EAST AFRICAN COMMUNITY
LAKE VICTORIA FISHERIES ORGANIZATION

A REPORT OF THE LAKE-WIDE HYDRO-ACOUSTIC SURVEY

15th September - 13th October 2019

Hydro-acoustics Regional Working Group
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Executive summary

In this report, we present results of the 22nd lake-wide hydro-acoustic survey that was conducted on Lake Victoria from 15th September to 13th October 2019. Acoustic data were collected alongside limnological and biological parameters from pre-defined transects following a radial design. Acoustic data were processed using Echoview 8/10 software (Myriax, Hobart, Australia), while data analysis was done using R software. Results showed total biomass of fish and *Caridina nilotica* in the lake to be 2.68 million tons (t), corresponding to a 21% increase in total biomass compared to the previous year (2018). The silver cyprinid, *Rastrineobola argentea*, also known as *dagaa*, was the most abundant (35%), followed by Nile perch, *Lates niloticus* (31%), while haplochromines and others constituted least (13%) and *Caridina niloticus* constituted 21% to the total biomass of the lake. Overall:

- Nile perch was more abundant in southwest and north-western parts of the lake, and in inshore and coastal areas, compared to the eastern parts and deeper waters;
- Nile perch registered a 48% increase in biomass, compared to the previous year, but the increase was only in the Ugandan and Tanzanian waters;
- There was a noticeable improvement in size structure of Nile perch, especially in the north-western parts of the lake (Uganda), with more fish above 50 cm TL compared to the previous years;
- *Dagaa* registered a 42% increase in biomass, but unlike Nile perch, the increase was apparent in all parts of the lake (Kenya, Uganda, Tanzania) with no discernible spatial differences in densities;
- Haplochromines, on the other hand, registered a 15.5% decrease in biomass compared to the previous year; the decrease was more pronounced in Tanzanian and Kenyan waters;
- *Caridina niloticus* on the other hand, registered a slight decrease of 2.6% decrease in biomass compared to the previous year; like in 2018 survey, the biomass was highest in the Ugandan waters and lowest in Kenyan waters.;
- Acoustic biomass estimates were consistent with catch rates from bottom net trawls;

- The south-western part of the lake appeared most productive following the patterns of chlorophyll a, while the north-western and south-eastern coastal parts showed slight stratification;
- Environmental conditions had an effect on fish distributions; Nile perch and haplochromines were negatively correlated with turbidity, total dissolved solids, and conductivity, which were highest in special regions (especially Emin Pasha and Nyanza Gulf).

From these observations, we conclude that the current enforcement especially in the Ugandan and Tanzanian parts of the lake may have contributed to the increase in fish biomass (Nile perch and dagaa) and continued improvement in size structure of Nile perch. The decrease in the biomass of haplochromines is not surprising, given the increase in predator (Nile perch) abundance. This is likely to affect Nile perch stock, although we observed in this survey adult Nile perch also ingesting *C. nilotica*, whose abundance has increased.

We recommend

i) Protection of prey species such as haplochromines and *Caridina nilotica* to sustain the recovering stocks;

ii) Lake-wide enforcement of fisheries regulations should be embraced. Empirical evidence shows an increase in number and size of fish in areas with enhanced enforcement and compliance with fisheries regulations;

iii) Re-analysis of all the data from all the past surveys so as to improve reporting on the trends for all the monitored taxa;

iv) Re-analysis of data for *dagaa* from previous surveys using the school detection algorithm for comparison with the conventional method being used, and

v) Every region and strata to have has at least one bottom trawl conducted,

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1.0. INTRODUCTION

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

However, hydro-acoustic methods have limited ability to estimate fish close to the surface and to the bottom and differentiating species, hence, bottom net hauls are carried out concurrently to gain species-specific information and also provide most accurate calculations of fish lengths and weight.

This report presents results of the 22nd Lake Victoria regional Hydro-acoustics and environmental survey conducted from 15th September to 13th October 2019. The biomass estimates reported here mainly focus on the four major groups; i.e. Nile perch, *daga*a, haplochromines, and freshwater prawn, *Caridina nilotica*. For Nile perch, we report on distribution and biomass estimates for individual fish ≥10 cm total length (TL). The size structure of Nile perch is also presented to assess outcomes of slot-size policy enforcement and to guide the focus of fisheries (especially on slot size). We also report on the catch composition, catch rates, and size structure from bottom trawl hauls to corroborate information from hydro-acoustics. Finally, information on physical, biological and chemical attributes is gathered and compared with fish distribution.

2.0. MATERIALS AND METHODS

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 15th September to 13th October 2019. 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 made. The first was conducted on 13th September 2019 at the beginning of the survey in Mwanza gulf, and the second on 10th October 2019 in Ukara island. Tungsten carbide sphere (diameter = 38.1 mm) was used in the calibration for the 70, 120, and 200 kHz transducers. The calibration protocol used for this survey is detailed in the new SOPs for hydro-acoustic surveys on Lake Victoria (LVFO 2018). At each calibration site, we lowered the CTD to determine the local environmental conditions. The average water temperature measured at the calibration site was used to predict sphere target strength using the formula provided at https://swfscdata.nmfs.noaa.gov/AST/SphereTS/ . Using the same CTD information and analysis protocol in the new SOPs, the temperature-dependent equivalent two-way beam angles was estimated and used to update transducer settings in the ER60 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.

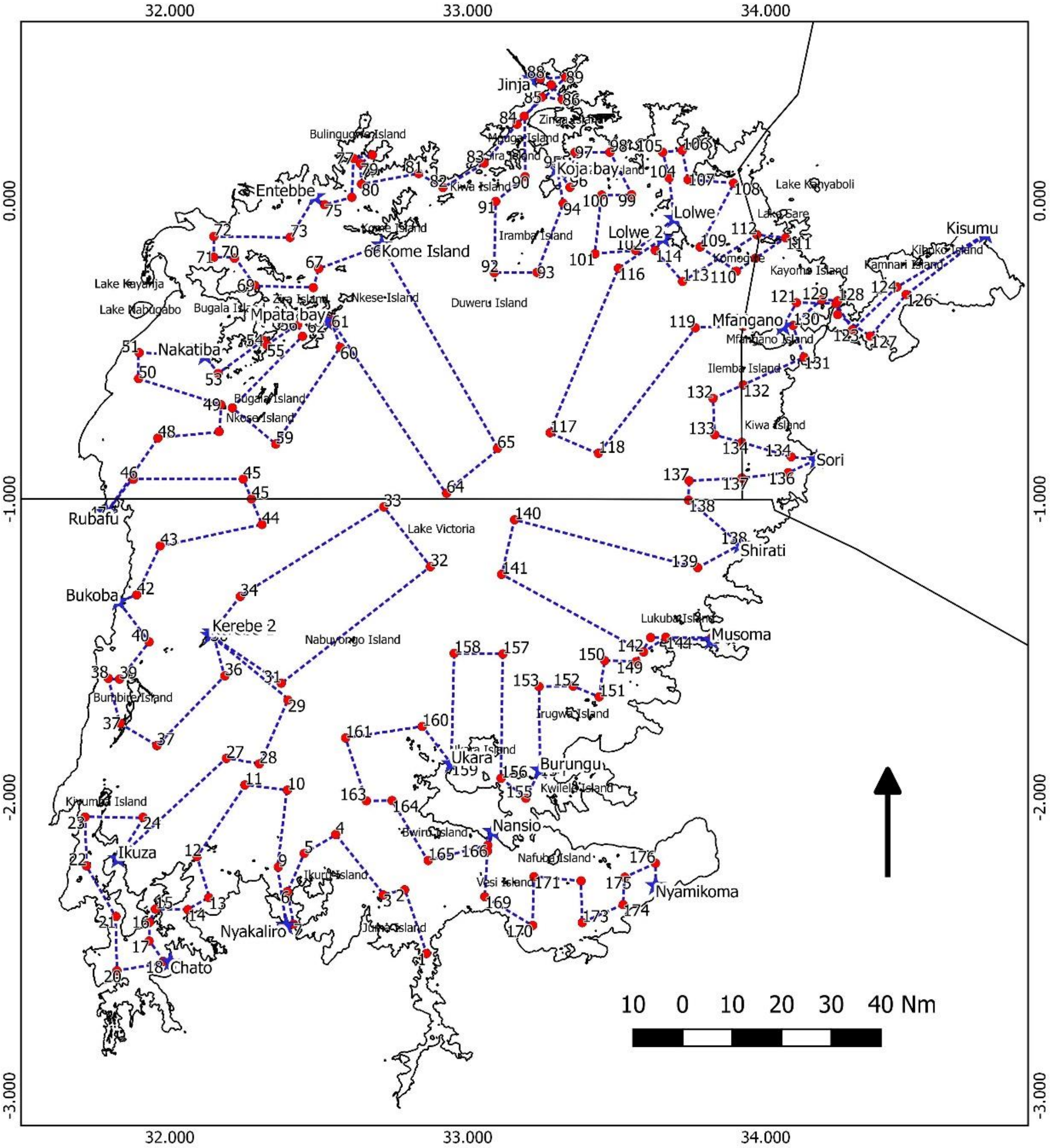

Figure 1. Survey cruise track. Numbers denote transects and deadheads (see appendix IV)

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

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

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

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

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

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

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

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

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

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 120 m) were thoroughly checked and recording directory set. Data were logged in files of length 1 GB and then transferred to two separate hard disks.

2.5.2. Acoustic data preparation

Each day's raw acoustic data files were loaded into Echoview (either v. 8.0 or 10.0 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 60 echosounders were utilized in acoustic measurements. The transducers, which are mounted on the protruding instrument keel, operated at the frequency of 70 kHz, 120 kHz and 200 kHz. The 200 kHz transducer was used for the first time during this survey. However, data recorded from the 200 kHz were too noisy, hence we could not be considered for analysis during this time, waiting for a method for noise removal to be developed. All the three 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 used for analyses for the estimation of standing stock. For single target detections, analysis from each cell were exported by transect and by cell. To ensure that cells where no target was recorded are included in the calculation of average density, the option of "Output empty cells" was selected in Echoview – EV File properties Export window prior to data export.

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

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 were exported by transect and by cells (constituting individual EDSUs). To produce results comparable to the previous surveys, only data from the 120 kHz transducer were used for standing stock estimation. Single targets were thresholded at -50 dB, equivalent to a minimum detection length for Nile Perch of ca. 10 cm (LVFO 2018).

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

$$Density = \left(\frac{NTargets}{VBeam}\right) \qquad (1)$$

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 that 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.

2.5.6.1. *Dagaa*

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

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

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 (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:-

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

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:

$$ABC\ dagaa = ABC_{dagaarange} - ABC_{Nileperchdagaarange} \quad (8)$$

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)

2.5.6.2. *Caridina nilotica*

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

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

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

2.5.6.3. Haplochromines and others

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

ABC Other-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)

2.5.7. Estimation of Standing Stock

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

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

2.5.7.1. Estimation of Standing Stock by country and by stratum

Stock of the three major taxa (Nile perch, *dagaa*, Haplochromine and others) were estimated by country and by strata. Any transect that crosses territorial boundaries was divided 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 (km^2) by quadrant and by country

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

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 caches 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 sub sampled. The catch was mixed thoroughly and a sub sample was taken for recording lengths and weights. The results were raised by the proportion by weight of the total catch (after the large fish were removed) against the sub sample taken from it.

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

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 sites were purposively selected to ensure even distribution and representation of all the strata, special regions, countries, and quadrants, while logically coinciding with the net bottom sampling points. Following this criteria, 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 by the revised acoustic cruise design and the weather. Figure 2 shows the spatial positions of the CTD stations. More detailed descriptions of the CTD stations are presented in Appendix II.

Assessment of water characteristics and general aquatic environmental conditions followed published standard methods for aquatic environmental studies (APHA, 2012). A combination of two depth-profiling systems; a submersible Sea and Sun Technologies)-Conductivity-Temperature-Depth profiling system (CTD), and a Yellow Springs Instruments (YSI) 650 multi-parameter probe were used to log the vertical profile data of the major water physical and chemical parameters. Calibration of the two water quality-profiling instruments were individually performed prior to commencement of the survey by running analytical tests on sample waters for pH, DO, chlorophyll-*a*, turbidity and nutrients and comparing with sensor logged values. Periodically the instruments were calibrated for particularly dissolved oxygen (DO) by adjusting for altitude and atmospheric pressure variations and replenishment of DO sensor electrolytes. The two systems were checked for accuracy during the survey by comparing mutual data.

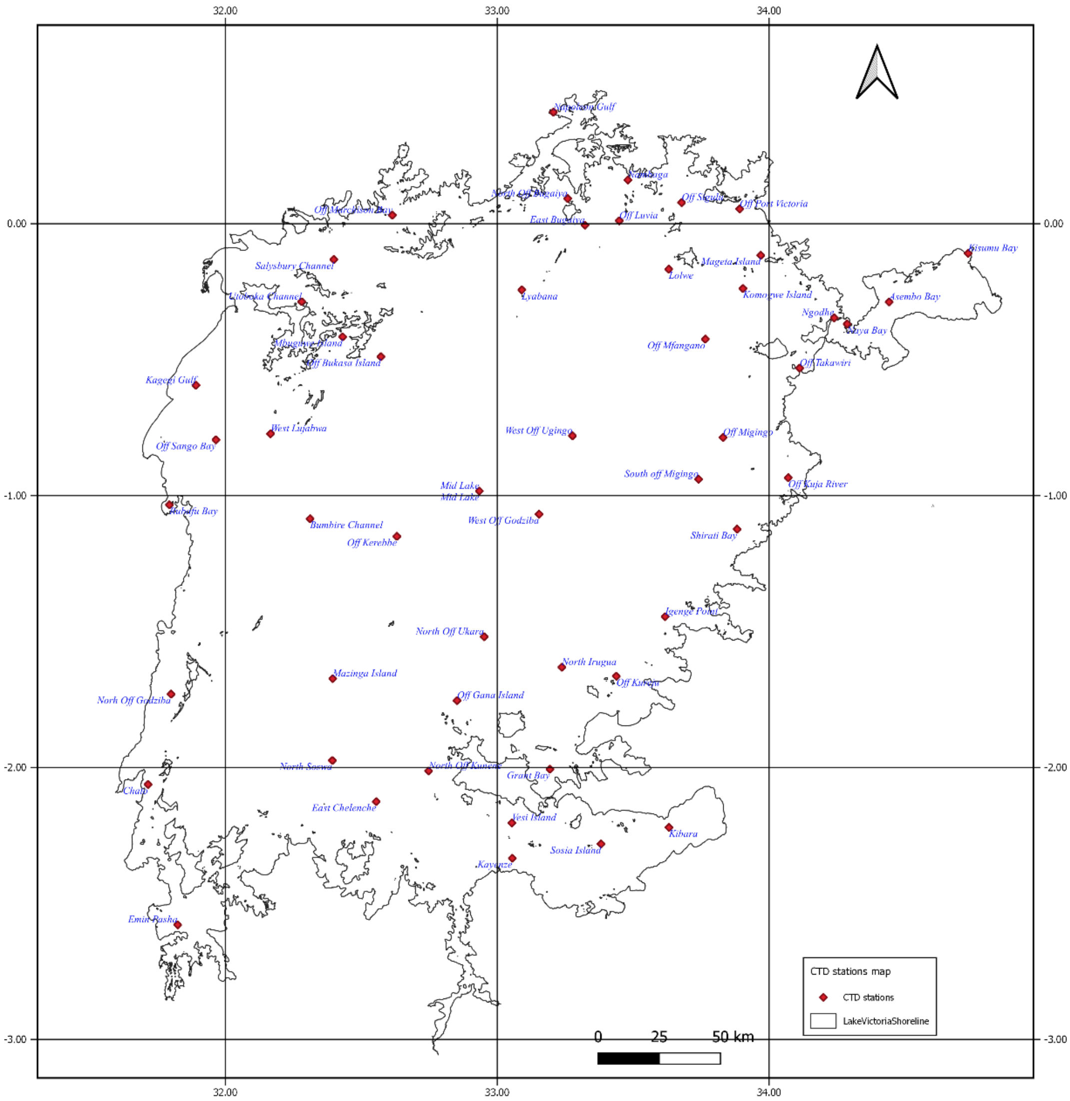

Figure 2. Map of Lake Victoria showing the CTD stations, September- October 2019

3.0. RESULTS AND DISCUSSION

3.1. Standing stock of Nile perch and size structure

The estimated densities and biomass of Nile perch in different regions of the lake are indicated in Table 3. The values are presented as means with 95% confidence interval (CI), indicating the lower and upper limits, for each quadrant and depth strata, and for each country. The lake-wide estimated biomass was 816,694 tons, with 705,458 tons as the lower limit and 940,922 tons as the upper limit, representing about 31% of the total fish biomass in the lake. At country level, the biomass was highest in the Tanzanian waters and lowest in the Kenyan waters. The average biomass per unit area was lowest in Kenyan waters (5.3 tons/km^2) and the highest in both Uganda and Tanzania (13.4 tons/km^2). There were spatial differences in biomass at strata level, with most fish distributed in inshore and coastal areas compared to the deep waters of the lake (Figure 3a).

