Honours Thesis

Title:

Fishing Down the Food Web in Lake Albert, Uganda

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1. Abstract

Over the last century, many small and large fishing industries throughout the planet have been deeply affected by immense anthropological exploitation pressure, leading to larger species being driven to near-extinction, and disappearance of large individuals of other species. Heavy harvesting that is characteristic of many capture fisheries can ultimately lead to a change in the assemblage structure of the fish community, often referred to as the *fishing-down process.* Lake Albert in Uganda is the third most productive lake in Uganda contributing to about 30% of the annual national fish production. This lake has a rich diversity of aquatic fauna and flora. However, its fishery and biodiversity are threatened by anthropogenic stressors such as excessive fishing effort, destruction of shoreline vegetation, and increasing water pollution. Excessive fishing has been reported for more than 20 years. The exploited species vary in size at maturity from the small *Engraulicypris bredoi* and *Brycinus nurse* that grow to only a few centimeters in length to large-bodied species like the Nile perch (*Lates niloticus*) that can grow to over a meter long. The objective of this study was to evaluate the presence of a fishing-down process and to understand how it has evolved between 2012-2013 and 2019-2020. This study was done in collaboration with the National Fisheries Resources Research Institute of Uganda (NaFIRRI) and takes one important step towards development of a more complete picture of the fisheries of Lake Albert by analyzing data from CAS surveys (2013-2014) and e-CAS surveys (2019-2020) with a focus on species richness and biomass, gears used, and catch per unit effort. An overall relationship was found between the size of the catch and the change in the gears used, the species, and the length of each species. Indeed, the shift away from gillnets and toward small seines and lights might have contributed to the decrease in certain species and in their total length and mass. Overall, small-scale subsistence fisheries need to be community-based managed, with gear regulations adapted to the socioeconomic and environmental issues that face the local communities of Lake Albert.

2. Introduction

2.1. Fishing-down process

Fisheries, defined as the harvest of fishing stocks for commercial usage in marine or inland bodies of water (Hilborn, 2024), are of critical importance to feed the growing human population of our planet and have great economic and social importance. Approximately 17% of global animal protein supply is derived from fish and shellfish. Only about 7% of the global capture harvest comes from freshwater. But this is still a great quantity of fish: close to 12.1 million tonnes per year are extracted from inland freshwater bodies (FAO, 2022).

Over the last century, many small and large fishing industries throughout the planet have been deeply affected by anthropogenic activities. These new disturbances have many negative impacts, including the extirpation or extinction of species, especially in regions with high levels fishing activities. A literature review found that fishing induced 55% of 133 documented local, regional, and global extinctions of marine populations (Dulvy et al., 2003). Heavy harvesting that is characteristic of many capture fisheries can ultimately lead to a change in the assemblage structure of the fish community, often referred to as the *fishing-down process* (Castello et al., 2015). Fishing-down is different from the concept of "growth over fishing" (Pauly et al., 1998). Growth overfishing is when large fish in a population are harvested first, then smaller ones of the same species; its multispecies counterpart is where fishers successively remove the largest bodied species or "fish down" the food web. In this study, I focused on the depletion of larger-bodied species and a shift towards harvesting of smaller-bodied species. When happening in a multispecies system, the body size of all the species present have seen to be affected.

This large-scale global process has impacts not only on ecosystems; many communities, especially around the tropics, practice subsistence fisheries, and a higher number of small-scale fishing industries are present (Stevens, 1989; Nunan, 2006). Livelihoods in these regions thus very dependent on sustained fish stocks. A fishing down process could therefore strongly affect the socio-economic conditions of such regions. As the populations are dependent of this industry, they are deeply vulnerable to rapid overfishing (Beddington et al., 2005). In particular, inland fisheries are greatly at risk in the Great Lakes of East Africa, a region with one of the highest population growth rates and among the poorest on the planet (Lowe et al., 2019). Moreover, small-scale fisheries are highly climate-dependant (Silas et al., 2023), which currently increases their vulnerability because of the ongoing climate crisis. Changes in socio-economic conditions, overfishing, species invasions, increase of human activity and water pollution (Cadwalladr and Stoneman, 1966; Wandera and Balirwa, 2010; Lowe et al., 2019; Nakiyende et al., 2023) are shown to have an important impact on the biodiversity of a freshwater great lake and thus on the fishing stocks. This thesis focuses on the analyses of how the fisheries have changed in the last decade and understanding the implications of those trend on the growing Ugandan population surrounding the great inland freshwater body, Lake Albert. The objective is also to evaluate what factors have the most influence on the changes happening in the fisheries of Lake Albert, whether it is the gear, the fishing effort, or other external factors.

