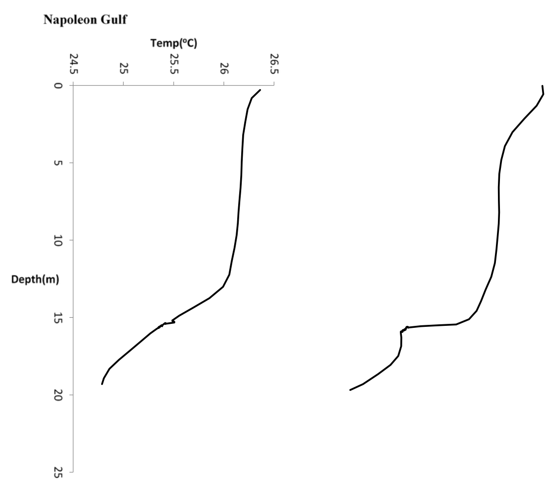
This study recorded comparatively more pronounced oxygen depletion within the deep sections of the water column, generally within the lake. This is attributable to the apparent highly stratified waters throughout the lake. Observations in the NE regions in Ugandan waters indicated more pronounced oxygen depleted waters throughout the column and surface occasioned by apparent recent overturn or intrusion oxygen depleted waters due to undercurrent flows. This was evidenced by the observed presence of suspended sediments, dense algal growth and surface lingering detritus.

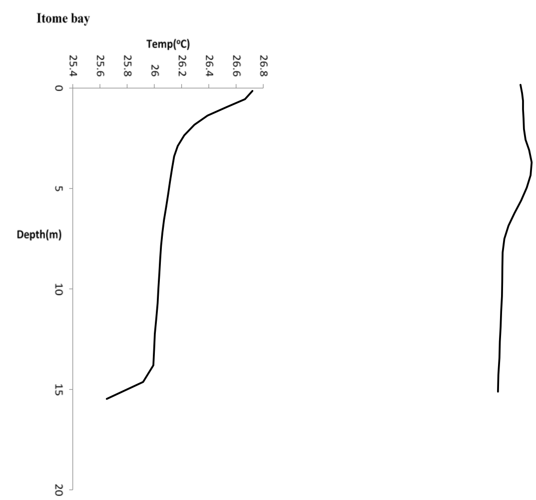
A comparison of the spatial trends by quadrants reveal that the North West recorded the highest DO levels with a mean of 6.51±0.80 mgL^{-1}, followed by the South West with 5.7±1.22 mgL^{-1}, the 5.02±2.05 mgL^{-1} and the South East at 4.9±1.08 mgL^{-1} (Table 1).

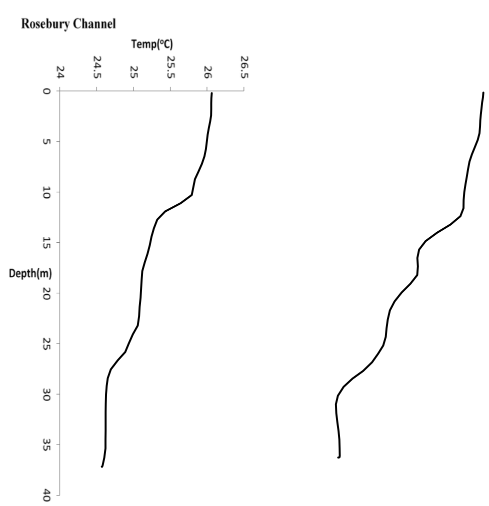
The mean (±SD) DO recorded within the depth strata and special regions in a descending order were; Ssese Island (6.74±1.25 mgL^{-1}), Speke gulf (6.66±0.71 mgL^{-1}), Emin Pasha (5.73±0.69 mgL^{-1}), Inshore (5.44±2.18 mgL^{-1}), Coastal (5.39±1.87 mgL^{-1}), Deep (5.01±2.29 mgL^{-1}) and Nyanza gulf (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 Nyanza gulf (Table 3).

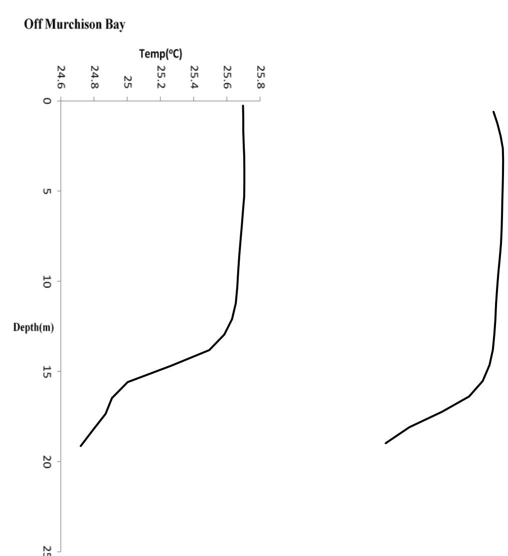
The water column profiles of dissolved oxygen are visualized alongside those of temperatures in figures (Fig. 2-8).

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









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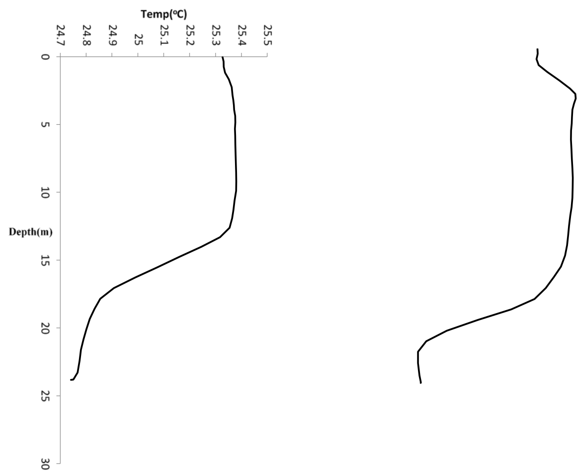

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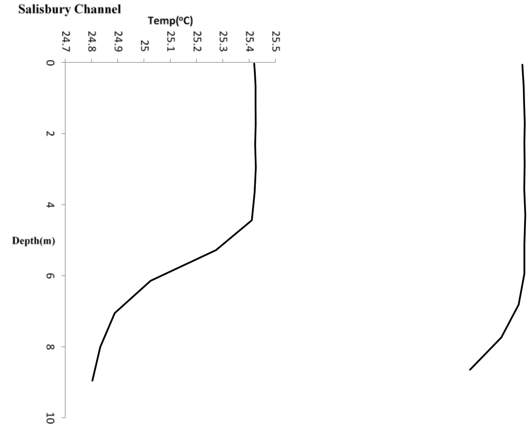
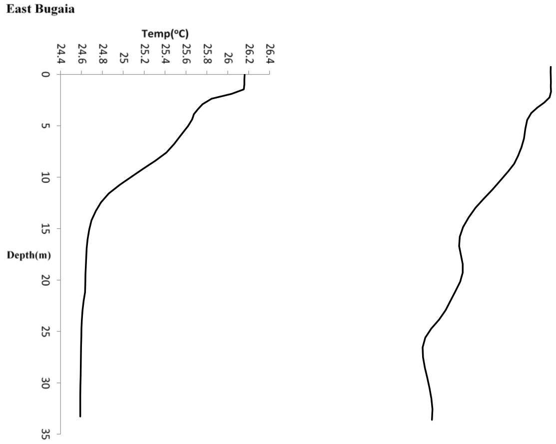


East Bugaia



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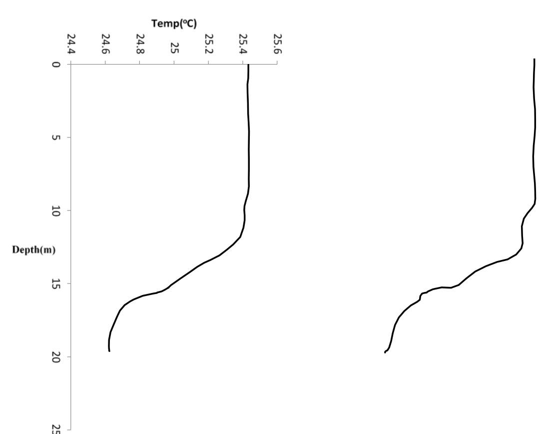

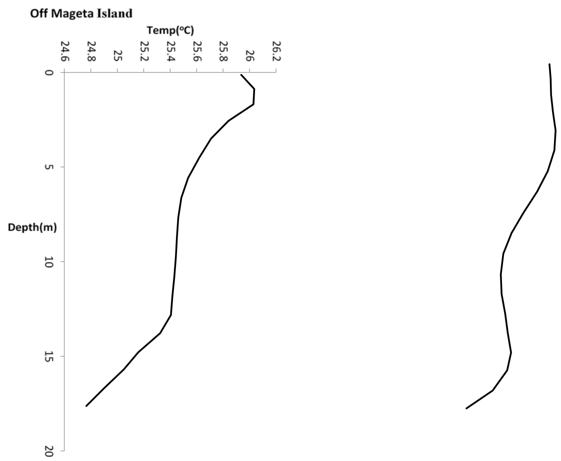
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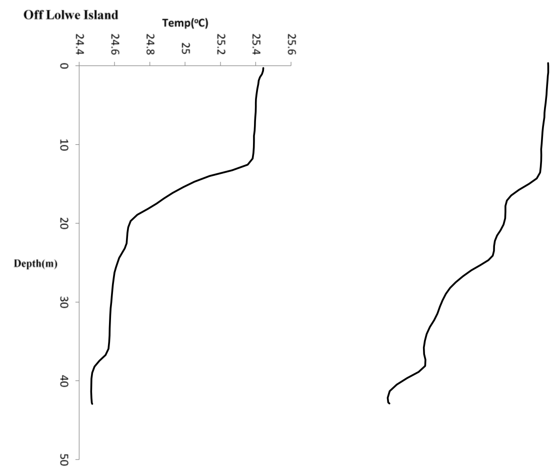
Depth(m)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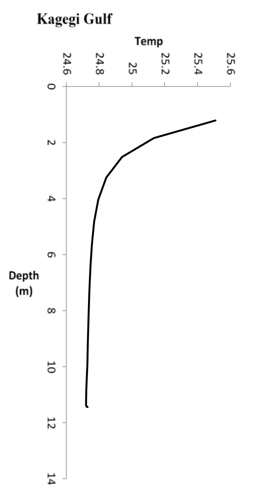
Depth(m)