Regarding temporal changes, the current lake-wide standing biomass is about 48% higher than the biomass estimated during the 2018 survey (Figure 4). However, the increase was only recorded in Tanzania and Uganda (Figure 5). This increase could be related to the strong enforcement effort to curb illegal fishing on the lake in the two sides of the lake.

Table 1: Density and biomass estimates of Nile perch greater than 10 cm TL, 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**
SE	Deep	6,166	9.65	14.48	11.68	59,514	89,299	72,010
SE	Coastal	5,786	17	20.84	18.86	98,368	120,585	109,116
SE	Inshore	2,003	22.54	29.73	26.03	45,151	59,558	52,145
SE	SG	2,909	9.34	11.43	10.36	27,167	33,241	30,141
SW	Deep	6,251	4.89	5.75	5.31	30,554	35,956	33,208
SW	Coastal	6,601	7.76	10.22	8.91	51,230	67,462	58,817
SW	Inshore	3,181	10.26	14.44	12.29	32,626	45,924	39,105
SW	EP	2,022	10.95	16.65	13.62	22,147	33,669	27,534
Subtotal						**366,757**	**485,694**	**422,076**
			Uganda					
NW	Deep	6,226	8.96	12.02	10.46	55,757	74,867	65,132
NW	Coastal	4,865	21.34	26.41	23.81	103,842	128,508	115,860
NW	Inshore	3,115	13.21	16.83	14.95	41,148	52,423	46,576
NW	SI	2,494	15.18	22.71	18.82	37,853	56,648	46,925
NE	Deep	4,724	4.66	6.22	5.39	21,992	29,369	25,451
NE	Coastal	2,704	8.24	9.78	8.99	22,279	26,442	24,318
NE	Inshore	3,966	10.14	13.24	11.62	40,205	52,501	46,083
Subtotal						**323,076**	**420,758**	**370,345**
			Kenya					
NE	Coastal	1,082	4.51	6.07	5.27	4,883	6,570	5,698
NE	Inshore	1,763	5.81	14.8	9.92	10,247	26,087	17,487
NE	NG	1,335	0.37	1.36	0.82	495	1,813	1,088
Subtotal						**15,625**	**34,470**	**24,273**
Total		**67,193**				**705,458**	**940,922**	**816,694**

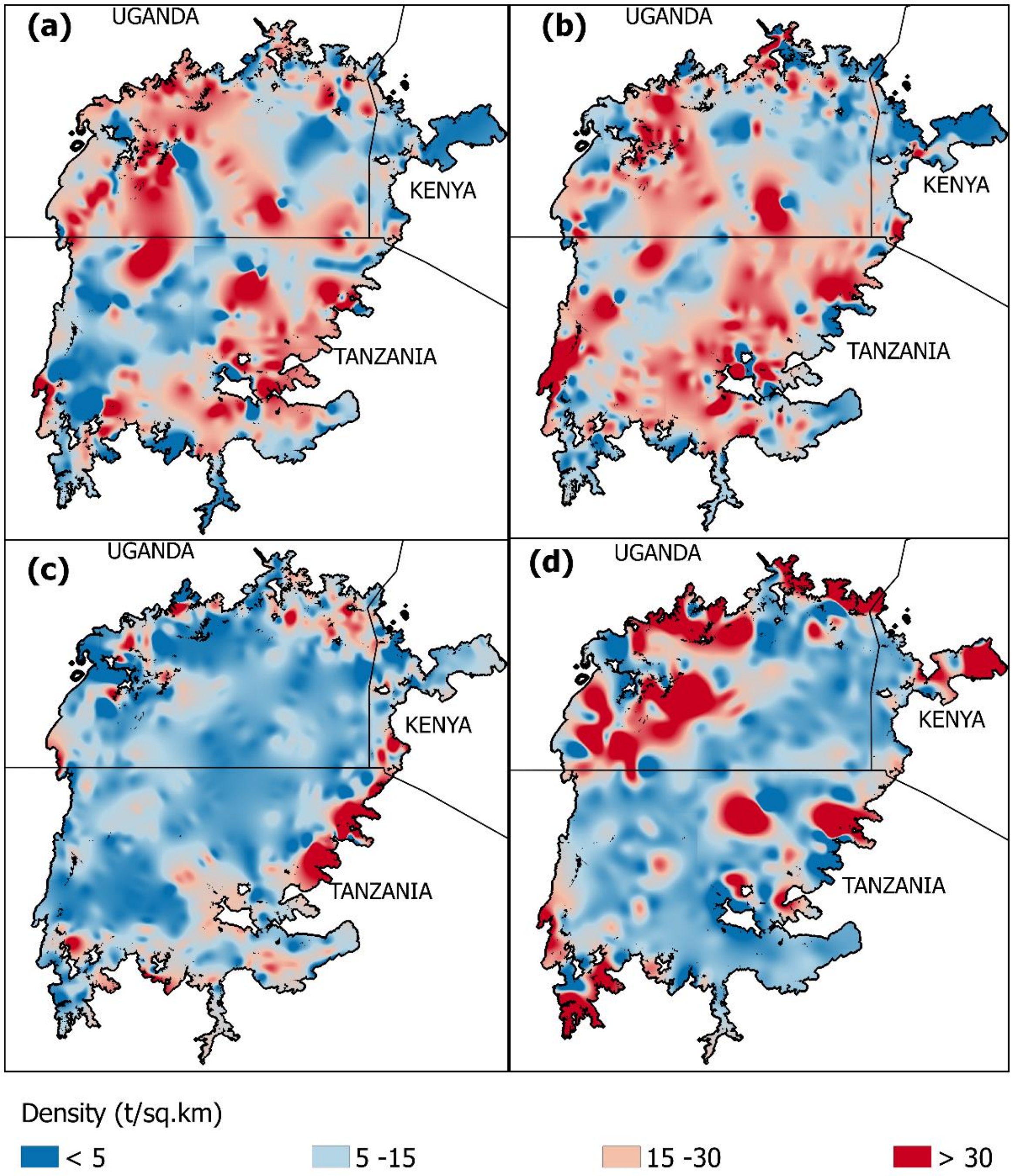

Figure 3. Spatial distribution of major fish groups and *caridina* in Lake Victoria during the 2019 hydro-acoustic survey. Panels represent: (a) Nile perch, (b) dagaa, (c) Haplochromines and others, and (d) and *Caridina nilotica*.

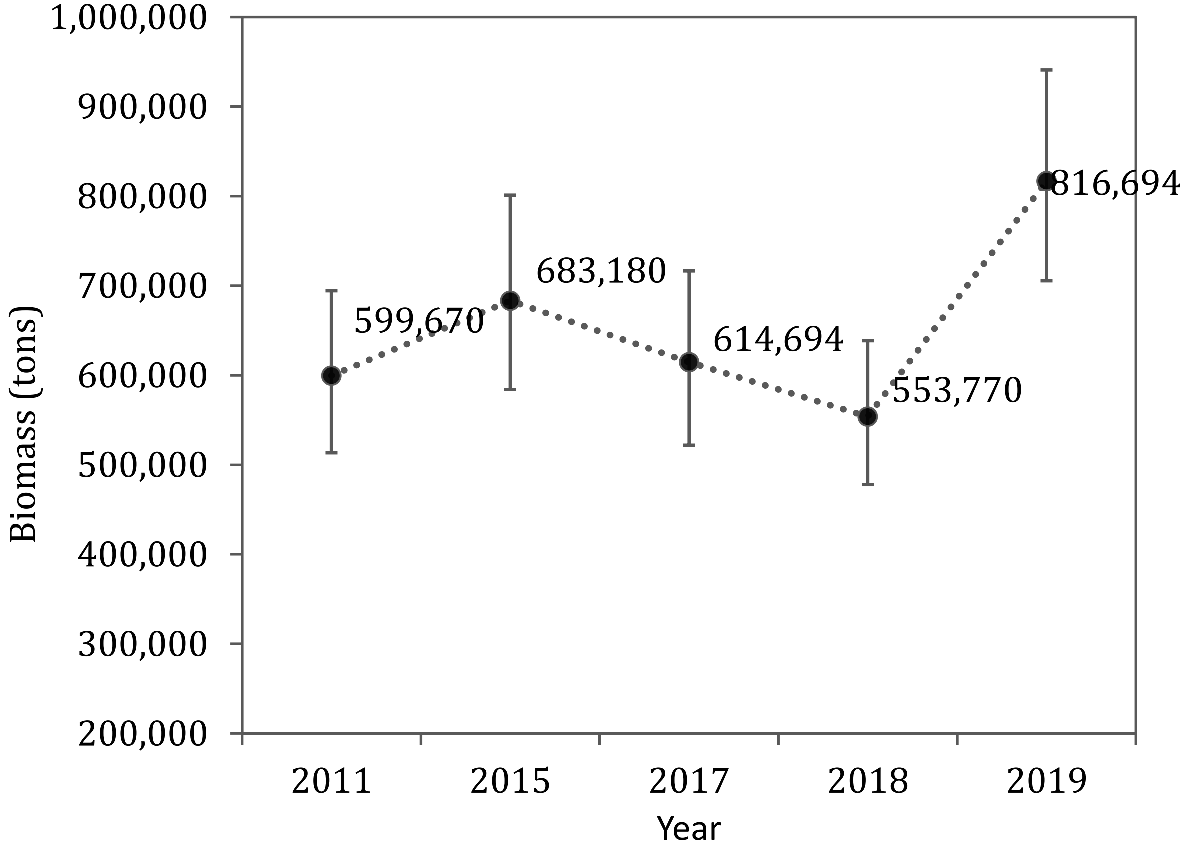

Figure 4. Biomass of Nile perch estimated through acoustic surveys between 2011 and 2019

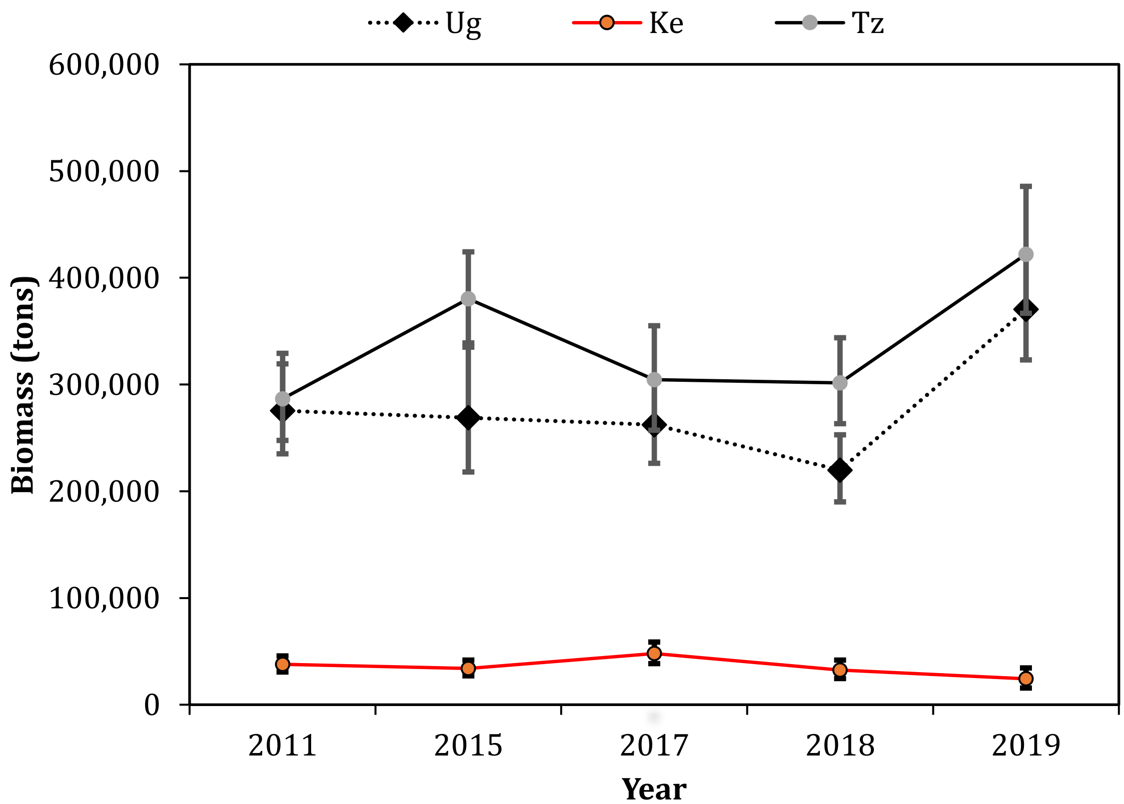

Figure 5. Biomass of Nile perch estimated through acoustic surveys for different countries between 2011 and 2019

The length frequency distribution of Nile perch above 10 cm total length (TL) recorded acoustically is shown in Figure 6. Generally, Nile perch in the lake (in terms of numbers) was dominated by small-sized individual less than 50 cm TL (the minimum recommended harvestable size). However, there was discernible increase in the proportion of fish above 50cm TL especially in the North-Western portion of the lake (Uganda). Almost all the Nile perch recorded in the Nyanza Gulf and Speke Gulf were below 50 cm TL.

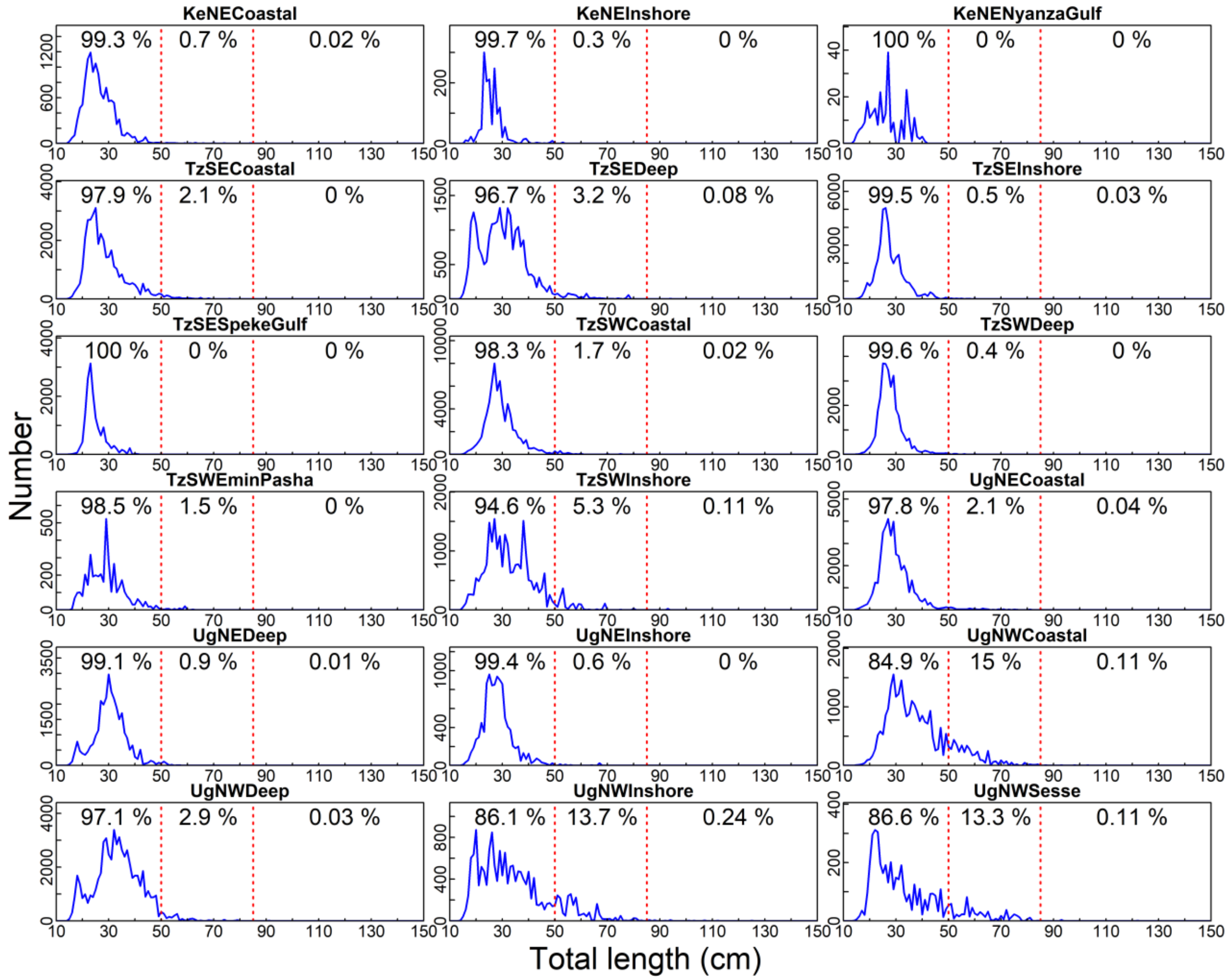

Figure 6. Length frequency distribution of Nile perch determined from acoustic single target detections during the September 2019 survey.