2.2. Lake Albert

Lake Albert, formerly known as Lake *Mobutu Sese Seko*, has a surface area of 5,500 km^2 and is located towards the tip of the western arm of the African Great Rift Valley. The lake is shared between Uganda (54%) and the Democratic Republic of Congo (46%) (Walker, 1972) (Figure 1). It is the third most productive lake in Uganda contributing to about 30% (180 000 tonnes in 2010) of the annual national fish production (Wandera and Balirwa, 2010). The lake has a rich diversity of aquatic fauna and flora. However, its fishery and biodiversity are threatened by anthropogenic stressors such as excessive fishing effort, destruction of shoreline vegetation, and increasing water pollution (Nakiyende et al., 2023). This excessive fishing has been reported for more than 20 years (since the beginning of the 2000s). Despite these threats, Lake Albert remains the most diverse commercial fishery in Uganda, still harvesting a large richness of species (Wandera and Balirwa, 2010).

Until the late 1990s, there were few fishing regulations, and Ugandan lakes were an open-access resource (LVFO 2005). This led to declining fish yields, and a shift to co-management was adopted to harness the knowledge and the capacities of the stakeholders (Government of Uganda 2003a, 2003b). This resulted in the creation of beach management units (BMUs; LVFO 2005), which emerged in Tanzania in 1998 and then spread to Kenya and Uganda. In Uganda, following the Presidential Directive of November 2015, the activities of BMUs were discontinued (MAAIF, 2017). The Ugandan government created the Fisheries Protection Unit (FPU) in 2017, an auxiliary unit of the Uganda Peoples Defense Forces (UPDF), with the mandate to protect the Nile perch and other stocks in the region. What followed was a heavily enforced intervention by the FPU, with the primarily aim to curb illegal fishing and which involved the destruction of fishing equipment including gears and boats in lakes Victoria, Kyoga, Edward, Albert amongst others (MAAIF, 2017).

The exploited species of Lake Albert vary in size at maturity from the small *Engraulicypris bredoi* and *Brycinus nurse* that grow to only a few centimeters in length to large size species like the Nile perch (*Lates niloticus*) that can grow to over a meter long (Nakiyende et al., 2013). The fisheries are faced with immense anthropological exploitation pressure, leading to larger species being driven to near-extinction, and disappearance of large individuals of other species (Hecky, 2007; Nakiyende et al., 2013). Because Uganda is bordering Lake Victoria, has four other medium-sized lakes (including Lake Albert), and an important number of small lakes, inland fishing stocks are significant resources for the growing Ugandan population. Over 300 000 households' livelihood were dependent on fisheries in 2005 (Nunan, 2006). This number has not stopped growing, with estimates going up to 3 million dependent households in 2022 (FAO, 2022), increasing the country's dependence on the fishing industry.

The history of fishing in Lake Albert resembles the fisheries of Lake Victoria, but at a later date (and a much faster rate after that date). While fisheries in Lake Victoria started when the railroad to Kisumu was built in the 1910s, the fisheries in Lake Albert began to rapidly increase only in the 1940s, although the demand for fish was present in the country since the 1920s (Cadwalladr and Stoneman, 1966). The expansion was mostly facilitated by the use of gillnets, first in what is now known as the Democratic Republic of Congo (DRC). Even though the fisheries in Lake Albert have been known to be diverse since the first catch assessment done by a British officer in 1928 (Worthington, 1929), the situation of over-fishing is easy to observe. In the 1950s, large fishes such as *Lates niloticus* and *Alestes baremose* made up 63% of the catch, while in 2012, small fishes such as the *Brycinus nurse* and *Engraulicypris bredoi* make up almost 80% of the catch (Mbabazi et al., 2012). Indeed, the 1929 report by Worthington highlights that the fishing pressure used to be low, with the use of harpoons, open baskets, basket traps and hand lines (Worthington, 1929). By the 1960s, the fisheries had changed to almost totally gillnet catch (Cadwalladr and Stoneman, 1966). Surveys done by the National Fisheries Resources Research institute (NaFIRRI) of Uganda showed a 31% increase in the amount of gillnets used between 2007 and 2012 (NaFIRRI, 2012; Taabu-Munyaho et al., 2012). The 2012 report also indicated that "a fluctuation in catch of the smaller species observed in Lake Albert could be indicative of uncertainty of sustainability of their fisheries" (Mbabazi et al., 2012), meaning that the future of the fisheries was uncertain.