Kagegi Gulf
Temp
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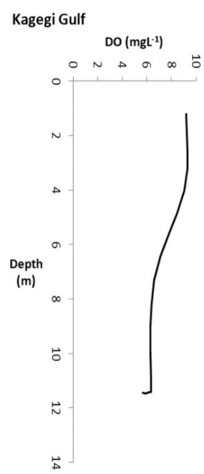
Depth
(m)


Kagegi Gulf
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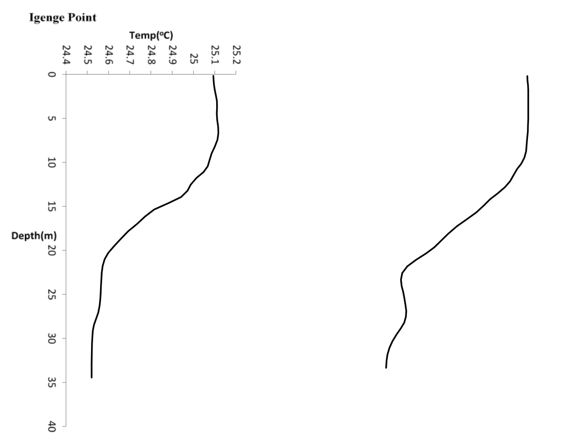
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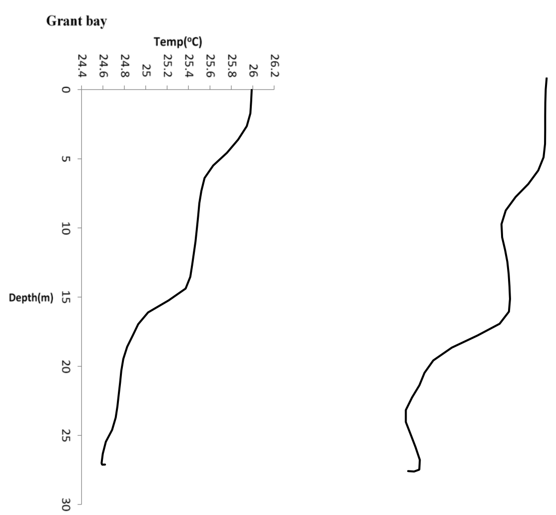
Depth(m)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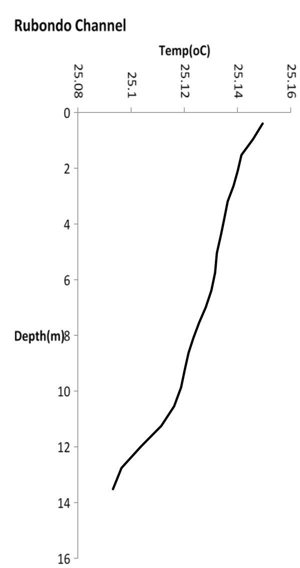
Depth(m)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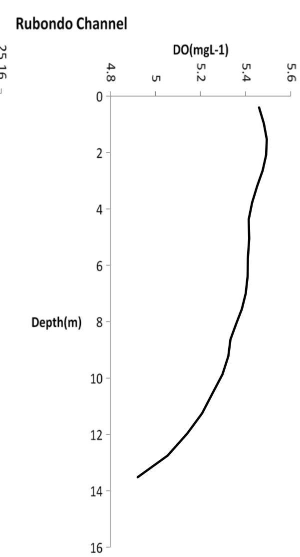
16
Depth(m)


Rubondo Channel
DO(mgL-1)
4.8
5
5.2
5.4
5.6
0
2
4
6
8
10
12
14
16
Depth(m)

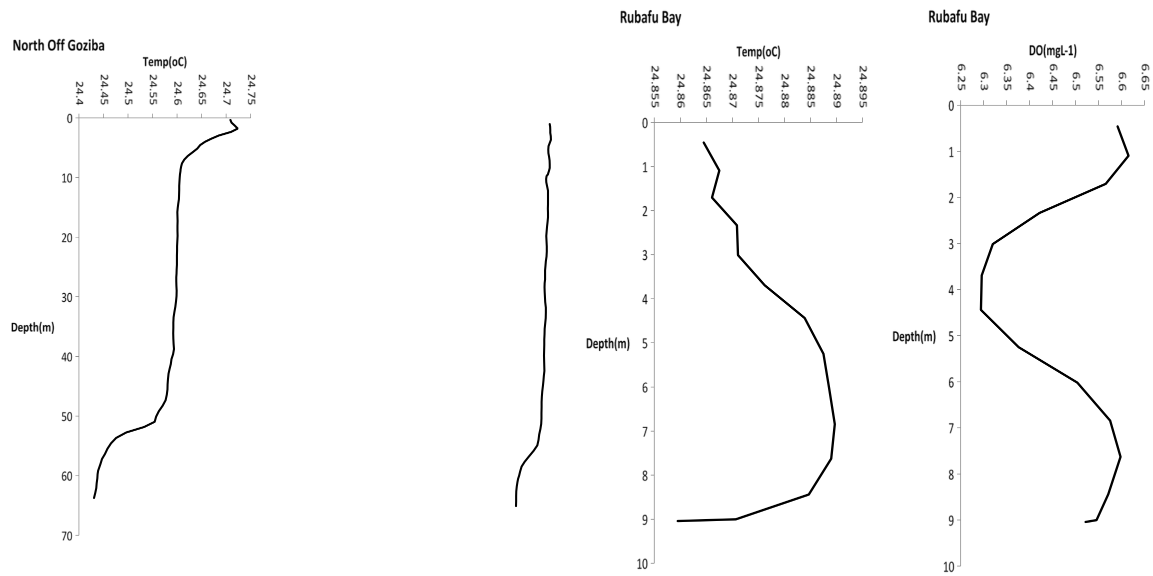
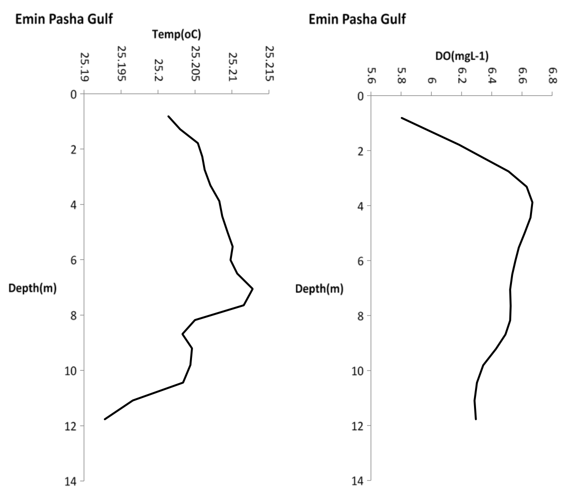


Fig. 2. Temperature and Dissolved oxygen (DO) profiles within the Inshore CTD stations



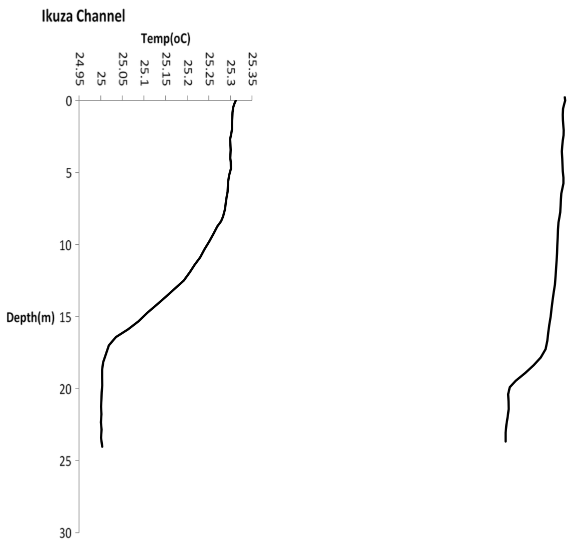


Fig. 3. Temperature and Dissolved oxygen (DO) profiles within the Emin Pasha CTD stations

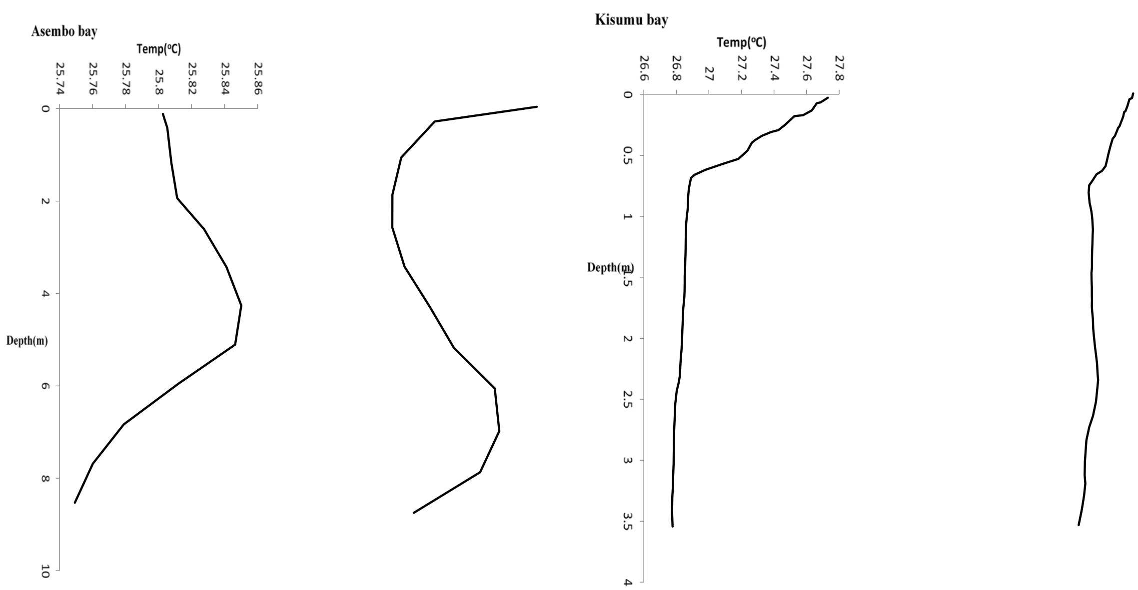


Fig. 4. Temperature and Dissolved oxygen (DO) profiles within the Nyanza Gulf CTD stations