3.2. Standing stock of *dagaa*

Table 4 shows the estimated densities and biomass of *dagaa* in different regions of the lake for each quadrant and depth strata in the countries riparian to the lake (Tanzania, Uganda and Kenya). The lake-wide estimated standing stock was 936,247 tons, accounting for 35% of the total fish biomass in the lake. The lower and upper limits of the 95% CI were 800,687 tons and 1,091,258 tons, respectively. At country level, the biomass was highest in the Tanzanian and lowest in the Kenyan waters, with the same trend being observed in the fish densities (15.3 tons/km^2 for Tanzania, 13.5 tons/km^2 for Uganda and 12.6 tons/km^2 for Kenya). There was no clear pattern in terms of abundance by strata, except that biomass was comparatively low in deep areas (Figure 3b, Table 4).

Regarding temporal changes, the current lake-wide standing biomass is about 42% higher than the biomass estimated during the 2018 survey, and the increase was recorded in all countries. It should be noted that *dagaa* is a highly schooling fish species and since hydro-acoustic surveys are usually conducted during daylight, when most *dagaa* are in schools, identifying schools in echograms may be the most effective way to evaluate *dagaa* biomass and distribution. The *dagaa* school classification algorithm is still under development, and it will be important that it is adopted in the next survey and in the re-analysis of data from all the previous surveys. Being a schooling fish that is also exploited using aggregation methods (i.e. by light attraction), a precautionary approach (harvesting not more than 70% of standing biomass) may be beneficial to the stock.

Table 2: 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**
SE	Deep	6,166	16.75	19.56	18.11	103,278	120,599	111,673
SE	Coastal	5,786	21.4	25.84	23.5	123,809	149,520	135,979
SE	Inshore	2,003	22.89	35.71	28.88	45,858	71,518	57,837
SE	SG	2,909	8.1	12.32	10.12	23,549	35,839	29,440
SW	Deep	6,251	4.2	5.48	4.81	26,224	34,261	30,070
SW	Coastal	6,601	10.92	13.39	12.12	72,114	88,365	79,972
SW	Inshore	3,181	11.97	18.06	14.68	38,074	57,456	46,709
SW	EP	2,022	7.3	14.4	10.47	14,758	29,119	21,160
Subtotal						**447,665**	**586,678**	**512,840**
			Uganda					
NW	Deep	6,226	12.03	14.85	13.41	74,923	92,460	83,502
NW	Coastal	4,865	10.95	14.57	12.73	53,282	70,889	61,912
NW	Inshore	3,115	15.05	19.02	16.94	46,880	59,252	52,769
NW	SI	2,494	14.16	23.79	18.71	35,316	59,329	46,652
NE	Deep	4,724	6.18	8.35	7.04	29,189	39,427	33,268
NE	Coastal	2,704	9.56	11.8	10.63	25,853	31,917	28,744
NE	Inshore	3,966	11.57	18.61	14.85	45,873	73,807	58,899
Subtotal						**311,316**	**427,080**	**365,747**
			Kenya					
NE	Coastal	1,082	5.19	8.23	6.39	5,617	8,899	6,914
NE	Inshore	1,763	14.49	29.07	21	25,538	51,242	37,024
NE	NG	1,335	7.9	13	10.28	10,551	17,359	13,723
Subtotal						**41,706**	**77,500**	**57,660**
Total		**67,193**				**800,687**	**1,091,258**	**936,247**

3.3. Standing stock of Haplochromines and others

The densities and biomass estimates of haplochromines and other unidentified fish species, by country and strata, are shown in Table 5. The estimated mean biomass of haplochromines and other unidentified fishes for the whole lake was 362,876 tons, representing 13.5% of the total fish biomass in the lake. The lower limit of the 95% confidence interval was 304,483 tons, while the upper limit was and 429,131 tons. The biomass was highest in Tanzanian water (175,016 tons), followed by Ugandan waters (164,286) and was lowest in the Kenyan waters (23,574 tons) (Figure 3c). The average densities were, however, comparatively similar (6.7 t/km^2 in Tz, 6.1 t/km^2 in Uganda, and 5.1 t/km^2 in Kenya).

The biomass of Haplochromine spp. and other unidentified fish species reduced by 15.5% compared to the biomass recorded during the 2018 survey, and the decline was recorded in the Tanzanian and Kenyan waters. Haplochromines form a major component in the diet of diet of adult Nile perch (Kishe-Machumu et al. 2012), and the decline recorded during the 2019 survey may be related to the increase in the biomass of its predator (the Nile perch). Important to note is that most of Haplochromines are habitat-specific and quite sensitive to changes in water quality. Protection of inshore habitats from continued degradation seems to be more holistic approach than for instance banning its fishing. The former should be prioritized to sustain the commercially important (adult) Nile perch.

Table 3. Estimated standing stock of Haplochromine cichlids and other unidentified fish species in Lake Victoria by country and by strata

Region parameters			**Densities (t/km^2)**			**Biomass**		
Quadrant	**Stratum**	**Areas (Sq. km)**	**Low**	**High**	**Mean**	**Low**	**High**	**Mean**
					Tanzania			
SE	Deep	6166	2.46	3.84	3.09	15,188	23,707	19,081
SE	Coastal	5786	4.36	5.88	5.09	25,247	34,011	29,453
SE	Inshore	2003	14.17	21.12	17.53	28,389	42,310	35,122
SE	SG	2909	7.96	9.18	8.57	23,164	26,690	24,923
SW	Deep	6251	1.51	1.78	1.64	9,413	11,134	10,252
SW	Coastal	6601	2.37	3.16	2.75	15,672	20,842	18,136
SW	Inshore	3181	5.34	7.50	6.38	16,971	23,868	20,283
SW	EP	2022	7.53	10.13	8.79	15,227	20,492	17,766
Subtotal						**149,271**	**203,054**	**175,016**
					Uganda			
NW	Deep	6226	4.36	6.10	5.13	27,118	37,983	31,945
NW	Coastal	4865	4.51	5.41	4.95	21,946	26,344	24,105
NW	Inshore	3115	6.82	8.66	7.70	21,253	26,980	23,975
NW	SI	2494	6.57	10.31	8.35	16,379	25,716	20,825
NE	Deep	4724	2.34	3.15	2.70	11,056	14,862	12,771
NE	Coastal	2704	2.61	3.39	2.98	7,046	9,156	8,053
NE	Inshore	3966	8.53	13.32	10.74	33,846	52,813	42,612
Subtotal						**138,645**	**193,854**	**164,286**
					Kenya			
NE	Coastal	1082	2.47	3.21	2.82	2,675	3,477	3,049
NE	Inshore	1763	5.50	13.51	9.06	9,699	23,824	15,974
NE	NG	1335	3.14	3.69	3.41	4,192	4,921	4,551
Subtotal						**16,567**	**32,222**	**23,574**
Total		**67,193**				**304,483**	**429,131**	**362,876**

3.4. Standing stock of *Caridina nilotica*

The estimated biomass and densities of *C. nilotica* in different regions of the lake are indicated in Table 6. The estimated lake-wide mean biomass of *C. nilotica* was 565,348 tons, representing about 21% of the total biomass in the lake. The lower limit of the 95% confidence interval was 340,257 tons, while the upper limit was 868,260 tons. Like the 2018 survey, the biomass was highest in the Ugandan waters and lowest in Kenyan waters. As in the case of Nile perch and haplochromines, there were spatial variations with higher densities in inshore and coastal regions compared to deep areas (Figure 3d).

Table 4. Estimated standing stock of *C. nilotica* in Lake Victoria by quadrant, country and stratum

Region parameters			Densities (t/km^2)			Biomass (tons)		
Quadrant	**Stratum**	**Areas (Sq. km)**	**Low**	**High**	**Mean**	**Low**	**High**	**Mean**
					Tanzania			
SE	Deep	6166	2.31	6.64	4.09	14,250	40,967	25,242
SE	Coastal	5786	3.21	5.38	4.24	18,580	31,141	24,517
SE	Inshore	2003	4.04	16.25	7.95	8,096	32,539	15,923
SE	SG	2909	-	-	-	-	-	-
SW	Deep	6251	1.48	3.56	2.39	9,272	22,280	14,919
SW	Coastal	6601	2.5	4.08	3.27	16,489	26,931	21,573
SW	Inshore	3181	2.18	5.76	3.71	6,940	18,323	11,805
SW	EP	2022	12.92	39.09	24.12	26,134	79,043	48,766
Subtotal						**99,761**	**251,223**	**162,745**
					Uganda			
NW	Deep	6226	2.21	6.35	4.08	13,751	39,539	25,387
NW	Coastal	4865	18.16	33.25	25.13	88,369	161,768	122,266
NW	Inshore	3115	18.93	33.03	25.54	58,956	102,881	79,554
NW	SI	2494	13.69	34.79	23.65	34,134	86,762	58,985
NE	Deep	4724	0.88	1.7	1.26	4,151	8,017	5,943
NE	Coastal	2704	2.77	5.66	4.05	7,491	15,299	10,947
NE	Inshore	3966	5.74	25.14	12.92	22,747	99,720	51,226
Subtotal						**229,599**	**513,988**	**354,309**
					Kenya			
NE	Coastal	1082	2.91	5.30	4.00	3,152	5,730	4,326
NE	Inshore	1763	-	-	-	-	-	-
NE	NG	1335	5.80	72.90	32.93	7,745	97,319	43,968
Subtotal						**10,897**	**103,049**	**48,294**
Total		**67,193**				**340,257**	**868,260**	**565,348**

3.5. 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. There was a strong linear association between biomass estimates of Nile perch from acoustics and catch rates from bottom trawls (r = 0.7). Unlike, the 2018 survey, where Nile perch was positively correlated with haplochromines, the relationship between the two groups was zero (from acoustic biomass estimates) and negative for the Nile perch acoustic biomass estimates and haplochromines' catch rates of from bottom trawls. This is not surprising considering that that the biomass of Nile perch increased, while the biomass of haplochromines, relative to estimates from the 2018 survey. Interestingly, there was a positive association between Nile perch and *C. nilotica* abundance, unlike the 2018 survey, and this was also reflected in the stomach contents of Nile perch with the contribution of *C. nilotica* to the diet of Nile perch increasing and that of haplochromines decreasing (Enock Mplaponi, personal observation).

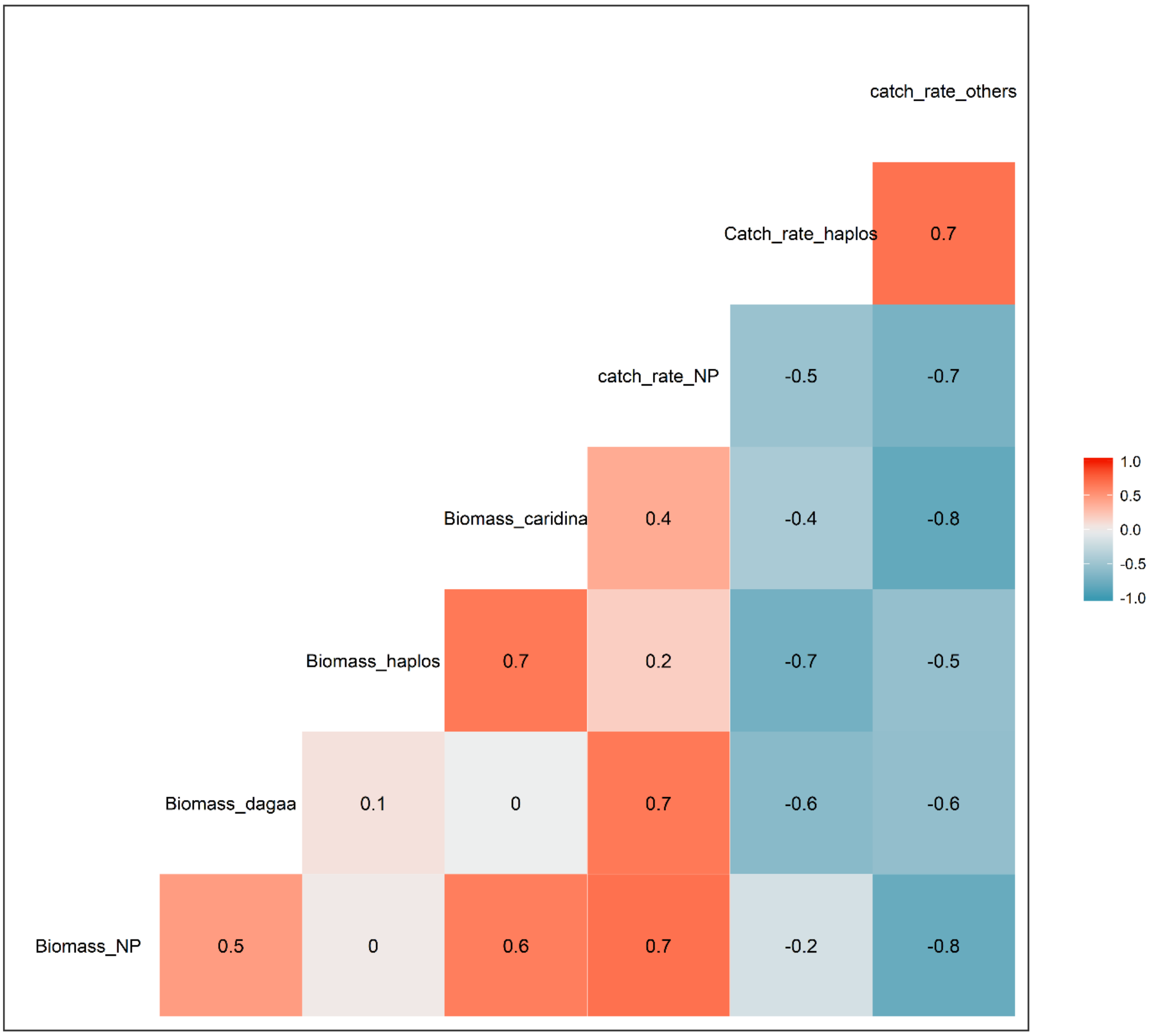

Figure 7. Relationship between spatial fish biomass trends and catch rates from net bottom hauls. NP stands for Nile perch, haplos stands for haplochromines

3.6. Relationship between fish distribution and environmental parameters

The relationship between fish abundance (biomass) and limnological parameters is shown in Figure 8. Nile perch is negatively correlated with haplochromines and *dagaa*, but the specie's densities are all distinguished by inshore and coastal regions and special areas (Sesse Island and Emin Pasha Gulf). In addition, the position of Nile perch and haplochromines shows that the groups are negatively correlated with turbidity, total dissolved solids, and conductivity which were highest in special regions (especially Emin Pasha and Nyanza Gulf, which clearly separate from the regions on the biplot).

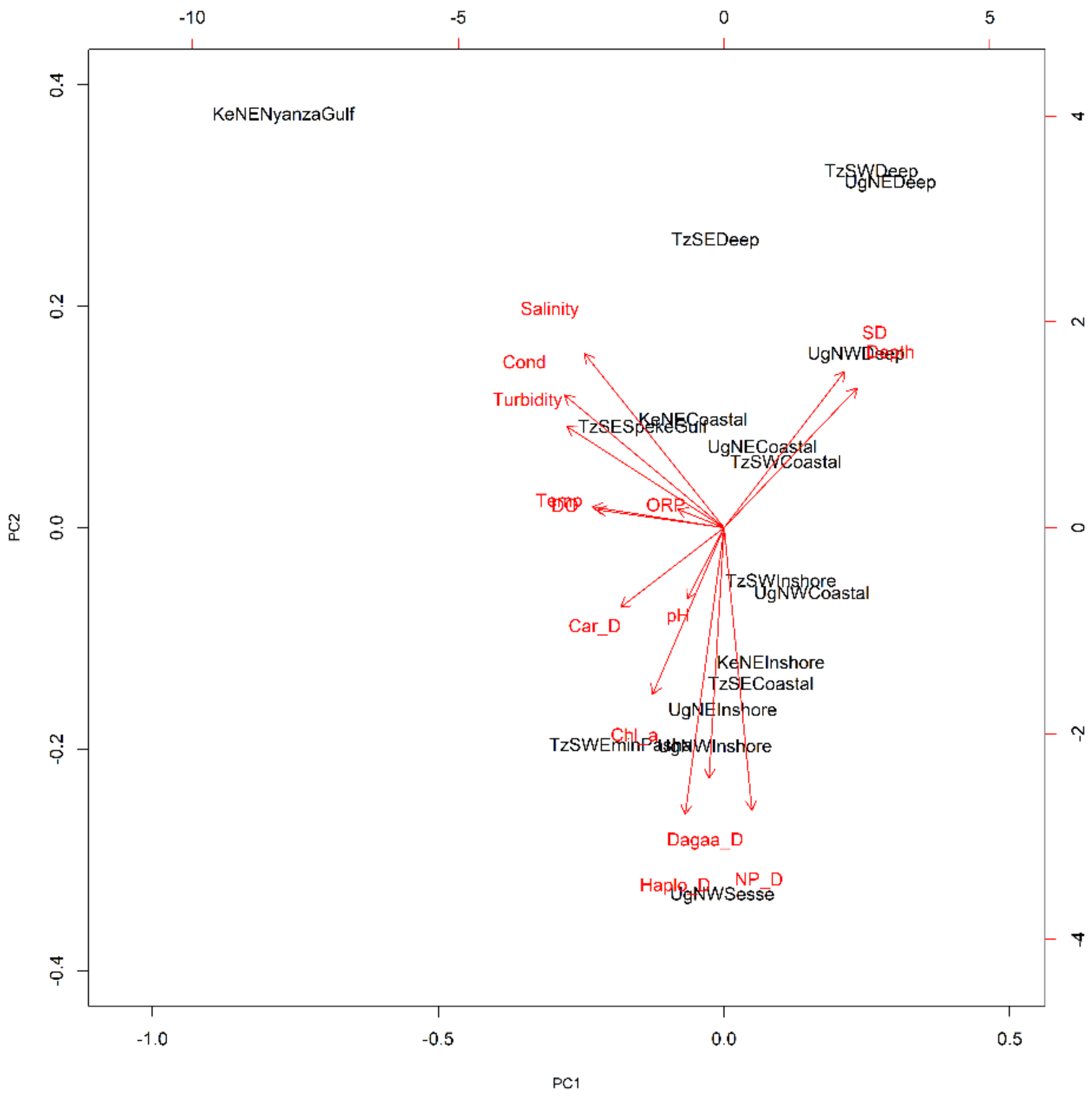

Figure 8. Principal component analysis (PCA) biplot of biomass densities and environmental parameters under different the different regions. Abbreviations stand for: Ug (Uganda), Ke (Kenya), Tz (Tanzania), NE (North East), NW (North West), SW (South West) and SE (South East), cond (conductivity), SD (secchi depth). *Dagaa*_D, haplochromine_D, Nile perch_D refer to fish densities in respective groups. Car-D stands for *caridina nilotica* densities.