To understand that important change in the fisheries, the National Fisheries Resources Research Institute (NaFIRRI) of Uganda have been doing catch assessment surveys (CAS) and frame surveys (FS) since 2002. Starting in 2019, electronic Catch Assessment Surveys (e-CAS) have been done. They constitute an app for smartphones where fishers directly enter data about catch quantity, type of fishing nets and boats used, and expected earnings. With the potential to accommodate unlimited data sets, the system is an invaluable resource for the sustainable development of fisheries for wealth creation and food security (International Development Research Centre (IDRC), 2023). Conducting CAS or e-CAS at different landing sites leads to a better understanding of all the processes of the area. Those data are crucial because they allow fisheries scientists and managers to develop solutions to mitigate the impacts of humans on fish stocks.

2.3. Gear

As the fisheries of Lake Albert is so diverse, many different gears are used. However, only a handful are legal, and all have strict regulations. Gillnets, small seines, hooks and lines, and long lines are the only gears that are currently legal. They must have, respectively, mesh over 4 inches, mesh over 8 mm, and less than 9 hooks. Additionally, lights are often used with small seines. The rest of the gear (boat and beach large seines, cast nets, fish traps and monofilament gillnets) are still used, but are illegal. In 2012, although the minimum legal gillnet mesh size limit allowed for harvesting the commercial fisheries on Lake Albert was four inches, over 65% of gillnets operated on Lake Albert were below the legal limits (Nakiyende et al., 2013). The transgression of this regulation allows the catch of smaller fish, but also may indicate the need to catch smaller fish because the larger species and larger individuals of large-bodied species are less and less present. Enforcing gear regulations on Lake Albert is a constant challenge, which seems to be complicated by many changes in the authority responsible of regulating activities. Starting in 2002, Beach Management Units (BMU) were in charge of the regulation, applying the Fishing Act, which is said to be archaic (Anon, 2004). The enforcement responsibility is transferred, in 2015, when the Department of Fisheries Resources changed direction and made the military forces in charge of the enforcement (Frank, 2017). Figure 2 shows pictures of the different gears for better understanding, informed by the Food and Agriculture Organisation of the United Nation (FAO) principally (FAO, 2023).

2.4. Fish species of Lake Albert

Although Lake Albert has a very diverse ecosystems containing a large number of species, some are economically and socially more important. Indeed, a handful species composes over 80% of the total catch (NaFIRRI, 2012; Taabu-Munyaho et al., 2012). Table 1 provides an overview of the life history, the IUCN category, and the range of those important fish taxa. It is based on data collected on the *Freshwater Biodiversity Data Portal for Uganda,* updated by Natugonza, V. & Musinguzi, L. in 2021, and supported by NaFIRRI. All the photography also come from this resource. It is although important to mention that this data base is for all the lakes in Uganda, therefore the total length (TL) might only be an estimate for Lake Albert.

2.5. Gaps in the literature

Although crucial for the livelihood of an important fraction of the Ugandan population, there are still important gaps in our understanding of the fisheries of Lake Albert, Uganda. The main reports in 1929, 1966, 2006 and 2012 (Worthington, 1929; Cadwalladr and Stoneman, 1966; NaFIRRI, 2006; Mbabazi *et al.*, 2012; NaFIRRI, 2012; Taabu-Munyaho et al., 2012) were detailed and outline the fishing-down process well. Those studies already reported the overfishing. Nakiyende et al., in 2013, found that the most important limiting factor that restrains the implementation of efficient regulation and guidelines of the fish stock of Lake Albert is the inadequate systematic and judicious biological data available. The study by Mpomwenda et al., published in 2022, shows that the average mass of fish harvested increased with increased mesh size and the average catch per trip increased with gillnet mesh size in Lake Victoria, when looking at the Nile Perch catches. The number of panels of gillnet mesh used also made a difference in the catch in that study. The link between the net size and the catch is therefore very important to identify. There are still important gaps to be filled in our understanding of the long-term trends in the fisheries of Lake Albert. This study is done in collaboration with the National Fisheries Resources Research Institute of Uganda (NaFIRRI) takes one important step towards development of a more complete picture of the fisheries of Lake Albert by analyzing data from CAS surveys (2013-2014) and e-CAS surveys (2019-2020) with a focus on species richness and biomass, gears used, and catch per unit effort.