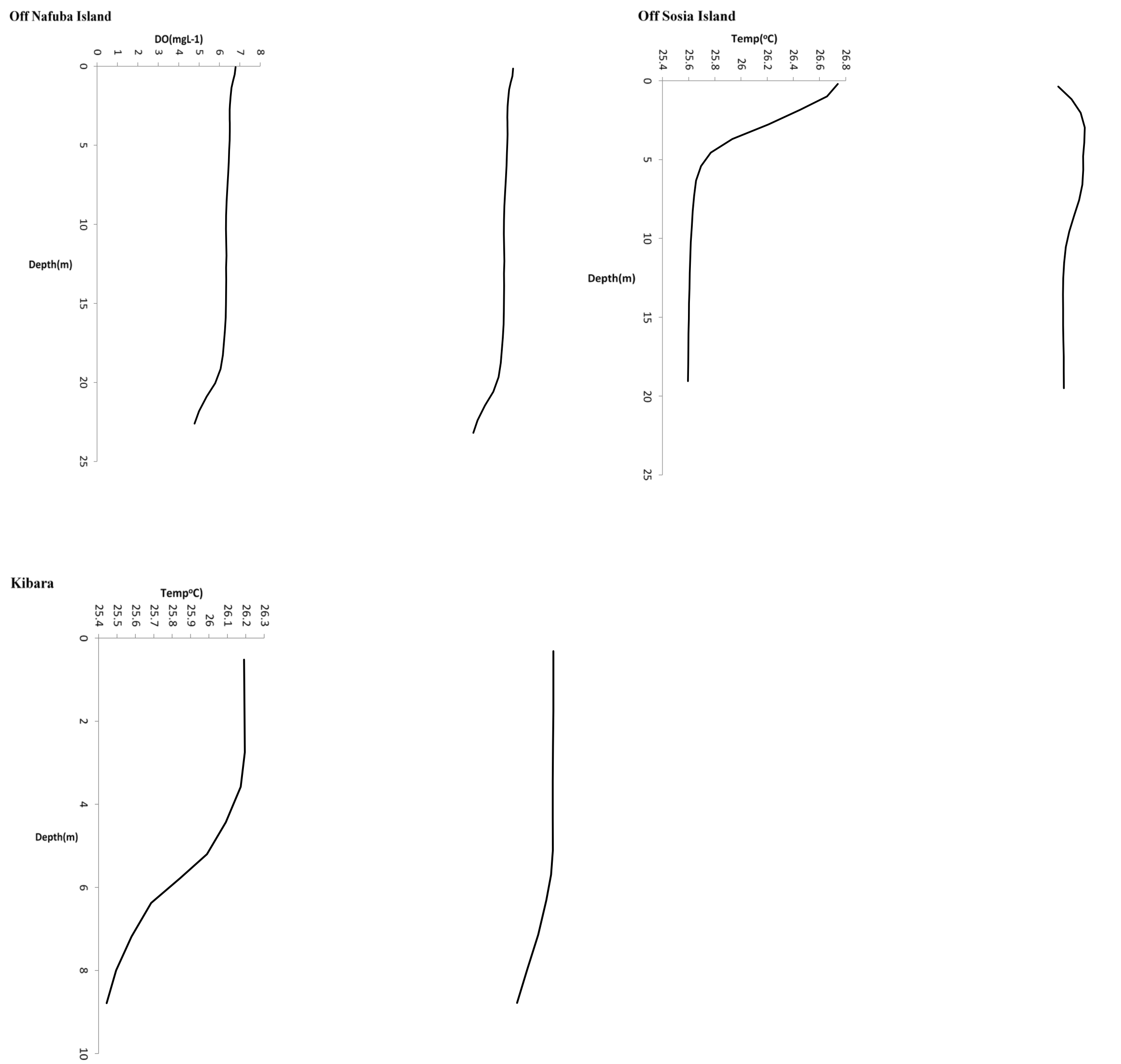


Fig. 5. Temperature and Dissolved oxygen (DO) profiles within the Speke Gulf CTD stations

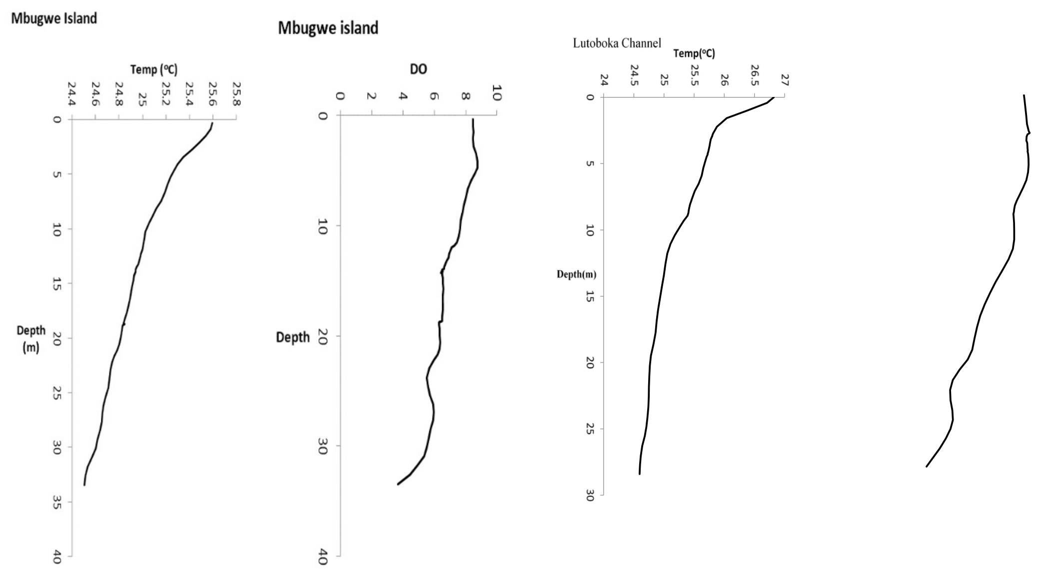
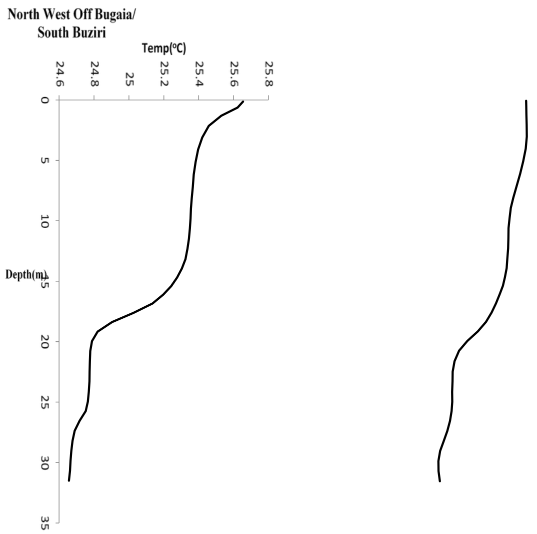
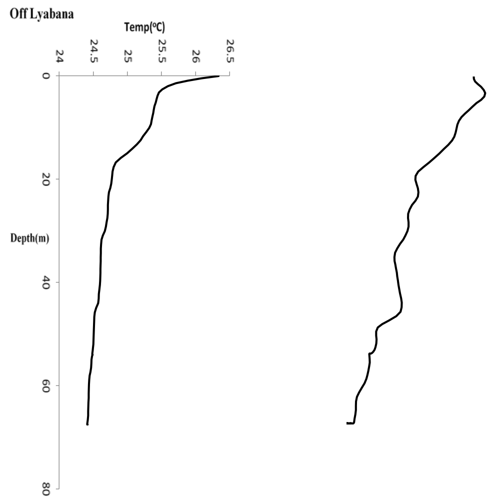
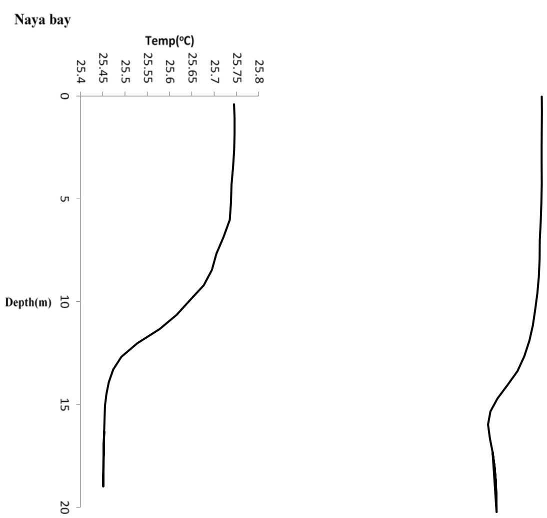
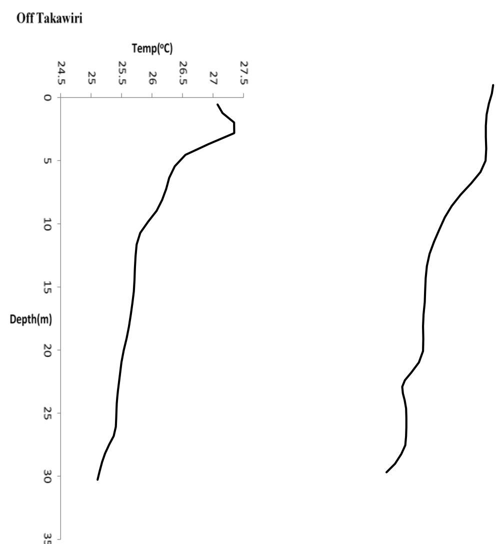


Fig. 6. Temperature and Dissolved oxygen (DO) profiles within the Ssese Islands CTD stations