4.0. CONCLUDING REMARKS

- Fish abundance is higher in inshore and coastal areas compared to deeper waters and seems to be influenced by water quality.
- The increase in fish biomass (Nile perch and *dagaa*) may be attributed to the current enforcement especially in the Ugandan and Tanzanian parts of the lake.
- The size structure of Nile perch has continued to improve, especially in the Ugandan parts of the lake, which may also be attributed to the ongoing effort by the military to enforce the minimum mesh size regulation.
- The decrease in the biomass of haplochromines is not surprising, given the increase in predator (Nile perch) abundance. This is likely to affect Nile perch stock, although we observed in this survey adult Nile perch also ingesting *C. nilotica*, whose abundance has increased.
- Overall physical and chemical attributes show that the lake to be in a fair and stable state of environmental health.

5.0. SURVEY RECOMMENDATIONS

- Prey species such as haplochromines and *Caridina nilotica* need to be protected to sustain the recovering stocks;
- Lake-wide enforcement of fisheries regulations should be embraced. Empirical evidence shows an increase in number and size of fish in areas with enhanced enforcement and compliance with fisheries regulations;
- There is still need to facilitate re-analysis of all the data from all the past surveys so as to improve reporting on the trends for all the monitored taxa.
- We still recommend that re-analysis of data for dagaa from previous surveys using the school detection algorithm is facilitated and fast-tracked.
- There is need to ensure, during the planning of the next survey, that every region and strata has at least one bottom trawl conducted.
- The long transects that end in the night is still a logistical challenge that needs a review.

6.0. REFERENCES

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7.0. APPENDICES

Appendix I: Detailed results from net bottom hauls

A1.1. Catch composition

A total of thirteen taxa of fish were recorded through 24 net hauls, which is equivalent to one less taxa compared to September 2018 survey, and two more less taxa for the September 2017 survey. *Lates niloticus* with 93.12% dominated the catch by weight, followed by haplochromines with 1.95%. The dominance of Nile perch in this year was higher compared to the past five years. Haplochromine, on the other hand, decreased from 8.19% for the last year survey to decline to 2% (Figure A1.1).

In the order of dominance, the species recorded were *L. niloticus*, *C. nilotica,* Haplochromines sp, *R. argentea, Barbus profoundus, Oreochromis niloticus, Protopterus aethiopicus, Clarius gariepinus, Synodontis victoriae, Brycinus sadleri, Afromastercemblus frenatus, Schilbe intermedius, S. afrofischeri.* Other fish species which were found in the previous surveys were not encountered in this survey. Some of this species are *Bagrus dockmac, B. jacksonii*, *Momyrus kanume*, *Coptodon rendali,* and *C. zillii.*

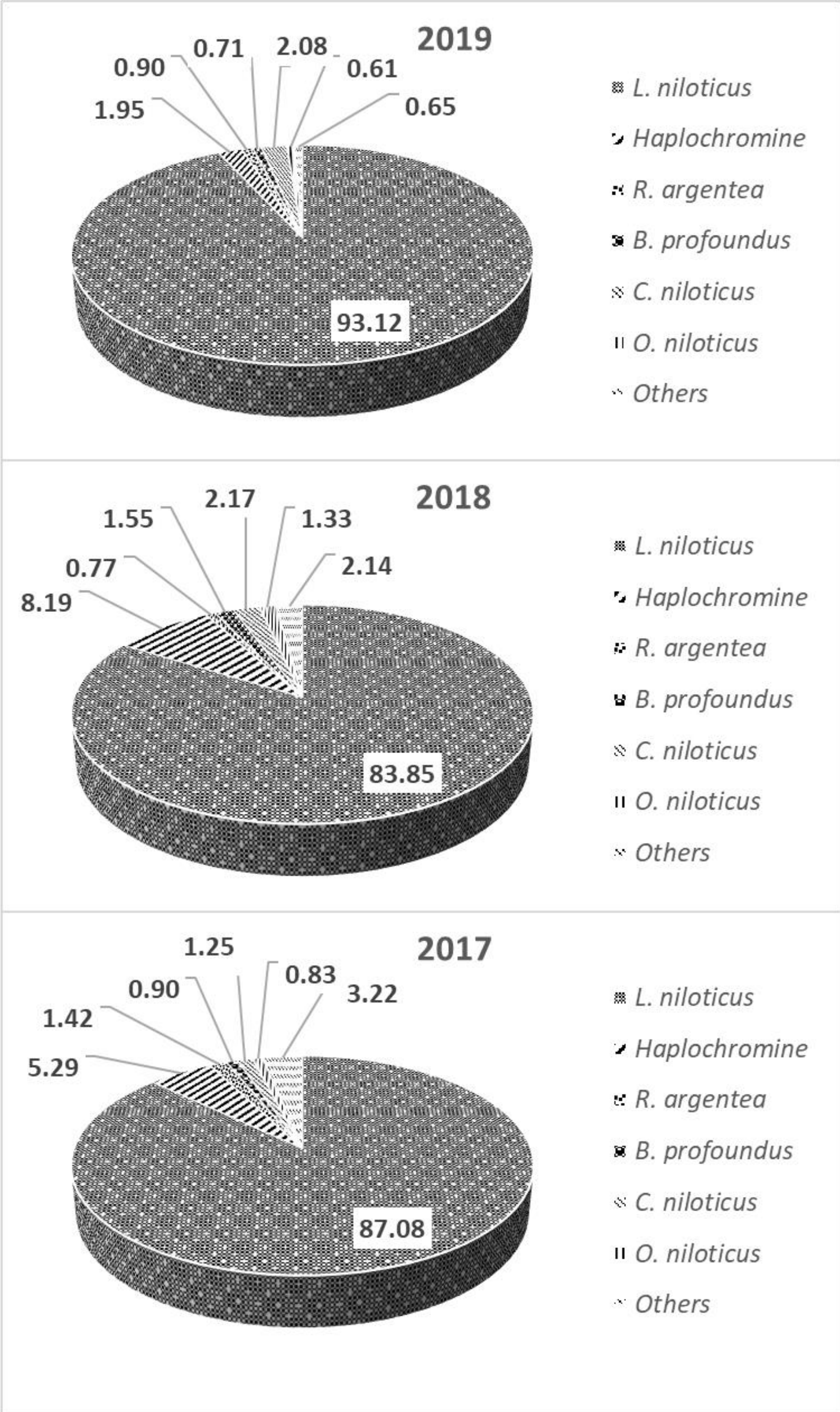


Figure A1.1: Catch composition for the survey period of 2017-2019

Table A1.1: Changes in catch composition (percentage weight) in Lake Victoria

Species	Nov. 2015	Sep. 2016	Sep 2017	Sep 2018	Sep 2019
Nile perch	64.27	64.210	87.08	83.85	93.12

Haplochromines	24.14	25.56	5.29	8.19	1.95
Dagaa	5.89	7.26	1.42	0.77	0.90
Others	1.16	0.36	3.22	2.14	0.65

A1.2. Catch per Unit Effort as an index of Relative abundance

Catch per Unit Effort (CPUE) for four consecutive years expressed as Kg/haul is shown in the Table A1.2 for the Nile perch, haplochromines, dagaa and other fish species. Nile perch recorded the highest CPUE since 2015 while haplochromines recorded the lowest over the same period. The high CPUE and low CPUE of Nile perch and haplochromines, respectively, are consistent with biomass estimates from hydro-acoustic surveys (see above).

Table A1.2: Changes in CPUE (Kg/haul) (Kg ± SE) since 2015 to 2019

Period	**n**	**Nile perch**	**Haplochromines**	**Dagaa**	**Others**
Nov 2015	25	46.03±13.55	17.29±5.25	4.22±1.32	4.92±1.77
Sep 2016	24	42.16±6.72	16.78±3.94	4.77±1.66	1.95±0.62
Sep 2017	30	103.55±14.71	6.29±1.40	1.69±0.71	7.58±2.07
Sep 2018	25	79.88±21.40	7.81±2.32	0.73±0.37	5.52±1.42
Sep 2019	24	116.36±29.69	2.43±0.83	1.12±0.54	5.05±1.43

A1.3 Catch per unit effort in different quadrants

CPUE for two successive years expressed as Kg/haul in different quadrants is shown in Table A1.3. The CPUE for Nile perch was highest and lowest in the NW and NE quadrants, respectively, but there was an increase in all quadrants compared to the previous years. Haplochromines, on the other hand, decreased in all quadrants.

Table A1.3: Changes in CPUE (Kg/haul) (Kg ± SE) based on quadrants

Quadrant	YEAR	Nile perch	Haplochromine	Dagaa	Others
SW	2017	134.50±26.97	4.82±1.99	1.55±1.33	8.94±4.72
	2018	24.197±5.35	8.12±3.13	1.31±1.17	9.80±3.23
	2019	45.26±26.91	3.55±2.29	1.53±1.29	8.39±4.05
NW	2017	101.62±28.17	4.16±1.37	5.39±3.33	9.62±5.05
	2018	153.83±55.89	4.75±2.57	0.01±0.01	2.97±1.24
	2019	181.36±102.44	3.04±2.42	1.06±0.60	0.75±0.47
NE	2017	59.67±19.99	6.45±2.48	0.71±0.59	4.19±2.03
	2018	38.86±16.62	6.43±4.76	0.92±0.55	3.88±2.76
	2019	93.46±33.41	1.09±0.31	1.77±1.75	7.59±3.59
SE	2017	132.23±38.75	9.26±4.36	0.63±0.23	9.43±5.85
	2018	103.52±55.33	13.30±9.01	0.71±0.59	5.07±3.83
	2019	145.37±41.95	2.05±0.92	0.14±0.09	3.45±0.72
Overall	**2017**	**103.55±14.71**	**6.29±1.40**	**1.69±0.71**	**7.58±2.07**
	2018	**79.88±21.40**	**7.81±2.32**	**0.73±0.37**	**5.52±1.42**
	2019	**116.36±29.69**	**2.43±0.83**	**1.12**±0.54	**5.05**±1.43

A1.4 Length frequency distribution of Nile perch

The size structure of Nile perch caught during the September 2019 surveys ranged from 1cm to 103 cm, with mean length of 15.0 cm TL. Generally, the size structure is the same as 2018; the difference in the appearance of the distribution is due to different sample sizes involved.

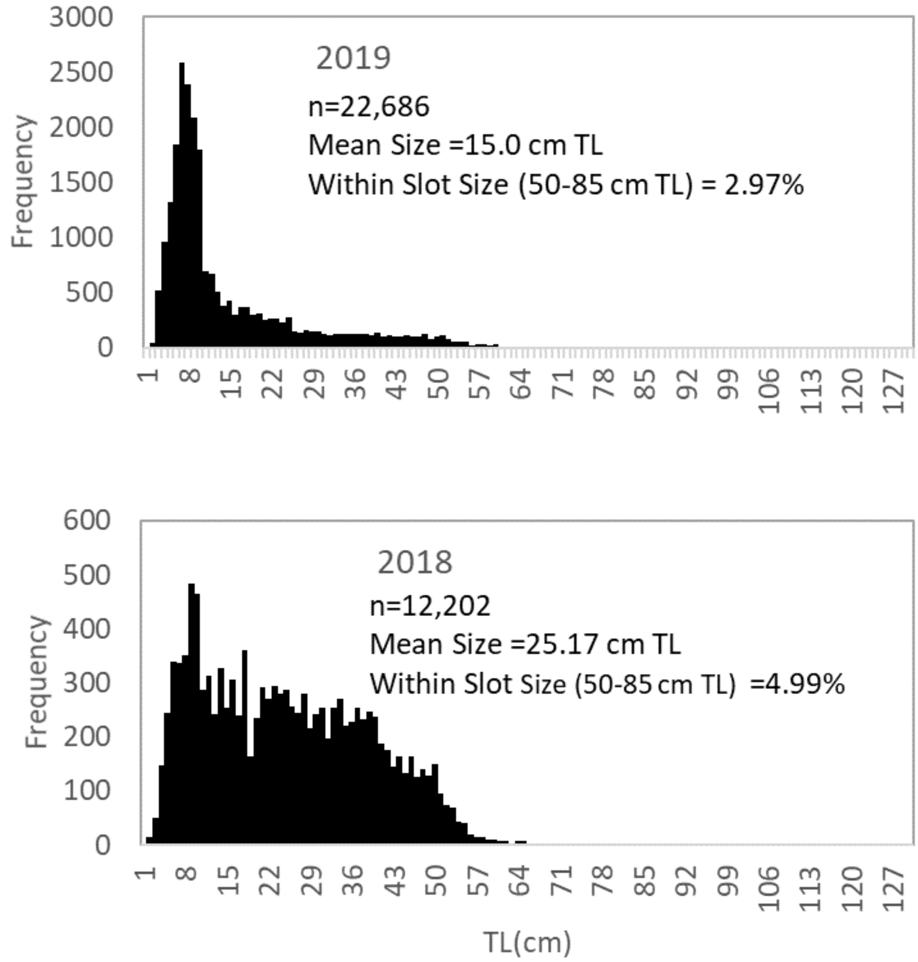


Figure A1.2: Overall population structure of *Lates niloticus* for 2018 and 2019.

Table A1.4 shows mean length of Nile perch recorded in different quadrants. Mean length was highest and lowest in NW and SW quadrants, respectively.

Table A1.4: Size characteristics of Nile perch by quadrants in Lake Victoria

Quadrant	*Year*	*Mean T L (cm)*	**N**	*%>50.0 cm TL*
SW	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	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	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	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

Appendix II: Detailed results for limnological parameters

A2.1 Overall limnological conditions of the lake

Limnological observations across the fifty three (53) CTD stations indicate sporadic minor thermal stratification patterns throughout the lake, with most of the apparently stratified waters occurring within the NE and NW Inshore and Coastal waters (Figures A2.2-A2.6). While the deep transects did not exhibit stratification, there were indications of hypoxia occurring especially close to the lake bottom (Figure A2.6). The lake wide mean temperature was (Mean±SD) 24.98±0.61 ºC which falls close to, but above the mean temperatures recorded in the previous year. Dissolved Oxygen (DO) recorded a lake-wide mean of 6.97±1.55 mg L^{-1}, which is falls above the critical levels for fish survival. The overall means of pH, conductivity, turbidity and transparency (Secchi) were 7.71±1.06, 94.09±9.92 µS cm^{-1}, 2.18±4.21 FTU and 2.21±1.76 m, respectively. Notable variations were observed when data was examined by summarising by quadrant and strata. The Principal Component Analysis plot on Figure A2.8 shows the interactions among the parameters at different CTD Stations.

A2.2 Spatial variations in temperature by quadrant and strata

Table A2.1 shows a summary (mean ±SD) of physical, chemical and biochemical attributes of the lake at different quadrants. The NE quadrant recorded temperatures of 25.07±0.66 ºC, while the SE had a mean temperature of 25.18±0.76 ºC, making it the warmest quadrant. Temperatures at the SW quadrant recorded a mean of 24.78±0.34 ºC, which makes it the coolest region, the same cases as the previous year's observation. The NW quadrant had a mean of 24.84±0.46 ºC. The lake became slightly warmer than the previous year by comparison of the means. See annex 1. The NW and NE quadrants showed slight stratification trends especially within the Coastal strata (Figure A2.6).