2.6. Research questions and objectives

Here, the goal is evaluating the presence of a fishing-down process (Castello et al., 2015), and if present, to understand how it has evolved over the last years. I address the following questions: Has the composition of the catch of the lake changed between 2013 and 2020? How did the size of the catch and the biomass of the catch change over the years? Is there a correlation between the size of the catch and the change in the gears used, the species, and the length of each species? Can that change be related to a change in the number of fishers or the fishing effort? What are the implications of these findings for biodiversity and fish stock availability to the surrounding population? Different mitigation recommendations to move away from the fishing-down process, if present, depending of the level of the change, will be suggested to NaFIRRI.

3. Methods

This study uses data collected by the National Fisheries Resources Research Institute of Uganda on fish catch from two time periods: 2013-2014 and 2019-2020. Catch assessment surveys were done through direct observations by NaFIRRI staff or NaFIRRI trained data collectors (2013-2014) and by electronic catch assessment surveys (e-CAS) for 2019-2020. Data include information from landings on Lake Albert and the Albert Nile. Below, I describe the collection protocols in detail.

3.1. Data collection

NaFIRRI describe the objective of a CAS as “provid[ing] information on the facilities and services at landing sites and the composition, magnitude and distribution of fishing effort to guide development and management of the fisheries resources of Lake Albert and Albert Nile” (NaFIRRI, 2012; Taabu-Munyaho et al., 2012).

In 2013-2014, data were collected by trained by NaFIRRI. These were often district fisheries officers and sub-county officers, and have the power to train other data collectors, but still must ensure data quality before handing them to NaFIRRI. The observations were carried out in 50 different landing sites (out of the 72 total landing sites). Twenty-eight of these sites were on the shores of Lake Albert, and the remaining 22 were on the Albert Nile (figure 1). There was a total of 13 data collection days; July 22th to 27th, 2013, inclusively and November 27th to December 2th, 2014, inclusively. The data were collected by interviewing fishers using a standard set of questions. Answers were later transcribed numerically on Excel Microsoft. The interviews do not represent the total number of fishes that landed on the day of the CASs, but provide a representative sample of the catch. The composition of the bycatch was often not taken into account, resulting in rough estimates of the mass of individual fish for certain species. The fish caught were identified by the data collector; and the number of each species was counted. The number of individual fish of each species were counted and the total catch per species was weighed. The reported mass originated from the division of this total mass by the number of fish captured per species (in kg), meaning that each fish was not individually weighed. The only exception to this method is with *E. bredoi* (*Engraulicypris bredoi*) and *B. nurse* (*Brycinus nurse*); they were weighted by buckets (in kg), and the total mass caught was multiplied by the number of buckets reported. The size of the bucket was not uniform between landing sites of fishers; therefore, the data collectors measure the size of each bucket and the mean size and its mean mass were recorded. The buckets generally vary in shape between some sort of jerrycan or some sort of basin. The total length of a few individuals of *Alestes baremose* and of *Oreochromis niloticus* selected randomly from the catch was also recorded. The time spent fishing was recorded as the number of hours spent in the day of the sampling. The numbers of days fished in the last week by each crew was also recorded. The average time spent fishing per day per boat was calculated from the multiplication of those two variables as follows:

$$time = number\ of\ days\ fished\ in\ last\ week\ \cdot hours\ per\ day$$

To estimate the fishing effort, the time was divided by the number of boats recorded during the day surveyed as follows:

$$Effort = \frac{time}{number\ of\ boats}$$

The catch rate was calculated by dividing the mass (in kg) caught in one day by species by the effort, by the number of boats as follows:

$$Catch\ rate = \frac{mass\ \cdot time}{number\ \ of\ boats}$$

The type and size of gear used was also recorded. When multiple sizes of the same gear were used in the same boat, the size of the gear was averaged or expressed as a range (i.e. 5-10 hooks). When lights were used (night-time light fishing), the total number of lights per boat during the day of data collection was recorded, as well as gears (small seines, boat seines, catch nets, or gillnets). The data collectors were not law enforcing officers and were therefore able to get a good picture of the catch.