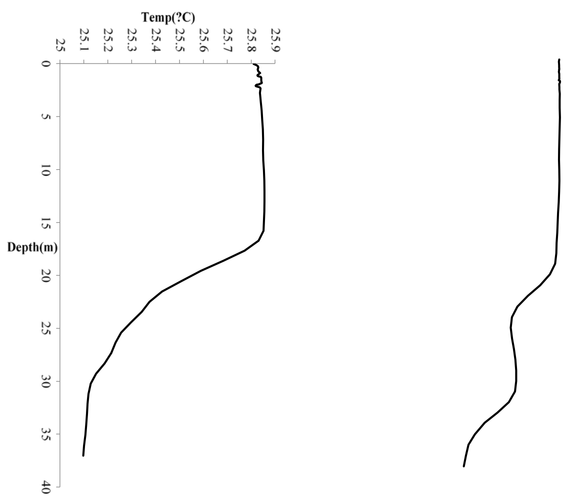

North West Off Bugaia/
South Buziri
Temp(°C)
24.6 24.8 25 25.2 25.4 25.6 25.8
Depth(m)
0 5 10 15 20 25 30 35


Off Lyabana
Temp(°C)
24 24.5 25 25.5 26 26.5
Depth(m)
0 20 40 60 80

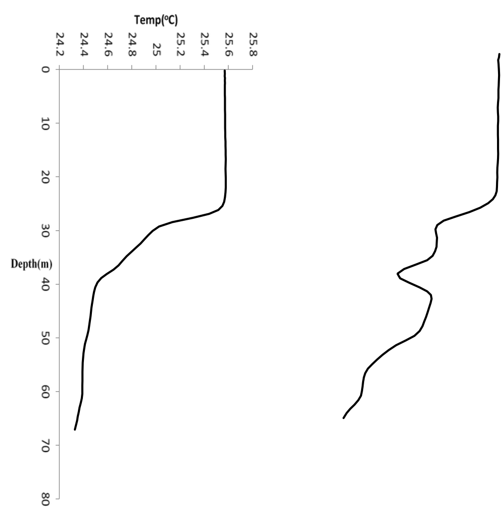

Naya bay
Temp(°C)
25.4 25.45 25.5 25.55 25.6 25.65 25.7 25.75 25.8
Depth(m)
0 5 10 15 20


Off Takawiri
Temp(°C)
24.5 25 25.5 26 26.5 27 27.5
Depth(m)
0 5 10 15 20 25 30 35

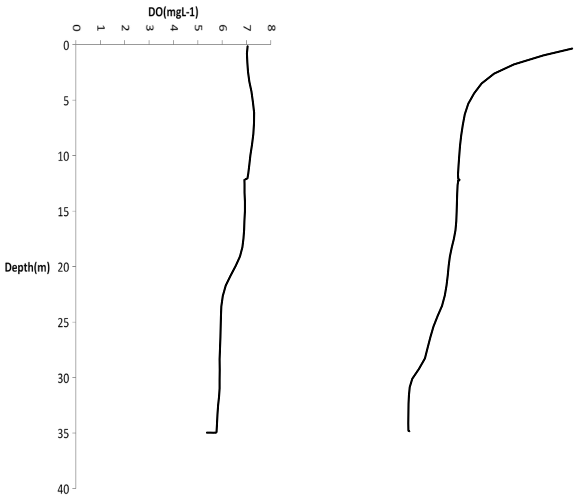
Muhuru Bay



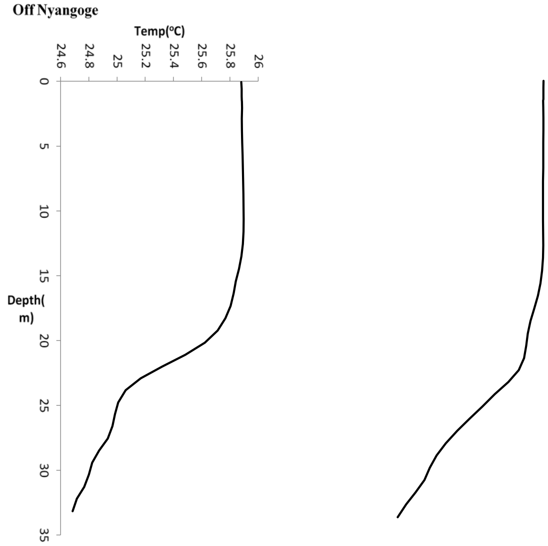
Off Shirati bay



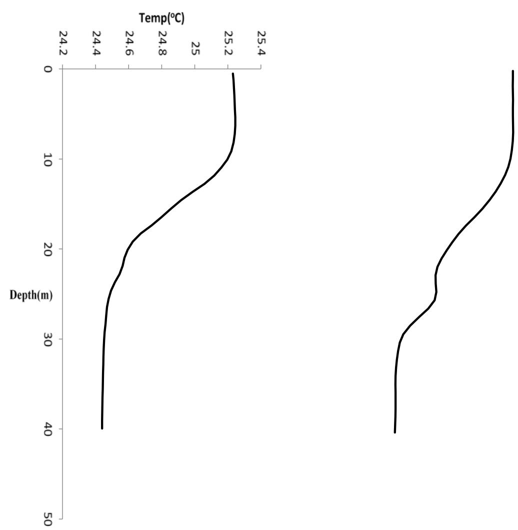
West Lujabwa



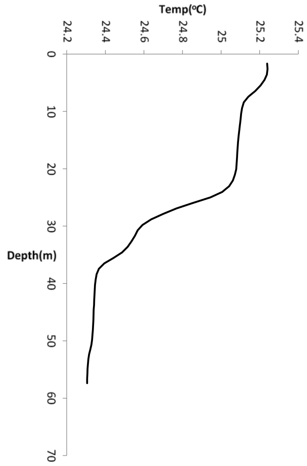
Off Nyangoge

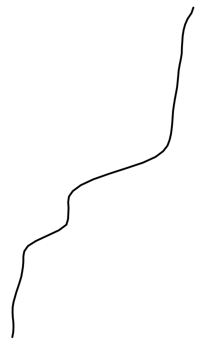


Off Kureju Island

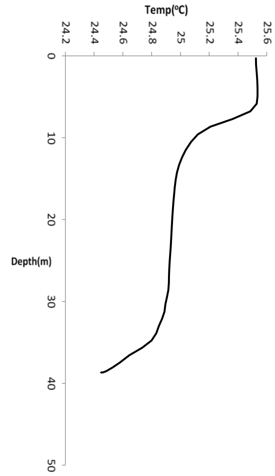


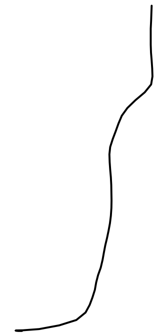
Off Irungua Island



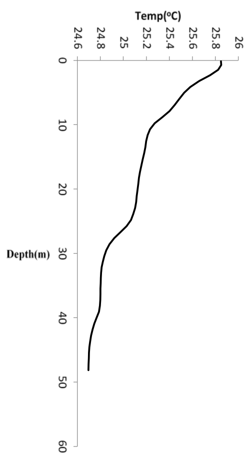


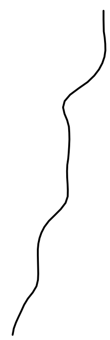
Off Ghana Island



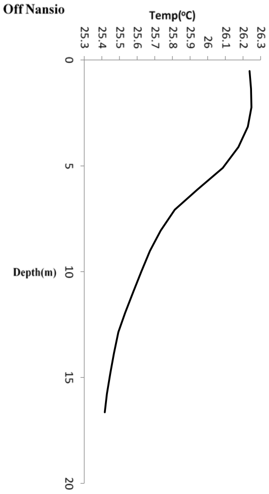


North Kunene





Off Nansio



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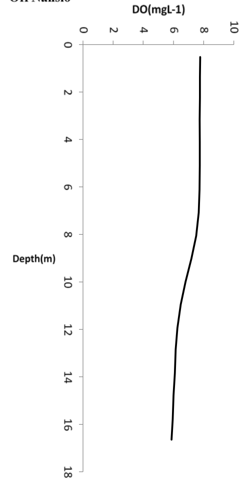
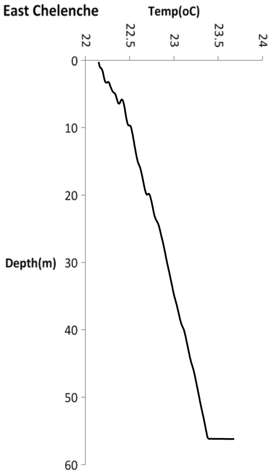
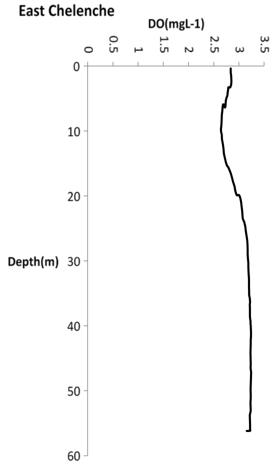