A2.3 Spatial variations in dissolved oxygen (DO) by quadrants and strata

The water column profiles of dissolved oxygen are visualized alongside those of temperatures in Figures A2.2-A2.8 for depth strata and special areas. Mean concentrations of DO for quadrant, strata, special regions and countries have been presented in Tables A2.1-A2.4. Notable variations in mean column dissolved oxygen concentrations between quadrants were observed in Table A2.1. In the North Eastern quadrant, DO concentrations recorded a mean of 6.79±1.66 mg L-1 while the South East sector of the lake had a mean of 6.11±1.62 mg L-1. The south West (SW) quadrant recorded mean column DO of 7.2±1.47 mg L-1. Highest DO values were recorded in the North Western with a mean of 7.61±1.11mg L-1.

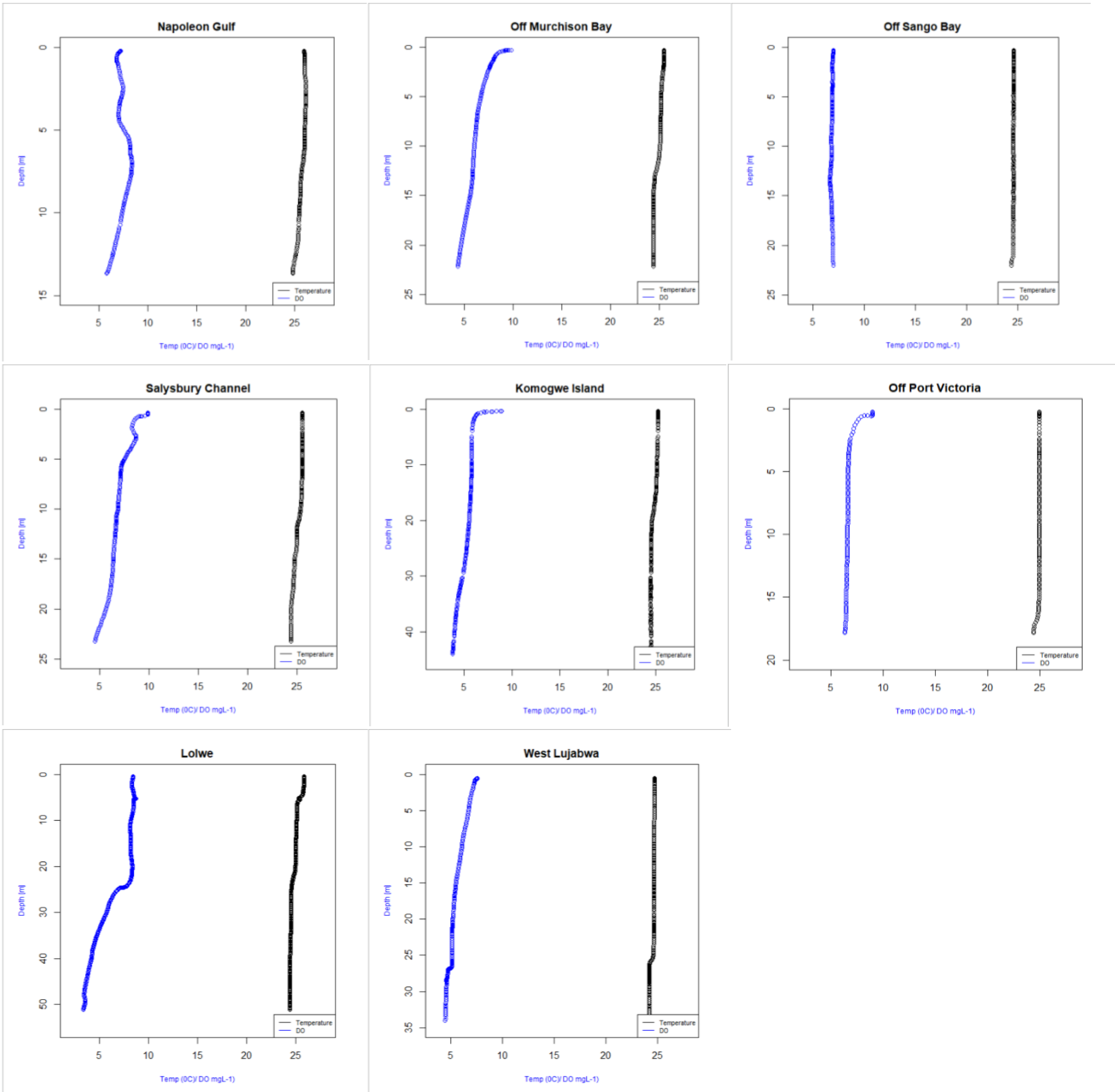


Figure A2.1. Temperature and Dissolved oxygen (DO) profiles within the Inshore CTD stations

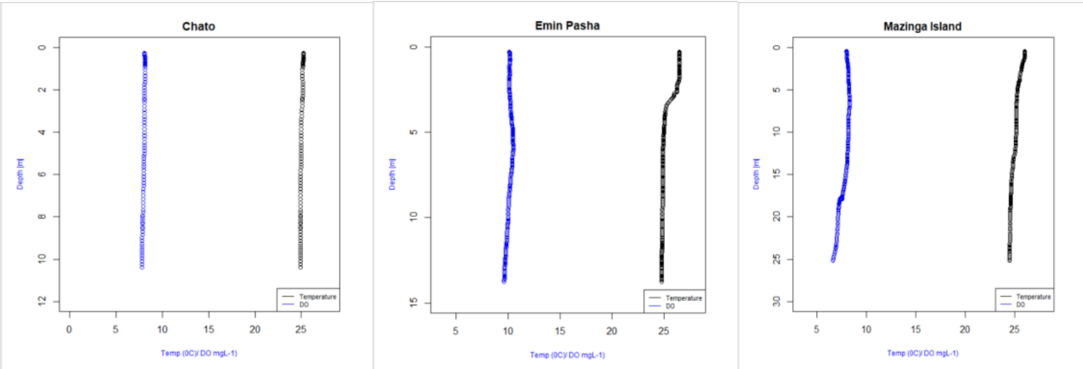


Figure A2.2. Temperature and Dissolved oxygen (DO) profiles within the Emin Pasha CTD stations

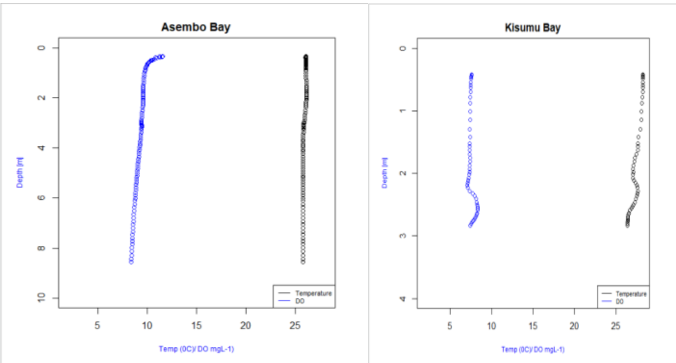


Figure A2.3. Temperature and Dissolved oxygen (DO) profiles within the Nyanza Gulf CTD stations

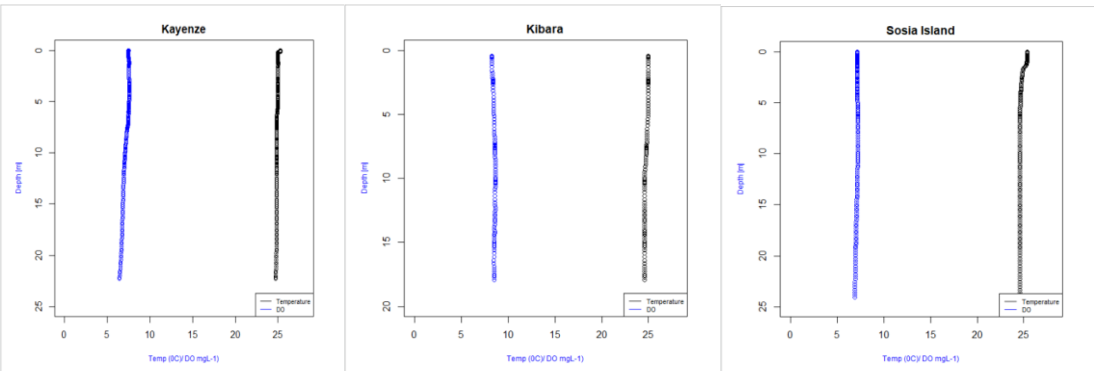


Figure A2.4. Temperature and Dissolved oxygen (DO) profiles within the Speke Gulf CTD stations

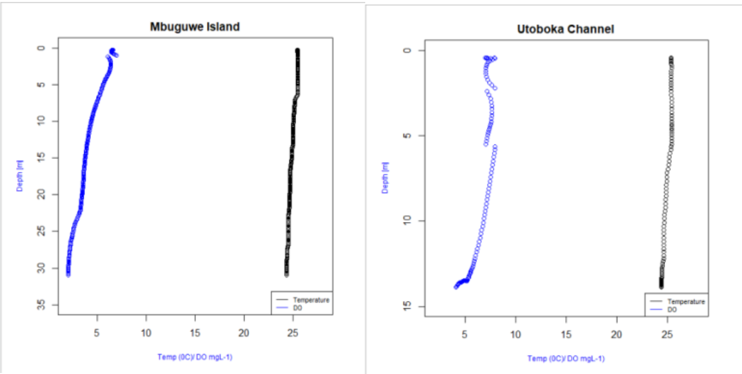
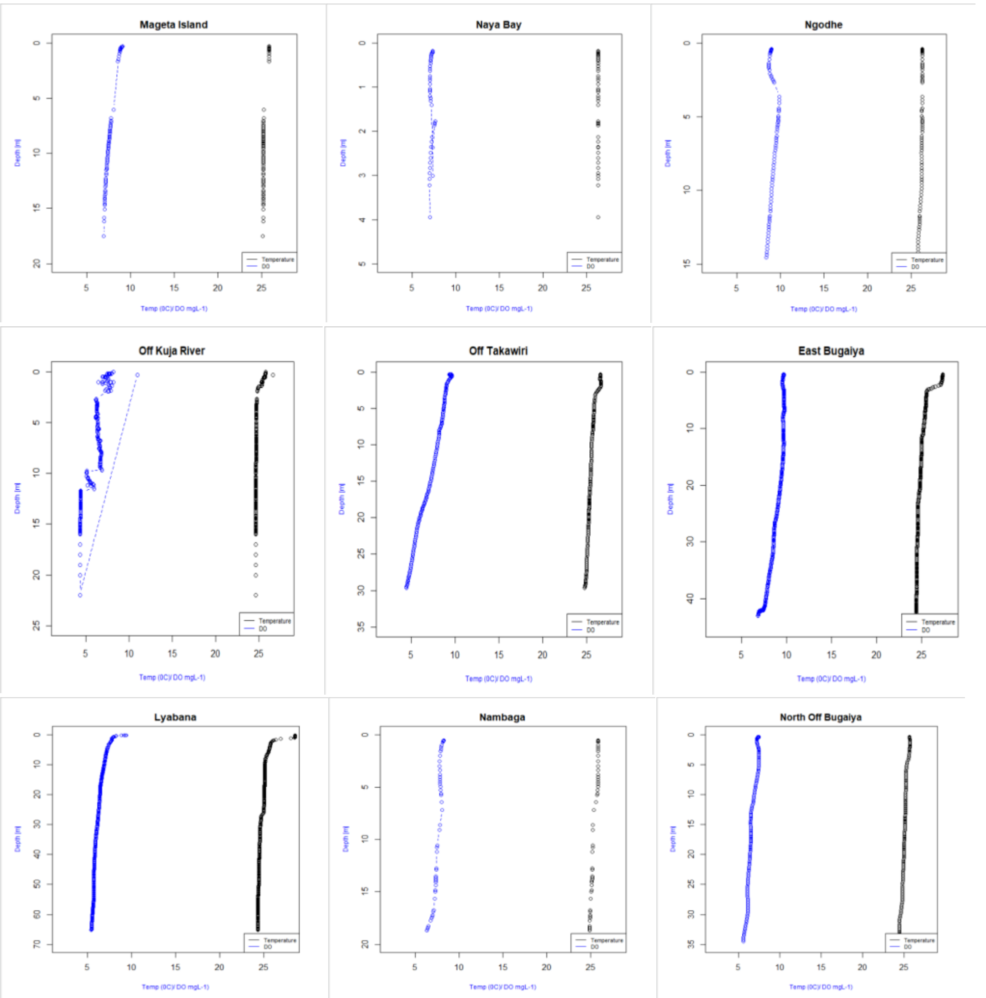
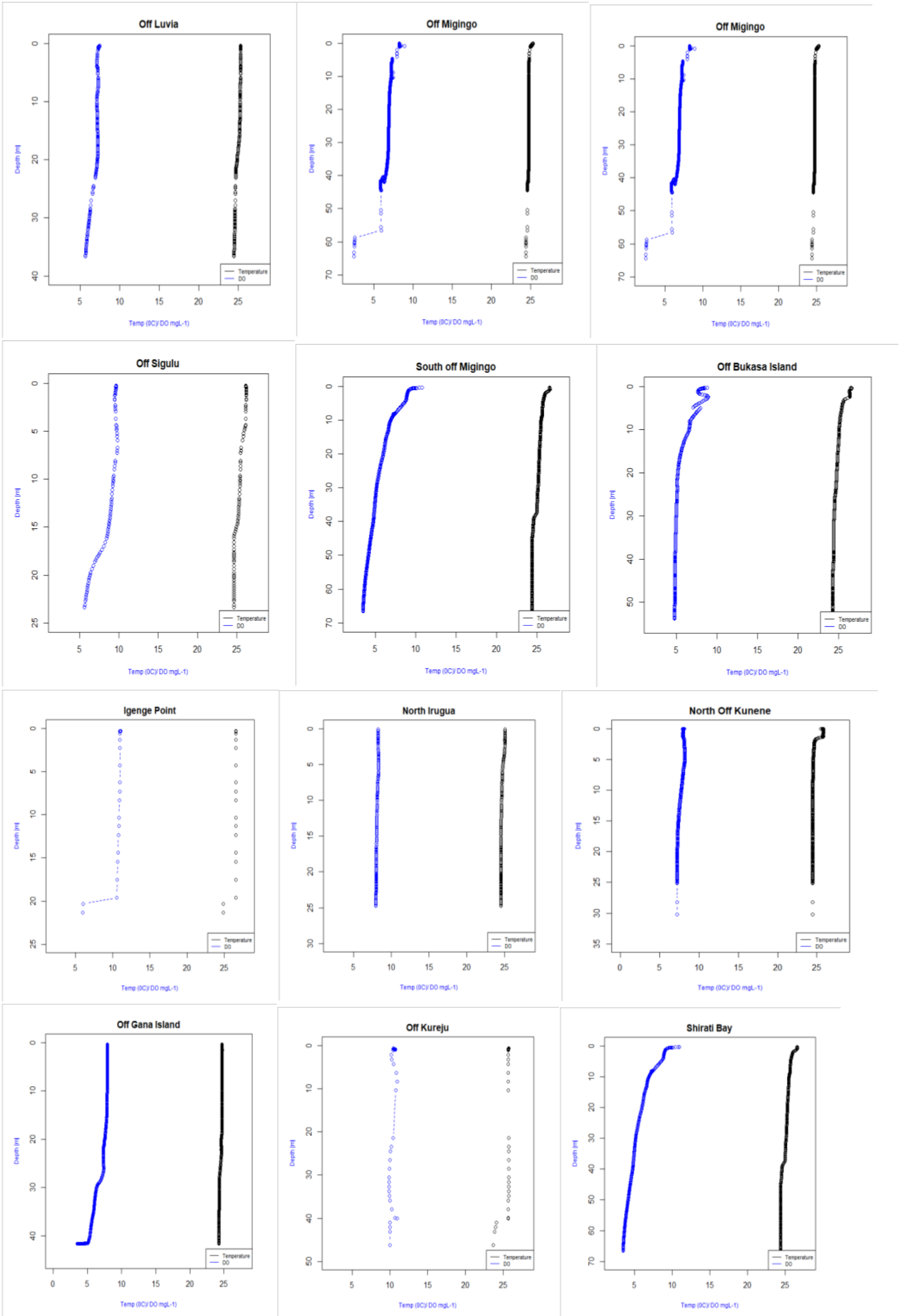


Figure A2.5. Temperature and Dissolved oxygen (DO) profiles within the Ssese Islands CTD stations




Off Luvia
Off Migingo
Off Migingo
Off Sigulu
South off Migingo
Off Bukasa Island
Igenge Point
North Irugua
North Off Kunene
Off Gana Island
Off Kureju
Shirati Bay
Depth (m)
Temp (0C)/ DO mgL-1
Temperature
DO