The 2019-2020 data were collected from 33 landing sites (out of the total 102 landing sites), all on the Ugandan shores of Lake Albert, from July 1st to 5th and 16th to 19th, 2019 and from November 5th to 8th and 16th to 18th, 2020, for a total of 16 days of data collection. They were collected through e-CAS, which is a partnership between NaFIRRI and local communities for monitoring fish catches using a smart phone application whereby mobile phones are given to members of the fisher communities to collect catch assessment data using an application designed for Catch Assessment Survey (e-CAS mobile application). CAS data collected by local fisher communities were uploaded to a centralized data base, where they were linked to water quality and climate data and shared with multiple stakeholders.

Contrarily to the 2013-2014 data, the species caught were recorded as genus or families only (Supplementary table 1). To be able to related historical and current data, the historical data were also placed in those larger groups, here called *taxa*. The rest of the data collection is similar to the historical data, with the exception that the total length for various species was measured for at least 10 randomly chosen individuals, by the fisher. This data collection for 2019-2020 has a greater sample size because instead of using pen and paper and then digitalizing the data, a tiresome process, the data collectors use the e-CAS mobile application. Around half of the boats landing on the sampling days were interviewed. Although less precise because of the format of the mobile application, there were more data collected.

3.2. Data analysis

All statistical analysis were done through the software R. The quantitative assessment of the catch data was taken from methods described in NaFIRRI reports (2006; 2012; Taabu-Munyaho et al., 2012), Wandera and Balirwa (2010), Nakiyende et al. (2013, 2023) and Silas et al. (2023).

A map of the landing sites was created using the software QGIS and the approximate location of each landing sites from Google maps and from local knowledge.

Data from the historical and the current surveys were cleaned and standardized, ensuring consistency and addressing any missing values, typos and outliers. For both time periods, the proportion (in percent) of the number of individuals caught and the mass for each species groups, the proportion of each gear used and the efforts (in boats per day) were calculated. Length frequency histograms were created for all the species for which sufficient data were available. The size and number of long lines, hooks and lines, small seines and gillnets were assessed and calculated. These data were used to quantify proportions of illegal gears.

4. Results

4.1. CAS vs e-CAS

In recent years, a change in the assessment method of the fisher catch in the Ugandan fishers of Lake Albert resulted in a major change in the quantity of data collected. In 2013-2014, catch assessment surveys (CAS) were done over 13 days at a total of 50 landing sites with 4055 data entries. In 2019-2020, with the transition to electronic catch assessment (e-CAS), data were collected over 16 days, in only 33 landing sites, but with an increase to 11 076 entries. The total mass of the catch recorded also doubled between the two periods, while the total number of fish captured was approximately six times more in 2019-2020. Because of this difference in the amount of catch directly recorded, I present the results as proportions of catch, to allow an assessment of changes in the catch composition.

In 2013-2014, a larger number of species were recorded, which may reflect a number of factors including (1) fishes targeted by fishers; (2) decline in some species in the lake; and/or (3) rigor of the catch assessments. In addition, it is important to note that the first survey included the Albert Nile, the more recent does not (figure 1). In addition, in 2019-2020, some species were grouped by the recorders into supra-specific groups (e.g., tilapia). It is also pertinent to mention that the total number of landing sites on the Ugandan shores of Lake Albert has increased by 30 (going from 72 to 102) between 2013 and 2020, with most of the new ones being illegal landing sites. While they have gone down since, because of the impact of the COVID-19 pandemic, they most certainly contributed to increasing the total catch (legal and illegal of Lake Albert).