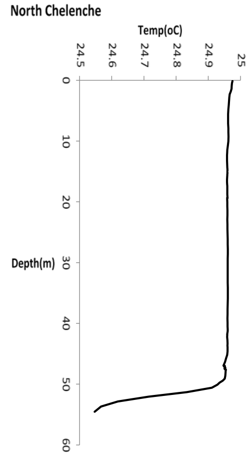
East Chelenche



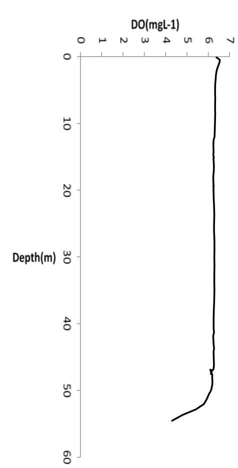
East Chelenche



North Chelenche



North Chelenche



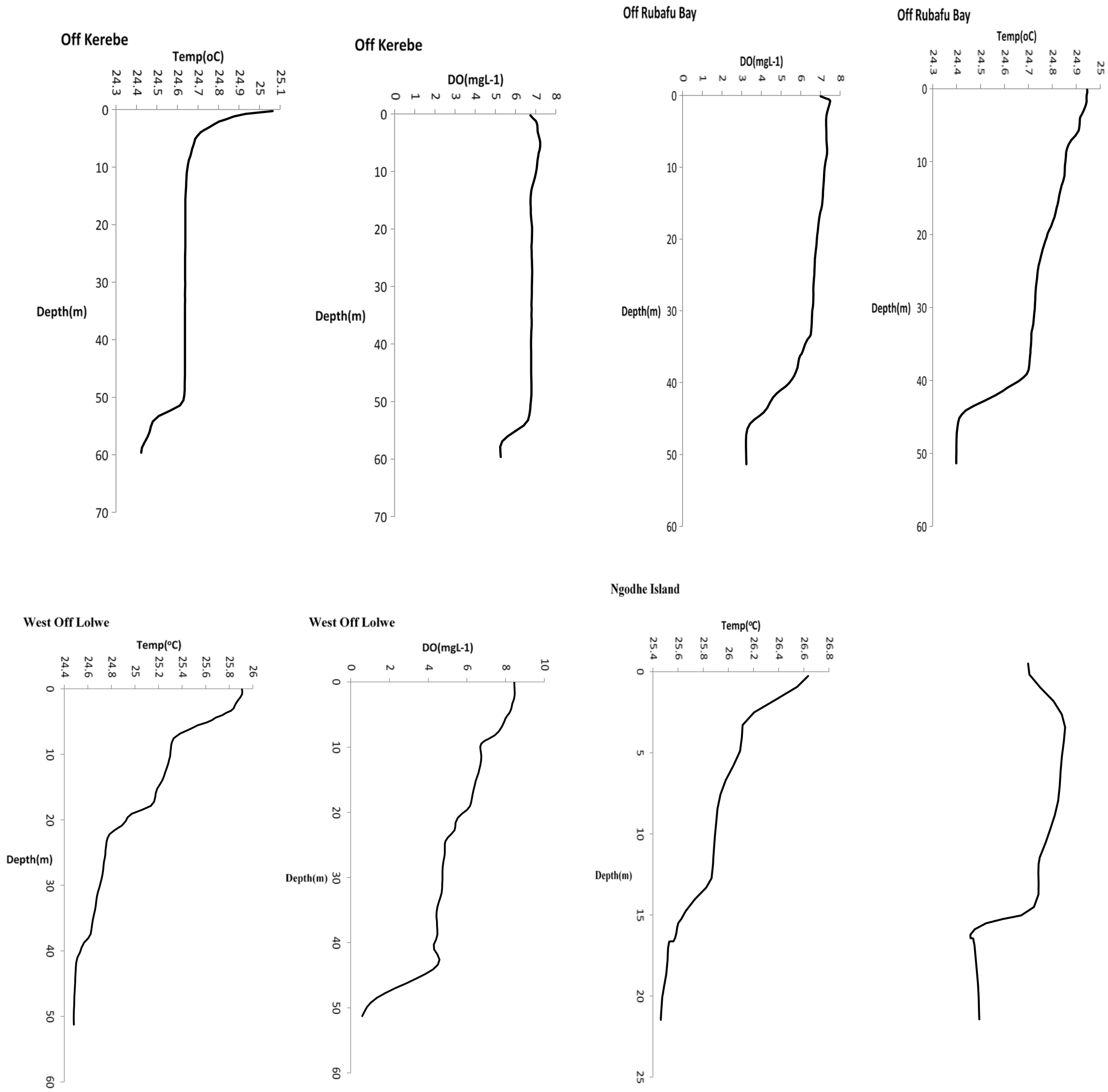
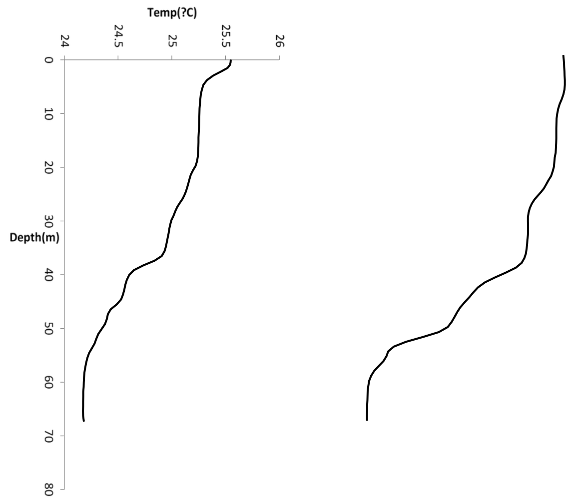
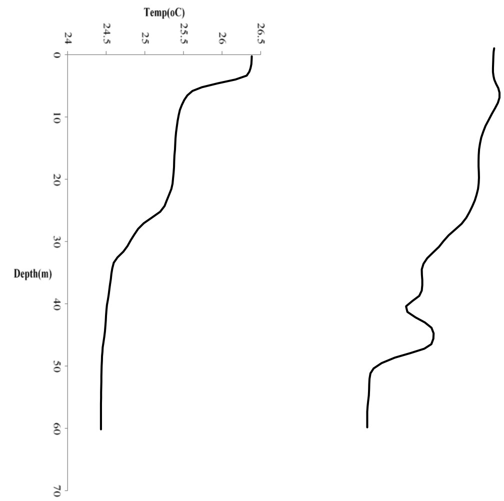


Fig. 7. Temperature and Dissolved Oxygen (DO) profiles within the Coastal CTD stations.

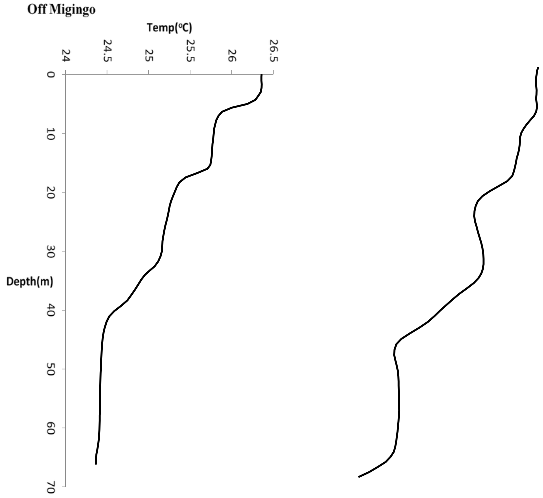
West of Ugingo Island



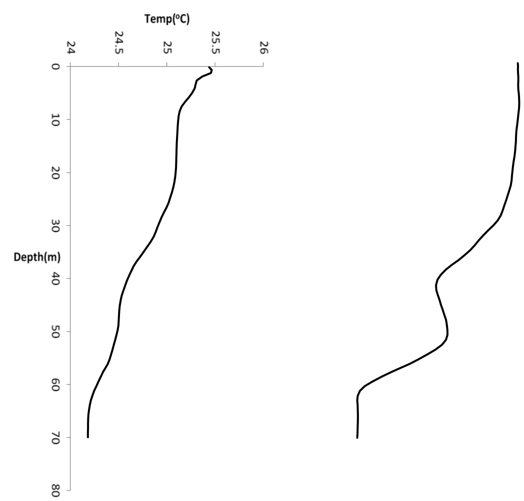
Off Mfangano



Off Migingo



East Off Gozbar



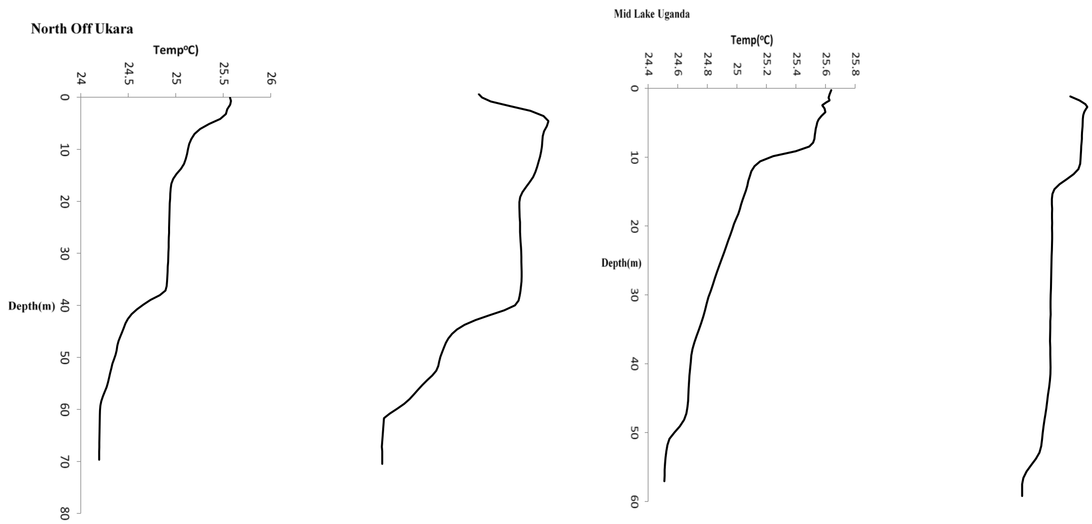


Fig. 8. Temperature and Dissolved oxygen (DO) profiles within the Deep CTD stations

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 were also noted within the Ugandan waters around Ssese islands, Murchison bay and further to the North Eastern 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 1. Mean (±SD) physical, chemical and biochemical attributes of water column compared among quadrants

Quadrant	Temp (°C)	DO (mgL^{-1})	Salinity (ppt)	Chlorophyll (ugL^{-1})	Cond (μScm^{-1})	Turb (FTU)	Total depth (m)	Secchi depth (m)
NE	25.21±0.62	5.02±2.05	0.05±0.01	2.23±1.18	102.55±14.79	3.79±7.16	35.92±20.73	1.84±0.95
NW	25.11±0.59	6.51±0.80	0.05±0.00	1.58±0.84	99.06±2.85	2.51±16.91	31.40±2.32	2.03±0.92
SE	25.03±0.47	4.9±1.08	0.05±0.00	1.7±1.09	97.77±4.37	1.48±19.99	37.38±1.15	2.66±0.94
SW	24.54±0.89	5.7±1.22	0.06±0.02	1.55±2.11	118.05±30.26	0.77±22.53	36.67±1.55	2.95±1.43
Lake-wide	24.98±1.1	5.44±1.9	0.05±0.01	1.83±1.14	105.25±29.9	2.31±3.97	35.95±19.9	2.32±1.15