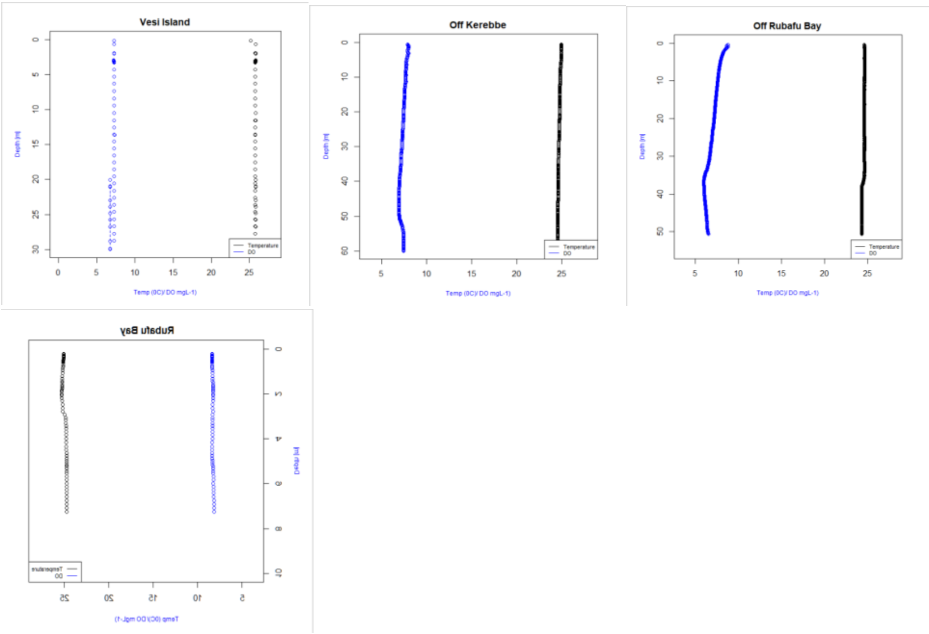


Figure A2.6. Temperature and Dissolved Oxygen (DO) profiles within the Coastal CTD stations

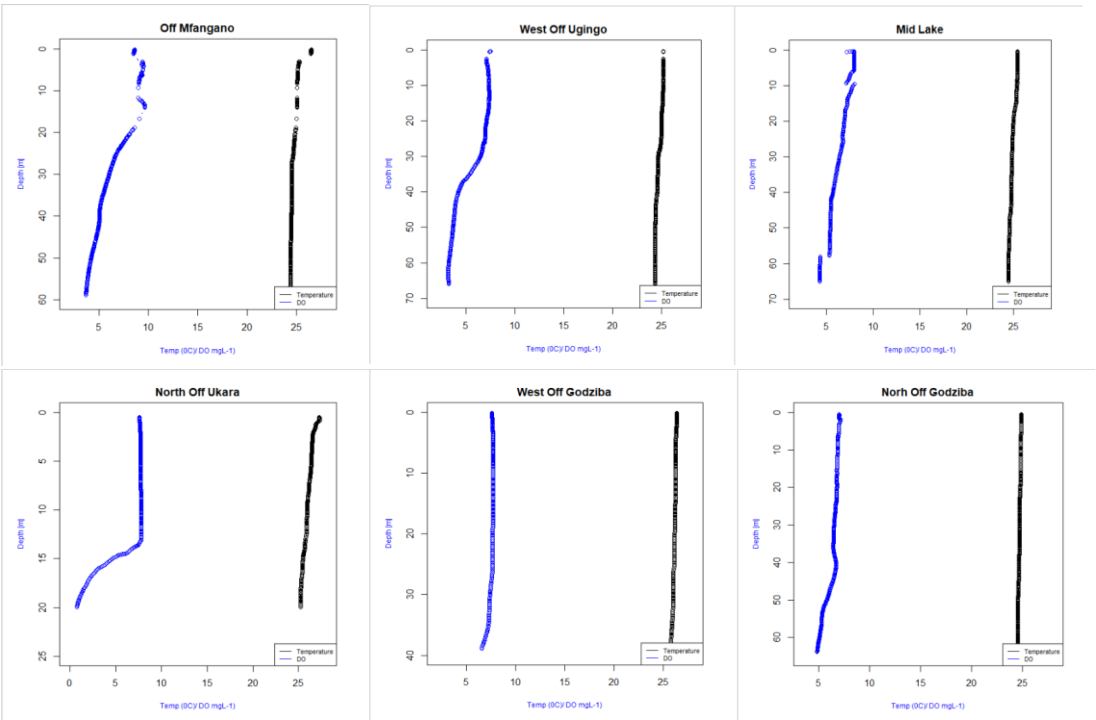


Figure A2.7. Temperature and Dissolved oxygen (DO) profiles within the Deep CTD stations

Table A2.1. Mean (±SD) physical, chemical and biochemical attributes of water column compared among quadrants

Quadrant	Temp (°C)	Salinity (ppt)	DO (mgL-1)	pH	ORP (mV)	Cond (µScm-1)	Turb (FTU)	Chloro (µg/l)	Secchi (m)
NE	25.07±0.6	0.05±0	6.79±1.6	7.96±0.5	84.3±30.61	94.38±10.7	2.72±6.19	15.21±6.81	2.03±2.5
NW	24.84±0.4	0.05±0	6.11±1.62	7.6±0.65	100.01±22.1	90.27±1.63	2.3±2.46	17.09±14.3	2.12±1.0
SE	25.18±0.7	0.05±0.01	7.2±1.47	7.65±1.8	184.67±181.4	100.7±13.54	1.72±2.53	10.92±4.97	2.22±0.6
SW	24.78±0.3	0.05±0	7.61±1.11	7.43±0.8	52.32±18.09	90.65±2.86	1.67±1.55	18.87±13.7	2.62±1.4

Table A2.2. Mean (±SD) physical and chemical attributes of water column compared among countries

Country	Temp (°C)	Salinity (ppt)	DO (mgL^{-1})	pH	ORP (mV)	Cond (μScm^{-1})	Turb (FTU)	Chloro(µg/l)	Secchi (m)
Ke	25.4±0.8	0.05±0.01	7.21±1.76	8.11±0.3	101.46±28.03	100.91±17.2	5.72±10.3	16.37±7.93	1.03±0.6
Tz	24.96±0.6	0.05±0	7.42±1.3	7.53±1.4	112.84±139.9	95.24±10.6	1.69±2.06	14.04±10.1	2.40±1.0
Ug	24.92±0.5	0.05±0	6.44±1.57	7.79±0.6	86.19±28.77	91.42±4.54	1.89±2.94	15.55±10.2	2.44±2.4

Table A2.3. Mean (±SD) physical, chemical and biochemical attributes of water column compared among strata

Strata	Temp (°C)	Salinity (ppt)	DO (mgL^{-1})	pH	ORP (mV)	Cond (μScm^{-1})	Turb (FTU)	Chloro (µg/l)	Secchi (m)
I	24.64±0.1	0.05±0	6.89±0.28	7.84±0.32	52.01±52.01	90±0	1.28±0.13	16.69±9.45	2.13±0.82
C	24.92±0.58	0.05±0	6.95±1.4	7.93±0.7	88.22±88.22	93.7±8.35	1.56±2.07	13.76±9.52	1.91±0.99
D	25.15±0.7	0.05±0	6.4±1.55	6.99±2.02	95.36±95.36	94.24±10.25	1.36±0.63	8.97±3.93	4.97±3.78

Table A2.4. Mean (±SD) physical, chemical and biochemical attributes of water column compared among special regions

Strata	Temp (°C)	Salinity (ppt)	DO (mgL^{-1})	pH	ORP (mV)	Cond (μScm^{-1})	Turb (FTU)	Chloro (µg/l)	Secchi (m)
EP	25.17±0.56	0.05±0	8.82±1.17	7.99±0.12	79.89±79.89	93.64±5.92	3.41±1.83	25.41±13.23	1.20±0.46
NG	26.46±0.84	0.07±0	8.78±1.06	8.11±0.02	122.36±122.36	139.17±11.49	26.69±14.53	16.73±7.55	0.40±0.14
SG	24.82±0.23	0.06±0.01	7.53±0.62	7.75±0.77	447.04±447.04	106.89±6.95	1.31±0.71	12.35±2.55	2.07±0.32
SI	24.95±0.41	0.05±0	4.91±1.73	7.76±0.34	110.8±110.8	90±0	2.89±2.74	27.34±12.81	1.35±0.78

Table A2.5. Mean (±SD) physical, chemical and biochemical attributes of water column compared among strata specified by quadrants and countries

Strata	**Depth**	**Temp**	**DO**	**pH**	**Salinity**	**Cond**	**ORP**	**Chl_a**	**Turbidity**	**Se**
TzSEDeep	70.85±1.63	26.14±0.43	7.04±1.69	5.58±3.20	0.06±0.00	105.92±14.46	136.05±15.45	7.35±1.21	2.21±0.17	2.8
TzSECoastal	44.17±9.77	24.85±0.57	7.09±1.58	8.43±0.47	0.05±0.01	96.32±13.83	115.94±42.44	10.26±5.58	1.53±3.22	2.2
TzSEInshore	25.70±0.00	26.23±0.54	8.05±0.20	7.03±0.03	0.05±0.00	99.91±0.93	131.81±2.53	17.28±2.05	3.63±0.74	1.6
TzSESpekeGulf	19.90±11.20	24.82±0.23	7.53±0.62	7.75±0.77	0.06±0.01	106.88±6.95	446.76±277.96	12.35±2.55	1.31±0.71	2.0
TzSWDeep	64.30±0.00	24.70±0.11	6.27±0.67	6.88±1.04	0.05±0.00	90.00±0.00	34.60±7.20	7.12±1.61	1.06±0.28	4.2
TzSWCoastal	39.37±28.85	24.64±0.18	7.19±0.65	7.37±0.65	0.05±0.00	90.00±0.00	47.92±10.01	19.99±17.59	1.46±1.73	3.1
TzSWInshore	30.00±0.00	24.64±0.10	6.89±0.28	7.84±0.32	0.05±0.00	90.00±0.00	52.00±7.47	10.98±0.31	1.28±0.13	2.4
TzSWEminPasha	16.43±7.38	25.17±0.56	8.82±1.17	7.99±0.12	0.05±0.00	93.64±5.92	79.89±15.09	25.41±13.23	3.41±1.83	1.2
UgNWDeep	65.30±0.00	24.90±0.32	6.22±1.08	7.17±1.04	0.05±0.00	90.00±0.00	123.05±2.56	3.53±0.12	0.99±0.32	4.3

UgNWCoastal	53.80±0.00	24.85±0.66	5.69±1.22	7.35±0.86	0.05±0.00	90.00±0.00	119.72±9.47	2.77±0.16	1.27±0.81	2.3
UgNWInshore	22.64±8.55	24.78±0.44	6.65±1.53	7.75±0.38	0.05±0.00	90.53±2.25	83.41±15.78	17.65±13.73	2.76±2.77	1.9
UgNWSesse	22.80±14.00	24.95±0.41	4.91±1.73	7.76±0.34	0.05±0.00	90.00±0.00	110.80±15.65	27.34±12.81	2.89±2.74	1.3
UgNEDeep	66.00±8.49	24.80±0.42	6.11±1.78	7.94±0.51	0.05±0.00	90.01±0.38	84.50±11.10	12.46±3.64	1.09±0.52	7.8
UgNECoastal	43.78±20.51	24.97±0.59	6.90±1.41	7.85±0.62	0.05±0.00	93.17±4.65	84.08±24.51	15.04±7.02	1.41±1.20	1.6
UgNEInshore	24.33±17.04	25.14±0.54	6.30±1.21	8.07±0.23	0.05±0.00	90.74±9.53	46.79±41.04	14.85±4.36	3.46±7.29	1.8
KeNECoastal	18.90±10.39	25.40±0.65	7.01±1.59	8.30±0.16	0.05±0.00	97.00±6.15	98.97±29.09	16.12±8.96	2.39±1.52	1.0
KeNEInshore	50.90±0.00	24.91±0.45	6.84±1.91	7.79±0.42	0.05±0.00	90.09±0.93	96.22±13.46	17.00±0.64	1.77±1.09	2.0
KeNENyanzaGulf	5.35±3.32	26.46±0.84	8.78±1.06	8.11±0.02	0.07±0.00	139.17±11.49	122.36±37.10	16.73±7.55	26.69±14.53	0.4

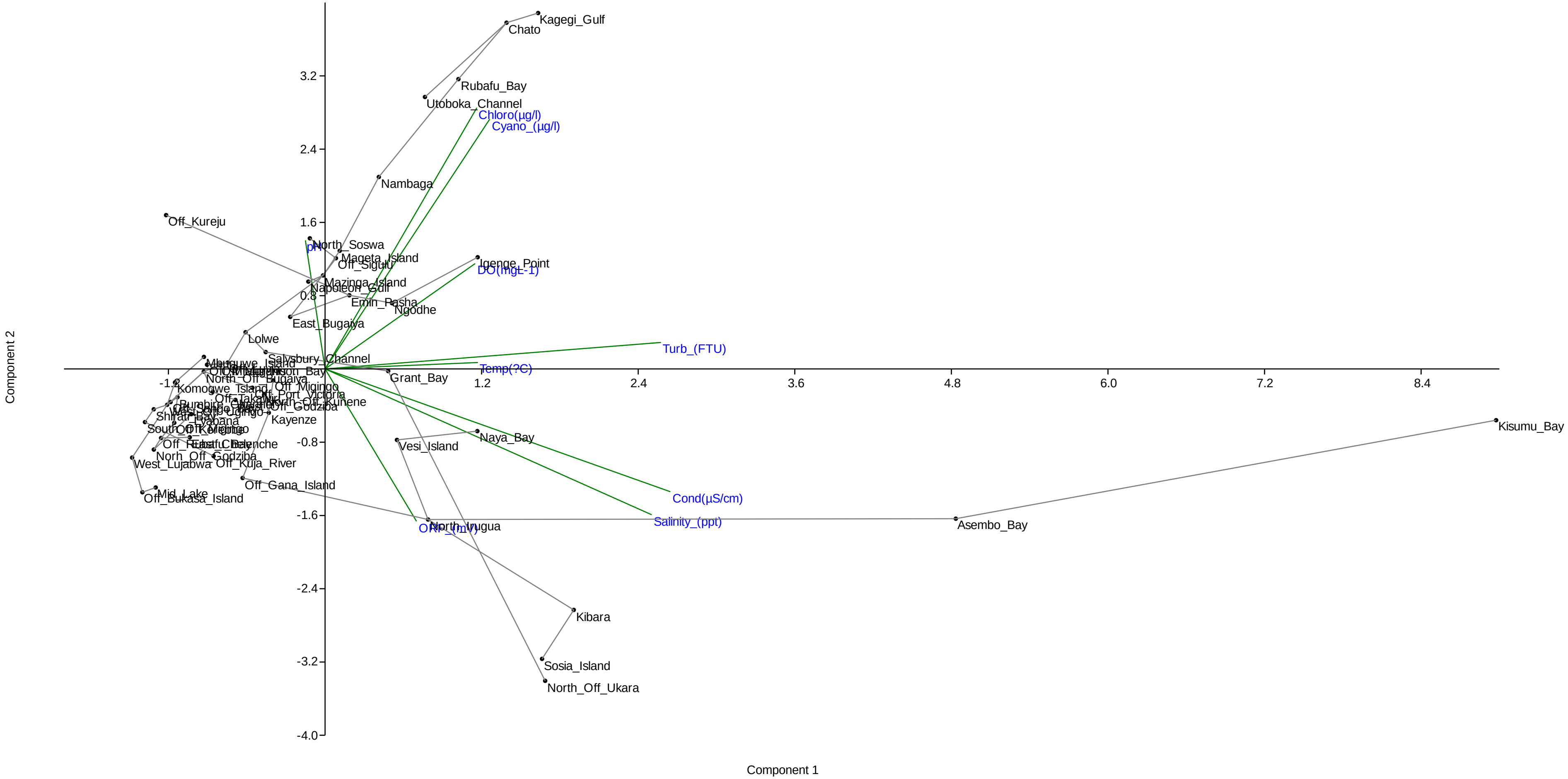


Figure A2.8. Principal Component Analysis (PCA) of physical and chemical attributes at different CTD stations

Table A2.6. Mean (±SD) physical, chemical and biochemical attributes of water column compared among CTD stations