4.2. Catch by mass and length

In both 2013-2014 and 2019-2020, the two species that constituted most of the catch were *Brycinus nurse* and *Engraulicypris bredoi*. The proportion of the *B. nurse* caught decreased from comprising 27.2% to 13.3% of the total mass of the catch, and the *E. bredoi* had a slighter decrease, with 60.5% to 54.1% (figure 3). However, a very steep increase in the amount of buckets of *B. nurse* was recorded in later years, which could indicate that this species' individual seems to be getting smaller (supplementary figure 1). Four species (*Auchenoglanis occidentalis*, *Barilius niloticus*, *Clitharanus latus*, and *Disticodus niloticus)* were not evident in the 2019-2020 catch; while the electric catfish *Malapterus*, was captured only in 2019-2020. The mass of the tilapias and of the Nile perch *Lates* caught increased from 3.2% to 14.1% and 2.5% to 7.7%, respectively (figure 3). Of the tilapias harvested in 2013-2013, 76.35% were Nile tilapia (*Oreochromis niloticus*), and there were no indications that this proportion has changed in current data (supplementary table 1). We therefore assume that out length data reflect primarily Nile tilapia (figure 4b). The length-frequency distributions of the tilapias show a shift from a concentration of fish between 13-37 cm in 2013-2014 to 15-30 cm in 2019-2020, with almost no fish greater than 45 cm in 2019-2020. In 2013-2014, there were many tilapias between 45 and 52 cm in length. There were no length data available for *Lates* in 2013-2014 that would permit a comparison between years. However, for *Alestes* group (figures 4a and 5), the mass caught has stayed relatively similar (0.84% to 0.85%) over the period of this study, but the mean length of the species caught shifted from ~30 cm (figure 4a) to ~20 cm (figure 5). The *Alestes* individuals caught are thus immature, and smaller than in the past. In 2019-2020, the top of the length frequency curve for the *Lates* was ~20 cm (figure 5).

4.3. Efforts and catch rates per year and per species

The mean fish catch rate in 2013-2014 was 75.9 kg/hour/boats, while it decreased to 31.4 kg/hour/boats in the latest CAS (e-CAS), a very large decrease indicating that more time is spent per boat, to catch the same amount of fish. This trend is also seen when investigating the catch rate per species (figure 6). The *Schilbe* and the *Malapterus* seem to now be a part of the fisheries. Indeed, they were considered as bycatch before, but are now a part of the fishing landscape, with efforts attributed to them. The main species targeted by the light fisheries, *B. nurse* and *E. bredoi*, are in both periods the species with the greatest catch rate. However, the mean fish catch rate decreased in the later years by about half, though the total mass caught has only decreased slightly (figure 3). The next section will make links with the gear used.

Concerning the larger species, the time spent on *Alestes*, *Lates* and Tilapia has increased. The time spent fishing species that are not fished anymore has thus been redistributed to species that used to be bycatch (figure 7). On the other hand, on average 1.16 hours per boats per days was spent fishing in 2013-2014, while it was 2.07 in 2019-2020. This significant global effort increase was also seen by species (figure 7), where the trend is toward a greater effort in later years for most species. Notably, the efforts on small pelagic fish were multiplied by 6 or 8 times. This is also true of species that have seen their total catch mass either decrease or increased, as *Alestes*, *Hydrocynus* or *Lates*.

4.4. Gear

Only four out of the 10 distinct fishing gears used on Lake Albert are legal. But, for the legal gears most of the size/number requirements are not met (table 3). For gillnets, 72.2% of the of the gillnets used were below the 4-inch legal mesh size in 2013-2014. This dropped to 46.6% in 2019-2020 (figure 8a). However, in both periods, the most heavily used gear was small seines (table 3), and all recorded mesh sizes were below the 8 mm legal limit. Most of the light fisheries that are conducted at night using small seines (figure 8d). No regulations exist on the number of lights used while fishing, but this number has greatly increased on average between both periods (figure 9). Virtually no boats used more than 6 lights in 2013-2014, while the average number of lights was between 20 and 25 in the 2019-2020 survey. This measure of effort also highlights the fact that a lot more time was spend using lights, while the mass caught did not increase (figure 9). The small seine is the only gear to have lost catching efficiency over the years (figure 9), as the catch rate was lower.

Long lines have greatly gained in popularity since 2013-2014; most of the long lines now have a number of hooks larger than the legal nine hooks (only 25.5% of the long line used were legal in 2013-2014 and this number dropped to 6.2% in 2019-2020) (figure 8c). The utilization of long lines is dominant in benthic species (*Malapterus, Protopterus, Clarias* and *Bagrus*) throughout the years. *Lates* are also caught on long lines, although they are caught by a multitude of gears.

In 2013-2014, out of the 1409 small seines fisheries event recorded, 1408 (99.9%) were light fisheries events. In 2019-2020, it was 1711 out of 1770 (96.7%). 21 events of gillnet fishing with lights were recorded in 2013-2014, and none were in 2019-2020. Virtually all small seine usage is thus toward light fisheries. Therefore, small seines will be interpreted as the usage of lights from now on. However, no regulations exist on the number of lights used while fishing, but this number has greatly increased on average between both periods (figure 9). As demonstrated in hours per boats to use a certain number of lights, virtually no boats used more than 6 lights in 2013-2014, while the average number of lights is between 20 and 25 in the later years. This measure of efforts also highlights that a lot more time was spend using lights, while the mass caught did not increase (figure 9). However, the catching rate was much more efficient (figure 11 – small seines). Small seine is the only gear to have lost catching efficiency in terms of times over the years, and it is likely due to the increasing number of lights used, or that more small pelagic individuals (intrinsically with less mass) are caught.