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

Country	**Temp (°C)**	**DO (mgL^{-1})**	**Salinity (ppt)**	**Chlorophyll (ugL^{-1})**	**Cond (μScm^{-1})**	**Turb (FTU)**	**Total depth (m)**	**Secchi depth (m)**
Ke	25.9±1.72	5.53±1.3	0.06±0.01	3.13±0.88	115.9±22.03	9.5±9.56	19.76±11.80	1.11±0.59
Tz	24.74±0.74	5.38±1.8	0.06±0.02	1.61±1.26	109.77±40.64	1.06±0.96	37.06±20.72	2.79±1.17
Ug	25.04±1.09	5.49±2.23	0.05±0.01	1.8±0.87	98.6±11.14	2.18±2.1	38.46±19.21	2.12±0.89

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

Strata	Temp (ºC)	DO (mgL^{-1})	Salinity (ppt)	Chlorophyll (ugL^{-1})	Cond (μScm^{-1})	Turb (FTU)	Total depth (m)	Secchi depth (m)
C	24.8±1.21	5.39±1.87	0.06±0.02	1.63±0.92	109.67±39.6	1.43±2.22	42.53±16.03	2.69±1.10
D	24.92±0.52	5.01±2.29	0.05±0	0.9±0.58	96.6±1.29	1.11±1.08	66.83±3.87	3.34±0.55
EP	25.17±0.11	5.73±0.69	0.05±0	5.12±1.15	97.42±0.49	1.63±0.36	16.73±7.29	1.53±0.40
I	25.08±1.08	5.44±2.18	0.05±0.01	2.43±0.98	100.24±15.58	2.52±1.75	26.15±14.59	1.98±1.02
NG	26.8±0.51	4.88±0.52	0.07±0	2.29±0.27	149.74±3.32	24.3±0	6±4.24	0.35±0.07
SG	25.7±0.28	6.66±0.71	0.05±0	2.05±0.7	103.94±2.76	2.29±0.88	18±6.24	1.6±0.40
SI	25.05±0.4	6.74±1.25	0.05±±0	1.69±0.24	96.93±1.45	3.34±1.64	32.75±2.47	1.45±0.21

Table 5. Mean (±SD) physical, chemical and biochemical attributes of water column compared among regions (strata specified by quadrants and countries)

Region	Temp (ºC)	DO (mgL^{-1})	Salinity (ppt)	Chlorophyll (ugL^{-1})	Cond (μScm^{-1})	Turb (FTU)	Total depth (m)	Secchi depth (m)
NECKe	25.58±	5.77±	0.05±	3.23±	103.27±	4.08±	27.08±	1.33±
NECUg	24.89±	4.84±	0.05±	1.73±	97.16±	2.22±	46.33±	2.28±
NEDUg	25.00±	4.97±	0.05±	1.33±	96.90±	0.69±	64.67±	3.03±
NEIKe	25.47±	5.90±	0.05±	5.50±	102.80±	2.83±	18.00±	1.80±
NE IUg	25.10±	4.75±	0.05±	2.78±	101.13±	2.83±	28.80±	1.60±
NENG	26.80±	4.88±	0.07±	2.29±	149.74±	24.30±	6.00±	0.35±

Ke								
NWCUg	24.87±	6.64±	0.05±	0.79±	96.35±	0.57±	44.95±	3.50±
NWDUg	25.00±	6.34±	0.05±	0.56±	96.42±	0.65±	65.00±	3.10±
NW IUg	25.35±	6.28±	0.05±	2.40±	103.85±	3.73±	20.83±	1.55±
NWSI Ug	25.05±	6.74±	0.05±	1.69±	96.93±	3.34±	32.75±	1.45±
SECTz	25.03±	4.97±	0.05±	2.10±	97.28±	0.88±	38.00±	2.87±
SEDTz	24.76±	4.44±	0.05±	0.39±	96.23±	2.01±	71.00±	3.93±
SEITz	24.97±	4.11±	0.05±	2.55±	97.19±	1.76±	31.00±	2.35±
SESGTz	25.70±	6.66±	0.05±	2.05±	103.94±	2.29±	18.00±	1.60±
SWITz	24.77±	6.26±	0.05±	1.47±	96.09±	1.05±	30.43±	2.98±
SWCTz	24.38±	5.54±	0.07±	1.02±	127.44±	0.56±	58.30±	4.08±
SWEP Tz	25.17±	5.73±	0.05±	5.12±	97.42±	1.63±	16.73±	1.53±

A.2.4. Conclusions

The environmental conditions of the lake remained within the normally recorded ranges with a dramatic shift only in stratification patterns in some regions. The study predicts an enhanced occurrence of fish within the pelagic zones rather than the bottom, while avoiding the regions and ecological areas currently experiencing perturbations. Far reaching measures should be taken to address the prevailing human driven ecosystem stressors in the lake to complement ongoing management measures aimed at rebuilding fish stocks

Annex 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 (ºC)	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**
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**
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**

Annex 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
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
Secchi (M)	2008	1.7 ±	3.1 ± 1.2	0.6 ± 0.10	3.0 ± 0.25

		0.82			
	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

Annex 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	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
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
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

Appendix III: Echo-sounder Calibration output files

Echo-sounder calibration output files

70 kHz Calibration
#Root Copyright="Copyright(c) Kongsberg Maritime AS" FileFormatVersion="1.05"
#Time of File Creation 2020-10-19
#Transducer
#Name ES70-7C Serial Number 70092019
#Depth 0.00
#Transceiver
#Channel Name ES70-7C #Type GPT
#SerialNumber 70 kHz 00907205aebd 2 ES70-7C
#Software Version 050112 #Impedance 1000.0
#Application
#Name EK80 #Software Version 1.12.2.0
#Previous Model Parameters
#Frequency 70000 Hz #Gain 28.11 dB
#Beam Width Alongship 6.74 #Beam Width Athwartship 6.86
#Angle Offset Alongship -0.09 deg #Angle Offset Athwartship 0.05 deg
#Sa Correction -0.77 dB #Equivalent Beam Angle -20.70 dB
#Impedance 75.00 #Phase 0.00
#Transceiver Setting
#Beam Type Split #Frequency Start 70000 Hz
#Frequency End 70000 Hz #PulseLength 0.256 ms
#PulseForm CW #Slope 0.000000
#Transmit Power 225.00 W #Sample Interval 0.000064
#Main Operation Normal
#SingleTarget Detector Setting
#TS Deviation 5.00 dB #Range Start 9.54
#Range 1.26 #Min TS Value -50.00 dB

#Min EchoLength 0.80 #Max EchoLength
1.80
#Max Phase Deviation 20.00 #MaxSweepPhaseDeviation
25.00
#Max Gain Compensation 3.00 #Min Spacing
0.00
#WBT Distance Before Trace Peak 0.15
#WBTDistanceAfterTracePeak 0.70
#EnvironmentData
#Sound Velocity 1498.28 m/s #Absorption Coefficient
0.000930
#Temperature 25.60 #Salinity 0
#Acidity 8.00
#Target Reference
#Name Copper (Cu) #Diameter 32
mm
#Density 8.9450
#Calibration Results
#Gain 26.04 dB #SaCorrection -
0.0139 dB
#Beam Width Alongship 6.73 #Beam Width Athwartship
6.82
#Angle Offset Alongship 0.00 deg #Angle Offset
Athwartship -0.03 deg
#Ts RMS Error 0.0669 dB #Impedance
75.00
Phase 0.00
<u>120 kHz Calibration</u>

#Root Copyright="Copyright(c) Kongsberg Maritime AS"
FileFormatVersion="1.05"
#Time of File Creation 2020-10-19
#Transducer
#Name ES120-7C #SerialNumber 1200919
#Depth 0.00
#Transceiver
#Channel Name ES120-7C #Type
GPT
#Serial Number GPT 120 kHz 00907209204d 1 ES120-7C
#Software Version 050112 #Impedance
1000.0
#Application
#Name EK80 #Software Version
1.12.2.0
#Previous Model Parameters
#Frequency 120000 Hz #Gain
27.00
#Beam Width Alongship 7.00 #BeamWidthAthwartship
7.00

#Angle Offset Alongship 0.00 deg #AngleOffsetAthwartship 0.00 deg
#SaCorrection 0.0000 dB #EquivalentBeamAngle -20.70 dB
#Impedance 75.00 #Phase 0.00
#TransceiverSetting
#Beam Type Split #FrequencyStart 120000 Hz
#Frequency End 120000 Hz #PulseLength 0.000256s
#PulseForm CW #Slope 0.000000
#Transmit Power 200.00 W #Sample Interval 0.000064
#Main Operation Normal
#Single Target Detector Setting
#TS Deviation 5.00 dB #RangeStart 6.29
#Range 1.02 #Min TS Value -50.00 dB
#Min Echo Length 0.80 #MaxEchoLength 1.80
#Max Phase Deviation 20.00 #MaxSweepPhaseDeviation 25.00
#Max Gain Compensation 3.00 #MinSpacing 0.00
#WBT Distance Before Trace Peak 0.15 #WBT Distance After Trace Peak 0.70
#**Environment Data**
#Sound Velocity 1498.28 m/s #AbsorptionCoefficient 0.002733
#Temperature 25.60 #Salinity 0
#Acidity 8.00
#Target Reference
#Name Copper (Cu) #Diameter 23mm
#**Calibration Results**
#Gain 25.25 dB #SaCorrection -0.6249 dB
#BeamWidthAlongship 6.77 #BeamWidthAthwartship 6.85
#AngleOffsetAlongship 0.07 deg #AngleOffsetAthwartship 0.09 deg
#TS RMS Error 0.0984 #Impedance 75.00
#Phase 0.00