CTD.Station	Temp (°C)	Salinity (ppt)	DO (mgL-1)	pH	ORP (mV)	Cond (µScm-1)	Turb (FTU)
Asembo Bay	25.945±0.15	0.07±0	9.4±0.7	8.11±0.02	148.66±2.82	131.54±3.63	16.52±3.09
Bumbire Channel	24.645±0.1	0.05±0	6.89±0.28	7.84±0.32	52.01±7.47	90±0	1.28±0.13
Chato	25.0450.12±0	0.05±0	8.01±0.11	8.07±0.02	52.8±5.68	93.93±4.91	6.49±1.51
East Bugaiya	255±0.78	0.05±0.87	8.83±0.39	7.62±14.51	92.72±2.86	90.89±1.37	1.52±
East Chelenche	24.835±0.23	0.05±0	8.02±0.57	6.95±1.05	36.71±5.92	90±0	1.28±0.64
Emin Pasha	25.355±0.69	0.05±0	10.12±0.24	7.95±0.12	88.27±5.79	93.17±4.66	2.89±0.29
Grant Bay	26.235±0.54	0.05±0	8.04±0.2	7.03±0.03	131.81±2.53	99.91±0.93	3.63±0.74
Igenge Point	26.425±0.49	0.05±0.01	10.42±1.45	9.42±0.2	58.6±36.51	104.09±13.33	3.72±11.81
Kagegi Gulf	24.975±0.51	0.05±0	8.75±1.57	8.08±0.03	79.56±7.32	93.4±4.76	7.69±3.82
Kayenze	24.91±0.12	0.05±0	7.25±0.35	8.44±0.31	116.95±5.71	100.6±5.77	1.77±0.81
Kibara	24.75±0.16	0.06±0	8.51±0.19	7.15±0	658.56±3.45	110±0	1.39±0.12
Kisumu Bay	27.5±0.66	0.07±0	7.57±0.34	8.11±0.02	70.75±3.81	154.1±54.97	46.64±1.43
Komogwe Island	24.78±0.31	0.05±0	5.24±0.9	7.95±0.27	73.6±4.92	90±0	1.42±0.56
Lolwe	24.91±0.45	0.05±0	6.84±1.91	7.79±0.42	96.22±13.46	90.09±0.93	1.77±1.09
Lyabana	24.93±0.87	0.05±0	6.22±0.74	7±0.85	60.55±10.39	90.45±2.07	1.17±0.84
Mageta Island	25.32±0.28	0.05±0	7.67±0.66	8±0.08	115.12±4.12	90±0	4.09±1.16
Mazinga Island	25.04±0.47	0.05±0	7.79±0.48	8±0.13	83.79±9.34	94.02±7.4	2.49±1.3
Mbuguwe Island	24.96±0.39	0.05±0	4.22±1.46	7.86±0.34	119.53±6.51	90±0	1.81±1.04
Mid Lake	24.9±0.32	0.05±0	6.22±1.08	7.17±1.04	123.05±2.56	90±0	0.99±0.32
Nambaga	25.45±0.4	0.05±0	7.56±0.51	8.06±0.03	67.3±16.25	90.19±1.37	4.45±3.15
Napoleon Gulf	25.78±0.36	0.05±0.01	7.3±0.61	8.22±0.14	-8.34±19.46	92.21±16.37	3.14±0.74
Naya Bay	26.35±0.01	0.06±0	7.18±0.17	8.38±0.02	63.18±4.6	110±0	5.68±0.22
Ngodhe	26.15±0.16	0.05±0	9.07±0.42	8.22±0.05	77.83±11.37	100±0	3.24±0.21
Norh Off Godziba	24.7±0.11	0.05±0	6.27±0.67	6.88±1.04	34.6±7.2	90±0	1.06±0.28
North Irugua	24.660.18±	0.06±0	8.09±0.13	8.2±0.1	119.48±0.69	110±0	0.76±0.27

North Off Bugaiya	25.11±0.37	0.05±0	6.62±0.57	8.20.23±	67.4±12.74	90±0	1.520.67±
North Off Kunene	24.76±0.52	0.05±0	7.72±0.36	8.97±0.1	141.48±5.27	99.59±5.17	1.89±6.4
North Off Ukara	26.12±0.55	0.06±0	6.66±2.16	3.12±1.99	148.91±6	118.01±5.32	2.34±0
North Soswa	24.72±0.1	0.05±0	8.64±0.26	7.58±0.86	62.18±9.95	90±0	1±0.24
Off Bukasa Island	24.85±0.66	0.05±0	5.69±1.22	7.35±0.86	119.72±9.47	90±0	1.27±0.81
Off Gana Island	24.53±0.21	0.05±0.01	6.9±1.24	8.09±0.13	150.34±0.45	96.61±18.69	1.76±0.64
Off Kerebbe	24.69±0.14	0.05±0	7.36±0.31	7.61±0.72	59.73±4.25	90±0	0.94±0.13
Off Kuja River	24.81±0.33	0.05±0	5.86±1.24	8.38±0.14	128.69±7.15	99.96±0.67	1.34±0.11
Off Kureju	25.5±0.57	0.05±0.01	10.31±0.34	9.54±0.26	21.41±7.56	79.17±31.11	1.45±0.52
Off Luvia	25.01±0.31	0.05±0	6.9±0.52	7.88±0.14	98.76±7.68	90±0	1.67±0.76
Off Mfangano	24.760.51±	0.05±0	6.35±1.93	7.82±0.43	92.53±9.79	90.03±0.57	1.18±0.7
Off Migingo	24.88±0.41	0.05±0	6.43±1.35	8.12±0.41	90.8±27.85	96.44±4.79	1.03±0.53
Off Murchison Bay	24.95±0.43	0.05±0	6.34±1.29	7.65±0.16	72.32±8.49	90±0	2.17±0.82
Off Port Victoria	24.9±0.11	0.05±0	6.8±0.67	8.07±0.08	76.68±3.91	90±0	7.57±14.13
Off Rubafu Bay	24.57±0.12	0.05±0	6.97±0.65	7.17±0.57	40.57±2.72	90±0	1±0.44
Off Sango Bay	24.57±0.03	0.05±0	6.85±0.09	8.17±0.09	68.15±5	90±0	1.33±0.11
Off Sigulu	25.35±0.63	0.05±0	8.48±1.39	7.99±0.03	87.06±10.43	90.88±2.85	3.07±1.61
Off Takawiri	25.6±0.53	0.05±0	7.25±1.59	8.32±0.05	70.04±11.87	90.13±1.14	1.63±0.88
Rubafu Bay	24.98±0.22	0.05±0	8.28±0.07	8±0.03	60.83±4.5	90±0	7.3±1
Salysbury Channel	25.15±0.43	0.05±0	6.94±1.17	7.43±0.2	109.27±11.11	90±0	3.06±1.17
Shirati Bay	25.09±±0.62	0.05±0	5.66±1.79	8.48±0.46	56.13±14.67	90±0	1.13±0.23
Sosia Island	24.77±0.31	0.06±0	7.13±0.09	7.34±0.79	695.75±3.97	112.3±4.22	0.67±0.13
Utoboka Channel	24.92±0.43	0.05±0	6.48±1.17	7.53±0.19	91.03±11.82	90±0	5.34±3.69
Vesi Island	25.77±0.08	0.06±0	7.18±0.2	8.16±0.01	111.97±0.39	95±0	1.25±0.65

West Lujabwa	24.47±0.24	0.05±0	5.39±0.86	7.56±0.43	85.86±5.1	90±0	1.19±0.07
West Off Godziba	26.18±0.18	0.05±0	7.53±0.25	8.82±0.09	119.11±0.28	90±0	2.03±0.1
West Off Ugingo	24.82±0.32	0.05±0	5.92±1.62	8.04±0.55	77.93±7.05	90±0	1.02±0.29

A2.4 CONCLUSSION

Notable spatial variations observed among quadrants and strata showed little departure from observations made in 2018. The SW sector of the lake appeared most productive following the patterns of chlorophyll a, while the NW and NE coastal transects had slight stratification. These trends are expected to reflect on the abundance and distribution patterns of 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
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	
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	

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
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
Secchi (M)	2008	1.7 ± 0.82	3.1 ± 1.2	0.6 ± 0.10	3.0 ± 0.25
	2009	1.4 ± 0.27	2.2 ± 0.21	0.6 ± 0.20	1.5 ± 0.71
	2011	0.9	1.8	0.5 ± 0.07	1.9 ± 0.07
	2014	1.4±0.21	2.9±	0.4±	2.1±0.28
	2015	0.9±0.0.1	3.1±0.4	0.5±0.1	1.8±0.3
	2016	1.20±	3.05±0.07	0.73±0.75	1.93±0.40
	2017	1.40±0.00	2.60±0.00	0.70±0.14	1.77±0.40
	2018	2.275±1.39	1.9±0.57	0.53±0.40	2.75±0.07
	2019	1.20±0.46	1.35±0.78	0.40±0.14	2.07±0.32

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
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
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

Annex 4. Summary descriptions of CTD stations

Strata	Quadrant	Country	CTD Stations	CTD No.	Event No.	GPS Lat	GPS Long
		Ke	Lolwe	30	179	-0.16717	33.63042
			Komogwe Island	28	171	-0.23817	33.90341
			Napoleon Gulf	20	139	0.410089	33.20661
	NE	Ug	Off Port Victoria	27	167	0.054032	33.89144
			Kagegi Gulf	13	82	-0.59436	31.89167
			Off Murchison Bay	19	119	0.031378	32.61405
			Off Sango Bay	11	68	-0.79452	31.96495
			Salysbury Channel	18	115	-0.13162	32.39882
	NW	Ug	West Lujabwa	12	71	-0.77243	32.16622
	SE	Tz	Grant Bay	46	249	-2.00613	33.19352
			East Chelenche	1	5	-2.12527	32.55482
			North Soswa	2	13	-1.97383	32.39332
I	SW	Tz	Bumbire Channel	8	49	-1.08512	32.3111
			Mageta Island	29	176	-0.11625	33.96914
			Naya Bay	34	192	-0.36875	34.28659
			Ngodhe	33	190	-0.34622	34.23906
			Off Kuja River	39	219	-0.93434	34.06971
		Ke	Off Takawiri	37	207	-0.53107	34.11203
			East Bugaiya	23	147	-0.00528	33.32238
			Lyabana	22	144	-0.24348	33.09008
			Nambaga	24	153	0.160812	33.48018
			North Off Bugaiya	21	143	0.092178	33.25885
			Off Luvia	25	157	0.010978	33.44842
			Off Migingo	38	211	-0.78628	33.83011
			Off Sigulu	26	162	0.077705	33.67781
	NE	Ug	South off Migingo	40	222	-0.93978	33.74053
	NW	Ug	Off Bukasa Island	15	97	-0.48911	32.57164
			Igenge Point	43	233	-1.44495	33.61717
			North Irugua	45	246	-1.63091	33.23727
			North Off Kunene	49	263	-2.01248	32.74756
			Off Gana Island	48	259	-1.75381	32.85203
			Off Kureju	44	242	-1.66422	33.43772
			Shirati Bay	41	226	-1.12353	33.88217
	SE	Tz	Vesi Island	50	267	-2.20354	33.05342
			Off Kerebbe	6	40	-1.15002	32.6307
			Off Rubafu Bay	9	58	-1.08512	32.3111
C	SW	Tz	Rubafu Bay	10	65	-1.03412	31.79385
			Off Mfangano	32	185	-0.42483	33.76507
	NE	Ug	West Off Ugingo	31	183	-0.78015	33.2765
	NW	Ug	Mid Lake	16	103	-0.98296	32.9337
D	SE	Tz	North Off Ukara	47	254	-1.51916	32.95166

			West Off Godziba	42	230	-1.06804	33.15384
	SW	Tz	Norh Off Godziba	7	45	-1.73009	31.79988
			Chato	4	28	-2.06221	31.71558
			Emin Pasha	3	22	-2.57813	31.82421
EP	SW	Tz	Mazinga Island	5	32	-1.67308	32.39442
			Asembo Bay	35	196	-0.28796	34.44101
NG	NE	Ke	Kisumu Bay	36	198	-0.10913	34.73172
			Kayenze	51	272	-2.33354	33.05502
			Kibara	53	285	-2.22035	33.63134
SG	SE	Tz	Sosia Island	52	277	-2.28097	33.38194
			Mbuguwe Island	14	90	-0.41595	32.43102
SI	NW	Ug	Utoboka Channel	17	109	-0.28681	32.28053

Appendix III: Echo-sounder Calibration output files

70 kHz calibration

```
#  Calibration  Version   2.1.0.11
#  Date:  9/13/2019
#  Comments:#
#  Reference Target:
#    TS                        -41.40 dB                      Min. Distance        9.00 m
#    TS Deviation              5.0 dB                         Max. Distance        11.50 m
#  Transducer:  ES70-7C  Serial No.   70092019
#    Frequency                 70000 Hz                       Beamtype             Split
#    Gain                      26.56 dB                       Two Way Beam Angle   -20.9 dB
#    Athw. Angle Sens.         23.00                          Along. Angle Sens.     23.00
#    Athw. Beam Angle          6.43 deg                       Along. Beam Angle    6.43 deg
#    Athw. Offset Angle        -0.05 deg                      Along. Offset Angle -0.06 deg
#    SaCorrection              -0.81 dB                       Depth              1.80  m
#  Transceiver:  GPT  70 kHz 00907205aebd 2 ES70-7C
#   Pulse Duration             0.256 ms                       Sample Interval     0.048   m
#   Power                      200  W                         Receiver Bandwidth   6.16 kHz
#  Sounder Type:
#   EK60 Version  2.1.2
#  TS Detection:
#   Min. Value                 -50.0 dB                       Min. Spacing         100 %
#   Max. Beam Comp.            6.0 dB                         Min. Echolength        80 %
#   Max. Phase Dev.            8.0                            Max. Echolength        180 %
#  Environment:
#   Absorption Coeff.          0.9 dB/km                      Sound Velocity     1497.4 m/s
#  Beam Model results:
#   Transducer Gain            = 26.51 dB                     SaCorrection       = -0.77 dB
#    Athw. Beam Angle          = 6.51 deg                     Along. Beam Angle  = 6.51 deg
#    Athw. Offset Angle        =-0.02 deg                     Along. Offset Angle=-0.08 deg
#  Data deviation from beam model:
#    RMS =    0.24 dB
#    Max =                    1.74 dB        No. =   116      Athw. =  2.1 deg        Along =  0.2 deg
#    Min =                    -0.71 dB       No. =   155      Athw. =  2.4 deg        Along =  3.8 deg
#  Data deviation from polynomial model:
#    RMS =    0.23 dB
#    Max =                    1.75 dB        No. =   116      Athw. =  2.1 deg        Along =  0.2 deg
#    Min =                    -0.73 dB       No. =   163      Athw. =  1.3 deg        Along =  2.3 deg
```

120 kHz calibration

Calibration Version 2.1.0.11
Date: 9/13/2019
Comments:
Reference Target:
TS -39.52 dB Min. Distance 9.50 m
TS Deviation 5.0 dB Max. Distance 12.00 m
Transducer: ES120-7C Serial No. 1200919
Frequency 120000 Hz Beamtype Split
Gain 25.53 dB Two Way Beam Angle -20.9 dB
Athw. Angle Sens. 23.00 Along. Angle Sens. 23.00
Athw. Beam Angle 6.55 deg Along. Beam Angle 6.47 deg
Athw. Offset Angle 0.05 deg Along. Offset Angle 0.08 deg
SaCorrection -0.63 dB Depth 1.80 m
Transceiver: GPT 120 kHz 00907209204d 1 ES120-7C
Pulse Duration 0.256 ms Sample Interval 0.048 m
Power 200 W Receiver Bandwidth 8.71 kHz
Sounder Type:
EK60 Version 2.1.2
TS Detection:
Min. Value -50.0 dB Min. Spacing 100 %
Max. Beam Comp. 6.0 dB Min. Echolength 80 %
Max. Phase Dev. 8.0 Max. Echolength 180 %
Environment:
Absorption Coeff. 2.5 dB/km Sound Velocity 1497.4 m/s
Beam Model results:
Transducer Gain = 25.56 dB SaCorrection = -0.55 dB
Athw. Beam Angle = 6.46 deg Along. Beam Angle = 6.39 deg
Athw. Offset Angle = 0.08 deg Along. Offset Angle= 0.04 deg
Data deviation from beam model:
RMS = 0.40 dB
Max = 1.99 dB No. = 137 Athw. = 0.0 deg Along = -3.6 deg
Min = -2.68 dB No. = 233 Athw. = -0.5 deg Along = -4.4 deg
Data deviation from polynomial model:
RMS = 0.38 dB
Max = 1.95 dB No. = 137 Athw. = 0.0 deg Along = -3.6 deg
Min = -2.50 dB No. = 233 Athw. = -0.5 deg Along = -4.4 deg

Appendix IV: September-October 2019 Acoustic Survey Event Log-sheet

Date	Event No.	Activities	Transect ID	Station	Quadrant	Strata	Country	Time Start	Time End	Remarks
15/09/2019	1	DH	1		SW	I	Tz	0804	0832	Left TAFIRI Pier
	2	TI	2		SW	I	Tz	0832	1004	0838-0840 power went off
	3	DH	3		SW	I	Tz	1004	1034	
	4	TC	4		SW	C	Tz	1034	1220	
	5	CTD		1	SW	C	Tz	1220	1237	
	6	DH	5		SW	C	Tz	1237	1325	
	7	TC	6		SW	C	Tz	1325	1419	
	8	TI	7		SW	I	Tz	1419	1501	
	9	DH	8		SW	I	Tz	1501	1504	End of Day Nyakaliro
16/09/2019	11	TI	9		SW	I	Tz	0353	0514	Left Nyakaliro
	12	TC	10		SW	C	Tz	0514	0657	
	13	CTD		2	SW	C	Tz	0657	0707	
	14	NB		2	SW		Tz	0724	0755	
	15	DH	11		SW	C	Tz	0815	0859	
	16	TC	12		SW	C	Tz	0859	1057	
	17	TI	13		SW	I	Tz	1057	1159	
	18	DH	14		SW	I	Tz	1159	1231	
	19	TI	15		SW	I	Tz	1231	1313	
	20	TI	16		SW	I	Tz	1313	1332	
	21	TI	17		SW	EP	Tz	1332	1357	
	22	CTD		3	SW	EP	Tz	1357	1409	
	23	TI	18		SW	EP	Tz	1409	1441	
	24	DH	19		SW	EP	Tz	1441	1443	
	25	TI	20		SW	EP	Tz	1443	1548	End of Day Chato