Appendix IV: October-November 2020 Acoustic Survey Event Log-sheet

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
20/10/2020	2	TI	2		SW	I	Tz	0750	0905	1050	1205	Left TAFICO Pier
	3	DH	3		SW	I	Tz	0905	0936	1205	1236	Echosounder stopped running at 1200. \restarted at 1215
	4	TC	4		SW	C	Tz	0936	1124	1236	1424	
	5	CTD	5	1	SW	C	Tz	1124	1146	1424	1446	
	6	DH	6		SW	C	Tz	1146	1238	1446	1538	
	7	TC	7		SW	C	Tz	1238	1356	1538	1636	Lowered speed due to shallowness and the nature of the seafloor (1618hrs)
	8	TI	8		SW	I	Tz			1636	1721	
	9	DH	9			I	Tz			1721	1732	End of Day Nyakaliro
21/10/2020	10	TI	10		SW	I	Tz			0620	0748	Left Nyakaliro
	11	TC	11		SW	C	Tz			0748	0937	
	12	CTD		2	SW	C	Tz			0937	0956	Sediment Grab conducted
	13	NB		2	SW	C	Tz			1005	1041	
	14	DH	12		SW	C	Tz			1100	1142	
	15	TC	13		SW	C	Tz			1142	1338	
	16	TI	14		SW	I	Tz			1338	1437	
	17	DH	15		SW	I	Tz			1437	1511	

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
	18	TI	16		SW	I	Tz			1511	1556	
	19	TI	17		SW	I	Tz			1556	1616	
	20	TI	18		SW	EP	Tz			1616	1643	
	21	CTD		3	SW	EP	Tz			1643	1656	Sediment Grab conducted but no sediments retrieved.
	22	TI	19		SW	EP	Tz			1656	1705	
	23	TI	20		SW	EP	Tz			1705	1825	End of Day Chato
22/10/2020	24	DH	21		SW	EP	Tz			0718	0730	Left Chato
	25	NB		4	SW	EP	Tz			0737	0759	
	26	CTD		4	SW	EP	Tz			0809	0824	Sediment Grab conducted but sediments retrieved were not enough for sample collection
	27	TI	22		SW	EP	Tz			0824	0939	
	28	TI	23		SW	EP	Tz			0939	1100	
	29	TI	24		SW	EP	Tz			1100	1207	
	30	CTD		5	SW	EP	Tz			1207	1226	
	31	NB		5	SW	EP	Tz			1237	1435	
	32	DH	25		SW	EP	Tz			1435	1628	End of Day Kimoyomoyo
23/10/2020	33	DH	26		SW	C	Tz			0600	0631	Left Kimoyomoyo
	34	TC	27		SW	C	Tz			0631	0742	small underwater hill (aprox 17m high)
	35	DH	28		SW	I	Tz			0742	0850	
	36	CTD		6	SW	I	Tz			0850	0906	

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
	37	TC	29		SW	I	Tz			0906	1232	Schools of dagaa observed in the echogram
	38	DH	30		SW	I	Tz			1232	1320	
	39	TC	31		SW	C	Tz			1320	1501	
	40	CTD		7	SW	C	Tz			1501	1506	
	41	NB		7	SW	C	Tz			1529	1559	
	42	TC	32		SW	C	Tz			1605	1822	End of Day Kerebe Is
24/10/2020	43	DH	33		SW	C	Tz			0128	0337	Left Kerebe Is
	44	TD	34		SW	D	Tz			0337	0812	
	45	DH	34		SW	I	Tz			0812	1004	
	46	CTD		8	SW	I	Tz			1004	1028	OFF GOZBAR
	47	TD	35		SW	D	Tz			1028	1419	
	48	TC	36		SW	C	Tz			1419	1610	
	49	TC	37		SW	C	Tz			1610	1821	
	50	DH	38		SW	I	Tz			1821	1915	End of day Bumbire
25/10/2020	51	DH	39		SW	I	Tz			0655	0708	Left Bumbire
	52	CTD		9	SW	I	Tz			0708	0719	
	53	NB		9	SW	I	Tz			0731	0931	
	54	TI	40		SW	I	Tz			1007	1029	
	55	DH	41		SW	C	Tz			1029	1045	

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
	56	TI	42		SW	D	Tz			1045	1152	
	57	TI	43		SW	D	Tz			1152	1300	
	558	DH	44		SW	I	Tz			1300	1308	End of Day Bukoba
25/10/2020												Rest day Bukoba until 1st November 2020 due to travel clearance challenges and general election in Tz.
2/11/2020	59	DH	45		SW	I	Tz	0640	0701	0940	1001	Left Bukoba
	60	TI	46		SW	C	Tz	0701	0815	1001	1115	
	61	TC	47		SW	C	Tz	0815	1048	1115	1348	
	62	CTD		10	SW	C	Tz	1049	1104	1349	1404	
	63	DH	48Aa	10	SW	C	Tz	1105	1144	1405	1444	NB not conducted, event 64 deleted, not conducted
		DH	48b		SW	C	Tz					Not carried out
	65	TC	48		SW	C	Ug	1144	1431	1444	1731	
	66	DH	49		SW	C	Ug	1431	1531	1731	1830	End of Day Rubafu
03/11/2020	67	NB	50	11	SW	I	Tz	0417	0447	0717	0747	Left Rubafu
	68	CTD		11	SW	I	Tz	0455	0506	0755	0806	
	69	TI	51		NW	I	Ug	0507	0707	0807	1007	
	70	TC	52		NW	C	Ug	0707	0831			
	71	CTD		12	NW	C	Ug	0831	0844			
	72	NB		12	NW	C	Ug	0853	0924			

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
	73	DH	53		NW	C	Ug	0938	1003			
	74	TI	54		NW	I	Ug	1003	1206			
	75	CTD		13	NW	I	Ug	1206	1216			
	76	NB		13	NW	I	Ug	1222	1253	1522	1553	
	77	DH	55		NW	I	Ug	1305	1326			
	78	TI	56		NW	I	Ug	1327	1500			End of Day Nakatiba landing site
04/11/2020	79	DH	57		NW	I	Ug	0327	0334			Left Nakatiba
	80	TI	58		NW	I	Ug	0334	0406			
	81	DH	59		NW	SI	Ug	0406	0526			Slowed speed after encountering underwater rock formation at around 0415
	82	TI	60		NW	SI	Ug	0526	0534			
	83	TI	62		NW	SI	Ug	0534	0628			
	84	CTD		14	NW	SI	Ug	0629	0641			
	85	NB		14	NW	SI	Ug	0648	0750			
	86	TC	63		NW	SI	Ug	0806	0858			
	87	DH	64		NW	C	Ug	0858	1003			
	88	TC	65		NW	C	Ug	1003	1126			
	89	CTD		15	NW	C	Ug	1126	1138			
	90	TI	66		NW	SI	Ug	1139	1217			
	91	DH	67		NW	SI	Ug	1217	1222			End of the day- Mpata Bay

Date	**Event No.**	**Activities**	**Transect ID**	**Station**	**Quadrant**	**Strata**	**Country**	**Time start (UTC)**	**Time end (UTC)**	**Time start (Local)**	**Time end (Local)**	**Remarks**
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
05/11/2020	92	DH	68		NW	SI	Ug	0335	0343			Left Mpata Bay
	93	TD	69		NW	D	Ug	0343	0724			
	94	CTD		16	NW	D	Ug	0724	0737			
	95	DH	70		NW	D	Ug	0737	0921			
	96	TD	71		NW	D	Ug	0921	1304			
	97	TC	72		NW	C	Ug	1304	1511			
	98	CTD		17	NW	SI	Ug	1511	1521			
	98	TI	73		NW	SI	Ug	1522	1644			
	99	DH	74		NW	SI	Ug	1644	1649			End of day(Lutoboka bay) Kalangala
06/11/2020	100	TI	75		NW		Ug	0346	0440			Left Kalangala
	101	TI			NW	I	Ug	0440	0509			
	102	CTD		18	NW	I	Ug	0510	0518			
	103	NB		18	NW	I	Ug	0528	0558			
	104	DH	76		NW	I	Ug	0615	0636			
	105	TI	77		NW	I	Ug	0636	0823			
	106	CTD	78	19	NW	I	Ug	0823	0834			
	107	DH	79		NW	I	Ug	0834	0931			
	108	DH	80		NW	I	Ug	0931	1021			Brief stopover at Entebbe pier for COVID 19 tests
	109	DH	81		NW	I	Ug	1334	1359			
	110	TI	82		NW	I	Ug	1359	1436			

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
	111	CTD		20	NW	I	Ug	1436	1448			
	112	TI	83		NW	I	Ug	1448	1543			
	113	TI	84		NW	I	Ug	1543	1611			End of the day Murchison bay
07/11/2020	114	DH	85		NW	I	Ug	0337	0359			Left Murchison bay
	115	DH	86		NW	I	Ug	0339	0428			
	116	TI	87		NW	I	Ug	0428	0553			
	117	TI	88		NW	I	Ug	0553	0632			
	118	TI	89		NW	I	Ug	0632	0739			
	119	CTD		21	NW	I	Ug	0739	0757			
	120	TI	90		NW	I	Ug	0757	0909			
	121	TI	91		NW	I	Ug	0909	0946			
	122	CTD		22	NW	I	Ug	0946	0959			
	123	NB		22	NW	I	Ug	1012	1035			
	124	DH	92		NE	I	Ug	1047	1120			
	125	TI	93		NE	I	Ug	1120	1211			
	126	TI	94		NE	I	Ug	1211	1245			
	127	CTD		23	NE	I	Ug	1245	1253			
	128	DH	95		NE	I	Ug	1253	1326			End of the day Jinja pier
08/11/2020												Rest day
09/11/202	129	DH	96		NE	I	Ug	0412	0430			Left Jinja