17/09/2019	26	DH	21		SW	EP	Tz	0639	0709	Left Chato
	27	CTD		4	SW	EP	Tz	0710	0718	
	28	NB		4	SW	EP	Tz	0725	0756	
	29	TI	22		SW	EP	Tz	0810	0908	
	30	TI	23		SW	EP	Tz	0908	1024	
	31	TI	24		SW	EP	Tz	1024	1127	
	32	CTD		5	SW	EP	Tz	1130	1141	
	33	NP		5	SW	EP	Tz	1141	1323	
	34	DH	25		SW	EP	Tz	1348	1426	End of Day Kimoyomoyo
18/09/2018	35	DH	26		SW	C	Tz	0324	0335	Left Kimoyomoyo
	36	TC	27		SW	C	Tz	0335	0512	
	37	DH	28		SW	I	Tz	0512	0739	
	38	TC	29		SW	I	Tz	0739	0828	
	39	TC	30		SW	C	Tz	0828	1011	
	40	CTD		6	SW	C	Tz	1011	1029	
	41	TC	31		SW	C	Tz	1030	1249	End of Day Kerebe Is
19/09/2018	42	DH	32		SW	C	Tz	0330	0624	Left Kerebe Is
	43	TD	33		SW	D	Tz	0624	0832	Transect shortened due to steering problem
	44	DH	34		SW	I	Tz	0832	0956	
	45	CTD		7			Tz	0956	1010	
	46	TD	35		SW	D	Tz	1010	1424	
	47	TC	36		SW	C	Tz	1424	1634	
	48	DH	37		SW	I	Tz	1634	1733	End of Day Bumbire
20/09/2019	49	CTD		8	SW	I	Tz	0436	0448	Left Bumbire
	50	NB		8	SW	I	Tz	0500	0659	System was interrupted by power failure
	51	DH	38		SW	C	Tz	0722	0738	

	52	TI	39		SW	D	Tz	0738	0841	
	53	TI	40		SW	D	Tz	0841	0948	
	54	DH	41		SW	I	Tz	0948	0953	End of Day Bukoba
21/09/2019										Rest day Bukoba
22/09/2019	55	DH	42		SW	I	Tz	0350	0435	Left Bukoba
	56	TI	43		SW	C	Tz	0435	0547	
	57	TC	44		SW	C	Tz	0547	0810	
	58	CTD		9	SW	C	Tz	0810	0828	
	59	NP		9	SW	C	Tz	0838	0929	
	60	DH	45a		SW	C	Tz	0944	1033	
	62	DH	45b		SW	C	Tz			
	63	TC	46		SW	C	13	1033	1315	
	64	DH	47		SW	C		1313	1410	
	65	CTD		10	SW	C	Tz	1410	1421	
	66	NB		10	SW	I	Tz	1436	1509	End of Day Rubafu Bay
23/09/2019	67	TI	49		NW	I	Ug	0333	0532	Left Rubafu Bay
	68	CTD		11	NW	I	Ug	0532	0545	
	69	NP		11	NW	I	Ug	0611	0643	
	70	TC	50		NW	C	Ug	0656	0803	
	71	CTD		12	NW	I	Ug	0806	0818	
	72	NB		12	NW	I	Ug	0825	0859	
	73	DH	51		NW	I	Ug	0859	0939	
	81	TI	52		NW	I	Ug	0939	1136	
	82	CTD		13	NW	I	Ug	1136	1148	
	83	NB		13	NW	I	Ug	1153	1230	
	84	DH	53		NW	I	Ug	1247	1257	
	85	TI	54		NW	I	Ug	1257	1426	End of Day Nakatiba landing site

24/09/2019	86	DH	55		NW	I	Ug	0320	0355	Left Nakatiba
	87	TI	56		NW	I	Ug	0355	0513	
	88	DH	57		NW	SI	Ug	0513	0521	
	89	TI	58		NW	SI	Ug	0521	0611	
	90	CTD		14	NW	SI	Ug	0613	0627	
	91	NB		14	NW	SI	Ug	0633	0704	
	92	DH	59		NW	SI	Ug	0725	0729	
	93	TC	60		NW	SI	Ug	0729	0830	
	94	DH	61		NW	C	Ug	0830	0931	
	96	TC	62		NW	C	Ug	0931	1054	
	97	CTD		15	NW	C	Ug	1056	1109	
	98	NB		15	NW	C	Ug	1123	1153	
	99	TI	63		NW	SI	Ug	1206	1231	
	100	DH	64		NW	SI	Ug	1231	1234	End of the day- Mpata Bay
25/09/2019	101	DH	65		NW	SI	Ug	0016	0025	Left Mpata Bay
	102	TD	66		NW	D	Ug	0025	0513	
	103	CTD		16	NW	D	Ug	0513	0532	
	104	DH	67		NW	D	Ug	0532	0707	
		TD	68		NW	D	Ug	0707	1125	
	105	TC	69		NW	C	Ug	1125	1331	
	106	TI	70		NW	SI	Ug	1331	1449	
	107	DH	71		NW	SI	Ug	1449	1455	End of day Kalangala
26/09/2019	108	DH	72		NW		Ug	0429	0440	Left Kalangala
	109	CTD		17	NW	SI	Ug	0440	0452	
	110	NB		17	NW	SI	Ug	0459	0528	
	111	TI	73		NW	SI	Ug	0535	0607	
	112	TI	74		NW	I	Ug	0607	0635	
	113	DH	75		NW	I	Ug	0635	0704	

	114	TI	76		NW	I	Ug	0704	0847	
	115	CTD		18	NW	I	Ug	0850	0900	
	116	TI	77		NW	I	Ug	0900	1002	
	117	DH	78		NW	I	Ug	1002	1019	
	118	TI	79		NW	I	Ug	1019	1056	
	119	CTD		19	NW	I	Ug	1057`	1111	
	120	TI	80		NW	I	Ug	1112	1152	
	121	DH	81		NW	I	Ug	1152	1157	
	122	TI	82		NW	I	Ug	1157	1224	At around 1220 to 124 reduced speed due to
	123	TI	83		NW	I	Ug	1224	1333	
	124	TI	84		NW	I	Ug	1333	1418	1
	125	TI	85		NW	I	Ug	1418	1727	1502 – 1606 stopped due to steering problem
	126	TI	86		NW	I	Ug	1727	1833	
	127	TI	87		NE	I	Ug	1833	1908	End of the day Jinja pier
27/09/2019	128		88		NE	I	Ug			Rest day
28/09/2019	129	DH	89		NE	I	Ug			
29/09/2019	139	DH	91		NE	I	Ug	0421	0437	Left Jinja
		CTD		20	NE	I	Ug	0438	0450	
	140	TI	92		NE	I	Ug	0451	0527	Went off track near Samuka
	141	DH	93		NE	I	Ug	0527	0638	
	142	TC	94		NE	C	Ug	0638	0802	
	143	CTD		21	NE	C	Ug	0803	0816	
	144	DH	95		NE	C	Ug	0816	0908	
	143	TC	96		NE	C	Ug	0908	1045	
	144	CTD		22	NE	C	Ug	1045	1101	
	145	DH	97		NE	C	Ug	1101	1159	
	146	TC	98		NE	C	Ug	1159	1339	

	147	CTD		23	NE	C	Ug	1339	1353	
	148	NB		23	NE	C	Ug	1355	1435	
	149	TC	99		NE	C	Ug	1448	1527	End of the day Kojja Bay
30/09/2019	150	DH	100		NE	C	Ug	0311	0342	Left Kojja Bay
	151	TI	101		NE	I	Ug	0342	0434	
	152	TI	102		NE	C	Ug	0434	0522	
	153	CTD		24	NE	C	Ug	0522	0535	
	154	NP		24						Bottom not good
	155	TI	103		NE	C	Ug	0535	0638	
	156	DH	104		NE	C	Ug	0638	0725	
	157	CTD		25	NE	C	Ug	0725	0739	
	158	TC	105		NE	C	Ug	0739	0854	
	159	TC	106		NE	C	Ug	0854	0947	
	160	DH	107		NE	C	Ug	0947	1053	
	161	TC	108		NE	C	Ug	1053	1152	
	162	CTD		27	NE	C	Ug	1153	1204	
	163	NB		27	NE	C	Ug	1212	1246	
	164	TI	110		NE	I	Ug	1256	1323	
	165	TI	111		NE	I	Ug	1323	1404	
	166	TI	112		NE	I	Ug	1404	1535	End of day Port Victoria, the DH to Port not included
01/10/2019		DH	113		NE	I	Ke	0330	0407	Leaving Port Victoria
	167	CTD		28	NE	I	Ug	0407	0419	
	168	NB		28	NE	I	Ug	0427	0446	Fishing interrupted due to bad bottom
	169	TI	114		NE	I	Ug	0455	0619	
	170	TC	115		NE	I	Ug	0619	0718	
	171	CTD		29	NE	I	Ug	0718	0733	

	172	NB		29	NE	I	Ug	0737	0813	
	173	TC	116a		NE	C	Ug	0825	0855	
	174	TC	116b		NE	C	Ke	0855	0944	Went out of the transect to avoid island with rocky outcrops.
	175	DH	117		NE	C	Ke	0944	1034	very risky transect (rocks)
	176	CTD		30	NE	C	Ug	1034	1047	
	177	TC	118		NE	C	Ug	1047	1256	Problem rocky outcrops at 1127. Temporary slow down
	178	TC	119		NE	C	Ke	1256	1356	
	179	CTD		31	NE	I	Ke	1356	1423	
	180	DH	120		NE	I	Ke	1423	1443	End of day Lolwe
02/10/2019	181	DH	121		NE	D	Ug	0015	0130	Leaving Lolwe
	182	TD	122		NE	D	Ug	0130	0529	
	183	CTD		33				0529	0548	
	184	DH	123		NE	D	Ug	0548	0658	
	185	TD	124		NE	D	Ug	0658	1037	
	186	CTD		34				1037	1058	Encountered Ugandan security officers
	187	TC	125a		NE	C	Ug	1058	1201	
	188	TC	125b		NE	C	Ke	1201	1319	
	189	TC	126		NE	C	Ke	1319	1415	
	190	CTD		35	NE	C	Ke	1415	1426	
	191	TI	127a		NE	C	Ke	1426	1446	Ended the transect midway to continue tomorrow. End of day Lwanda K'otieno
										TI 127 continues
03/10/2019	192	CTD		36	NE	C	Ke	0410	0418	Left Lwanda K
	193	NB		36	NE	I	Ke	0422	0525	

	194	TI	127b		NE	I	Ke	0540	0606	Continue with TI 127
	195	TI	128		NE	NG	Ke	0606	0732	
	196	CTD		37	NE	NG	Ke	0732	0748	
	197	TI	129		NE	NG	Ke	0749	1012	
	198	CTD_NG						1012	1023	
	199	DH	130		NE	NG	Ke	1023	1035	End of day Kisumu
										Rest day Kisumu
04/10/2019	200	DH	131		NE	NG	Ke	0351	0623	Left Kisumu
	201	TI	132		NE	NG	Ke	0623	0721	
	202	DH	133		NE	NG	Ke	0721	0822	
	203	DH	134		NE	NG	Ke	0822	0840	
	204	DH	135		NE	C	Ke	0840	0902	
	205	DH	136		NE			0902	0954	
	206	TI	137		NE			0954	1036	
	207	CTD		38	NE	C	Ke	1036	1049	
	208	TC	138a		NE	C	Ke	1049	1221	
	209	TC	138b		NE	C	Ug	1221	1306	
	210	DH	139		NE	C	Ug	1306	1356	
	211	CTD		39	NE	C	Ug	1356	1415	
	212	TC	140a		NE	C	Ug	1415	1454	
	213	TC	140b		NE	C	Ke	1454	1604	
	214	CTD		40	NE	C	Ke			skipped
	215	NB		40	NE	C	Ke			
	216	DH	141		NE	C	Ke	1604	1639	End day at Sori
06/10/2019	217	DH	142		NE	C	Ke	0355	0412	Left Sori
	218	NB		41	NE	C	Ke	0418	0554	
	219	CTD		41	NE	C	Ke	0612	0703	
	220	TC	143a		NE	C	Ke	0703	0801	
	221	TC	143b		NE	C	Ug	0801	0909	

	222	CTD		42	NE	C	Ug	0909	0925	
	223	NP		42						
	224	DH	144		NE	C	Ug	0925	0950	
	225	TC	145		SE	C	Tz	0950	1105	
	226	CTD		43	SE	C	Tz	1105	1118	
	227	NB		43	SE	C	Tz	1127	1157	
	228	DH	146		SE	I	Tz	1214	1232	End of day Shirati
07/10/2019	229	DH	147		SE	D	Tz	0028	0201	Left Shirati
	229	TD	148		SE	D	Tz	0201	0614	
	230	CTD		44	SE	D	Tz	0614	0634	
	231	DH	149			D	Tz	0634	0751	
	232	TD	150			D	Tz	0751	1140	
	233	CTD		46	SE	C	Tz	1140	1156	
	234	NB		46	SE	C	Tz	1203	1310	
	235	TI	151		SE	I	Tz	1332	1438	End of day Musoma
08/10/2019	236	DH	152		SE	I	Tz			Rest day
09/10/2019	237	DH	153		SE	I	Tz	0415	0426	Left Musoma
	238	TI	154		SE	I	Tz	0426	0545	
	239	TI	155		SE	I	Tz	0545	0622	
	240	TC	156		SE	C	Tz	0622	0705	
	241	TC	157		SE	C	Tz	0705	0755	
	242	CTD	47	45	SE	C	Tz	0755	0812	
	243	NB	47	45	SE	C	Tz	0821	0850	
	244	TC	158		SE	C	Tz	0901	0926	
	245	DH	159		SE	C	Tz	0926	1011	
	246	CTD	48	46	SE	C	Tz	1011	1028	
	247	TC	160		SE	C	Tz	1033	1222	
	248	TI	161		SE	I	Tz	1222	1307	
	249	CTD		47	SE	I	Tz	1307		Not recorded on ER60

										Calibration and End of day off Burungu
10/10/2019	250	DH	162		SE	I	Tz	0329	0337	Left Burungu
	251	TI	163		SE	I	Tz	0337	0411	
	252	TD	164		SE	D	Tz	0411	0700	
	253	DH	165		SE	D	Tz	0700	0805	
	254	CTD		48	SE	D	Tz	0805	0832	
	255	TD	166		SE	D	Tz	0832	1047	
	256	DH	167		SE	C	Tz	1047	1123	End of day off Ukara—for calibration
11/10/2019	257	DH	167		SE	I	Tz	0316	0348	Left Ukara
	258	DH	168		SE	C	Tz	0348	0504	
	259	CTD		49				0504	0520	
	260	TC	169		SE	C	Tz	0520	0708	
	261	TC	170		SE	C	Tz	0708	0834	
	262	TC	171		SE	C	Tz	0834	0910	
	263	CTD		50	SE	C	Tz	0910	0925	
	264	NB		50	SE					No NB Bad bottom
	265	TI	172		SE	I	Tz	0925	1056	
	266	TI	173		SE	I	Tz	1056	1151	
	267	NB		51		C	Tz	1158	1258	
	268	CTD		51		C	Tz	1320	1335	
	269	DH	174		SE	I	Tz	1335	1413	End of day Nansio
12/10/2019	270	TI	175		SE	SG	Tz	0334	0402	Left Nansio
	271	TI	176		SE	SG	Tz	0402	0507	
	272	CTD		52	SE	SG	Tz	0507	0518	
	273	NB		52	SE	SG	Tz	0529	0632	
	274	DH	177		SE	SG	Tz	0653	0759	
	275	TI	178		SE	SG	Tz	0759	0905	

	276	DH	179		SE	SG	Tz	0905	1013	
	277	CTD		53	SE	SG	Tz	1013	1030	
	278	NB		53	SE	SG	Tz	1035	1136	
	281	TI	180		SE	SG	Tz	1153	1222	
	282	DH	181		SE	SG	Tz	1222	1314	
	283	TI	182		SE	SG	Tz	1314	1350	
	284	TI	183		SE	SG	Tz	1350	1435	
	285	CTD		54	SE	SG	Tz	1435	1442	
	286	DH	184		SE	SG	Tz	1442	1520	End of day and survey at Nyamikoma
13/10/2019										Travel to TAFIRI pier