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
0												
	130	DH	97		NE	I	Ug	0430	0507			
	131	TI	98		NE	I	Ug	0507	0628			
	132	TI	99		NE	I	Ug	0628	0752			
	133	CTD		24	NE	C	Ug	0753	0812			
	134	DH	100		NE	C	Ug	0813	0902			
	135	TC	101		NE	C	Ug	0902	1037			
	136	CTD		25	NE	C	Ug	1039	1055			
	137	NB		25	NE	C	Ug					Observed a steep slope with a strong bottom back scatter and abandoned the NB
	138	DH	102		NE	C	Ug	1056	1156			
	139	TC	103		NE	C	Ug	1156	1349			
	140	TC	104		NE	C	Ug	1349	1433			End of the day Koja Bay
10/11/2020	141	DH	105		NE	I	Ug	0306	0339			Left Koja Bay
	142	CTD		26	NE	I	Ug	0340	0349			
	143	TI	106		NE	I	Ug	0349	0443			
	144	DH	107		NE	I	Ug	0443	0532			
	145	CTD	108	27	NE	I	Ug	0532	0543			
	146	TI	109		NE	I	Ug	0543	0645			
	147	DH	110		NE	C	Ug	0645	0729			
	148	CTD	111	28	NE	C	Ug	0729	0745			
	149	TC	112		NE	C	Ug	0745	0905			

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
	150	TC	113		NE	C	Ug	0905	1001			
	151	DH	114		NE	C	Ug	1001	1111			
	152	TC	115		NE	C	Ug	1111	1210			
	153	NB		29	NE	C	Ug	1216	1246			
	154	CTD		29	NE	C	Ug	1246	1303			
	155	TI	116		NE	I	Ug	1303	1331			
	156	DH	117		NE	I	Ug	1331	1441			
	157	TI	118		NE	I	Ug	1441	1543			
	158	DHa	119a		NE	I	Ug	1543	1555			
	159	DHb	119b		NE	I	Ke	1555	1616			End of day, Port Victoria
11/11/2020	160	DHa	120		NE	I	Ke	0312	0340			Left Port Victoria
	161	DHb	121		NE	I	Ug	0340	0349			
	162	CTD		30	NE	I	Ug	0349	0400			
	163	NB		30	NE	I	Ug	0409	0439			
	164	TC	122		NE	C	Ug	0501	0634			
	165	TC	123		NE	C	Ug	0634	0649			
	166	CTD		31	NE	C	Ug	0650	0702			
	167	TC	124		NE	C	Ug	0702	0752			
	168	TC	125a		NE	C	Ug	0752	0818			
	169	TI	125b		NE	I	Ke	0818	0859			Hard bottom surface not suitable for net bottom but possibly for net pelagic
	170	CTD		32	NE	I	Ke	0859	0908			

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
	171	TC	126a		NE	C	Ke	0908	1007			
	172	TC	126b		NE	C	Ug	1007	1043			
	173	TC	127		NE	C	Ug	1043	1204			
	174	TC	128		NE	C	Ug	1204	1304			
	175	CTD		33	NE	I	Ug	1304	1321			
	176	DH	129		NE	I	Ug	1322	1338			End of day Lolwe
12/11/2020	177	DH	130		NE	D	Ug	0235	0400			Leaving Lolwe
	178	TD	131		NE	D	Ug	0400	0813			
	179	CTD		34		D	Ug	0814	0828			
	180	NB		34		D	Ug	0835	0905			
	181	DH	132		NE	D	Ug	0920	1023			
	182	TD	133		NE	D	Ug	1023	1403			
	183	CTD		35				1403	1416			
	184	TC	134a		NE	C	Ug	1416	1520			
	185	TC	135b		NE	C	Ke	1520	1641			
	186	DH	136		NE	C	Ke	1641	1739			
	187	TI	137		NE	C	Ke	1739	1804			End of day Luanda Kotieno
13/11/2020	188	NB		36	NE	I	Ke	0343	0443			Left Lwanda Kotieno
	189	CTD		36	NE	C	Ke	0456	0504			
	190	TI	138		NE	I	Ke	0505	0535			
	191	TI	139		NE	NG	Ke	0535	0707			Reduced engine speed:

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
												disengaged the gear; stopped to enable minor contingent mechanical troubleshooting.
	192	CTD		37	NE	NG	Ke	0708	0717			
	193	TI	140		NE	NG	Ke	0717	0939			
	194	CTD		38				0940	0944			
	195	DH	141		NE	NG	Ke	0944	0952			End of day Kisumu
	196											Rest day Kisumu
15/11/2020	197	DH	142		NE	NG	Ke	0305	0521			Left Kisumu Pier
	198	TI	143		NE	NG	Ke	0521	0648			
	199	DH	144		NE	NG	Ke	0648	0744			
	200	DH	145		NE	NG	Ke	0744	0804			
	201	DH	146		NE	C	Ke	0804	0826			
	202	CTD		39	NE	C	Ke	0826	0837			
	203	DH	147		NE	C	Ke	0837	0930			
	204	TC	148		NE	C	Ke	0930	1014			
	205	CTD		40	NE	C	Ke	1014	1024			
	206	TD	149a		NE	D	Ke	1024	1201			
	207	TD	150b		NE	D	Ug	1201	1249			
	208	DH	151		NE	D	Ug	1249	1341			
	209	CTD		41	NE	D	Ug	1341	1353			
	210	TD	152a		NE	D	Ug	1353	1430			
	211	TD	153b		NE	D	Ke	1430	1542			

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
	212	DH	154		NE	C	Ke	1542	1614			End day at Sori
16/11/2020	213	DH	155		NE	C	Ke	0413	0420			Left Sori
	214	NB		42a	NE	C	Ke	0426	0459			Stopped at 0459 because of many fishing nets around the first area;
	215	NB		42b	NE	C	Ke	0532	0636			
	216	CTD		42	NE	C	Ke	0640	0651			
	217	TC	156a		NE	C	Ke	0724	0822			
	218	TC	156b		NE	C	Ug	0822	0939			
	219	CTD		43	NE	C	Ug	0939	0951			
	220	DH	157		NE	C	Ug	0951	1021			
	221	TC	158		NE	C	Ug	1021	1151			
	222	CTD		44	SE	C	Tz	1151	1202			
	223	NB		44	SE	C	Tz	1210	1240			
	224	DH	159		SE	C	Tz	1256	1318			End of Day, Shirati
17/11/2020	225	DH	160		SE	D	Tz	0202	0337			Left Shirati
	226	TD	161		SE	D	Tz	0337	0800			
	227	CTD		45	SE	D	Tz	0800	0814			
	228	DH	162		SE	D	Tz	0814	0932			
	229	TD	163		SE	D	Tz	0932	1336			
	230	DH	164		SE	C	Tz	1336	1435			End of day Musoma
18/11/2020												Rest day

Date	**Event No.**	**Activities**	**Transect ID**	**Station**	**Quadrant**	**Strata**	**Country**	**Time start (UTC)**	**Time end (UTC)**	**Time start (Local)**	**Time end (Local)**	**Remarks**
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
19/11/2020	231	DH	165		SE	I	Tz	0337	0348			Left Musoma
	232	TI	166		SE	I	Tz	0348	0511			
	233	CTD		46	SE	I	Tz	0511	0522			
	234	TC	167		SE	C	Tz	0522	0601			
	235	TC	168		SE	C	Tz	0601	0645			
	236	TC	169		SE	C	Tz	0645	0738			
	237	CTD		47	SE	C	Tz	0738	0750			
	238	NB		47	SE	C	Tz	0756	0826			
	239	TC	170		SE	C	Tz	0838	0905			
	240	DH	171		SE	C	Tz	0905	0953			
	241	CTD		48	SE	C	Tz	0953	1007			
	242	TC	172		SE	C	Tz	1007	1209			
	243	TI	173		SE	I	Tz	1209	1255			
	244	CTD		49	SE	I	Tz	1255	1308			
	245	DH	174		SE	I	Tz	1308	1351			End of day Irondo bay (Ukerewe Island)
20/11/2020	246	DH	175		SE	I	Tz	0326	0344			Left Irondo bay (Ukerewe Island)
	247	TI	176		SE	I	Tz	0344	0637			
	248	TD	177		SE	D	Tz	0637	0744			
	249	CTD		50	SE	D	Tz	0744	0801			
	250	TD	178a		SE	D	Tz	0801	1048			Stopped to redo CTD 50 at 0819 to 0827

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
	252	TD	178b		SE	D	Tz	0827	1048			End of Transect
					SE	D	Tz	1054	1349			Calibration off Ukara
	253	NB		Calib	SE	C	Tz	1414	1444			End of day Ukara (Bwisya)
21/11/2020	254	DH	179		SE	I	Tz	0308	0334			Left Ukara (Bwisya)
	255	DH	180		SE	C	Tz	0334	0444			
	256	CTD		51	SE	C		0444	0454			
	257	TC	181		SE	C	Tz	0454	0642			
	258	TC	182		SE	C	Tz	0642	0819			
	259	TC	183		SE	C	Tz	0819	0856			
	260	CTD		52	SE	C	Tz	0857	0908			
	261	TI	184		SE	I	Tz	0912	1049			
	262	TI	185		SE	I	Tz	1049	1224			
	263	CTD		53	SE	C	Tz	1224	1237			
	264	NB		53	SE	C	Tz	1243	1343			
	265	DH	186		SE	D	Tz	1416	1444			End of day Nansio
22/11/2020	266	DH	187		SE	SG	Tz	0308	0340			Left Nansio
	267	TI	189					0340	0618			Bridge GPS reception lost at 0430 hrs; Transect abandoned.
	268	TI	190		SE	SG	Tz	0430	0618			
	269	DH	191		SE	SG	Tz	0618	0644			
	270	CTD		54	SE	SG	Tz	0644	0656			

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time start (UTC)	Time end (UTC)	Time start (Local)	Time end (Local)	Remarks
	1	DH	1		SW	I	Tz					Abandoned due to change of starting point
	271	NB		54	SE	SG	Tz	0701	0732			
	272	DH	192		SE	SG	Tz	0750	0848			
	273	NB		55	SE	SG	Tz	0900	1000			
	274	CTD		55	SE	SG	Tz	1000	1017			
	275	TI	193		SE	SG	Tz	1017	1054			
	276	DH	194		SE	SG	Tz	1054	1157			
	277	TI	195		SE	SG	Tz	1157	1236			
	278	DH	196		SE	SG	Tz	1236	1323			
	279	CTD		56	SE	SG	Tz	1323	1335			
	280	NB		56	SE	SG	Tz	1341	1411			
	281	TI	197		SE	SG	Tz	1422	1446			End of day and survey at Nyamikoma
23/11/2020												Travel to TAFIRI pier, Mwanza