A new gear was added in 2019-2020: monofilament fisheries (figure 10). Used mainly to target small pelagic species fisheries, monofilaments seem to catch more juvenile individuals or small species (Nakiyende et al., 2023), such as *B. nurse* (figure 10b). Additionally, practically all species are now in part caught by monofilaments. No more gillnets are used on *E. bredoi* in later years. The species is uniquely caught with small seines, therefore by light fisheries. The general trend is a greater diversity of gear used per species and the decreasing utilization of gillnets (figure 10a and 10b). This is significant, as the main species that are still caught in majority with gillnets are larger species (*Alestes, Hydrocynus*, *Mormyrus*, *Schilbe* and *Labeo)*. However, as previously established, close to 50% of the gillnets used on Lake Albert are too small to be legal, thus catching manly juvenile individuals of those “larger” species. The catch rate per number of gillnets has not increased much (figure 11), which could indicate a that the gillnets used now are more efficient, which means that they catch smaller individuals in a greater number.

5. Discussion

5.1. Presence of a fishing-down process

The findings of this study indicate that an important fishing-down process is taking place in Lake Albert, and that it has been accelerating between 2013 and 2020. Over this time frame, the number of taxa captured decreased; the total length of some species decreased, and the catch per unit effort increased, while the catch rate of fish decreased.

The number of taxa captured has decreased by a factor of two since 2013-2014. The number of individuals of each species group captured has not decreased for all species; however, in general, this was the case for the larger-bodied taxa (i.e., *Labeo, Hydrocynus, Alestes*), which can indicate that larger individuals are mostly absent from the fishery, and likely from the fish populations. The two taxa (Tilapias and *Alestes*) that can be compared in terms of individual sizes and size frequency distributions between 2013-2014 and 2019-2020 are generally smaller, which is an important change since the gap is only seven years. Yet, the landed mass of *Alestes* individuals has stayed similar, which could be an indicator that more juvenile or small individuals have been captured. This phenomenon has also been seen in in similar studies in the tropics (Castello et al., 2013; Dulvy et al., 2003; Nunan, 2006).

Analysis of catch per unit of biomass and of efforts indicated that the fishers are generally spending more time fishing, but that the mass caught per day is less, meaning that it has become harder for fishers in 2020 to capture the same biomass as in 2013. The species that have a catch rate that is larger in 2019-2020 (meaning that they are caught more efficiently, with less effort) seem to be the taxa that used to be considered as bycatch (*Schilbe, Malapterus*) or the taxa that were previously less targeted for food (*Bagrus, Protopterus, Synodontis*) (Mcclanahan et al., 2005). The *Clarias* and the *Barbus* species used to be abundant, but decreased dramatically since 2006 (NaFIRRI, 2006). Their high catch rate can be due to their low mass caught, as there might be not enough individual caught to have a statistically significant mean. For *Alestes* and Tilapia, the catch rate is slightly higher in 2019-2020, which is most likely due to the shift to smaller individuals in length, and the likely scenario that all fish were kept rather than discarded as bycatch, which decreases the total effort for a species. This is in line with the finding that a larger total mass was caught for both species in 2019-2020. For *Lates* species, which also have higher catch rate and high fishing effort, The average total length was closer to 25 cm in 2007-2008, and was around 70 cm between 1989 and 1995 (Lake monograph, 2008). There has thus been a decrease of approximately 45 cm in the total length of the taxon by 2007-2008. As the relative total mass of *Lates* species caught was multiplied by a factor 3 by 2019-2020, it is most likely that the increase in efforts for the taxon is due to the fact that, as *Alestes* and Tilapia, all individuals caught were kept in the total capture. It is although curious that both the effort and the catching rate increased. As in the Amazon (Castello et al., 2015), it can be caused by an intensification of the number of fishers and boats. This phenomenon must be further studied.

It is interesting to note that the species that were previously only seen as bycatch (*Malapterus* and *Schilbe*) seem to be considered to be part of the fishing industry now. However, implementation of the new e-CAS system might not differentiate bycatch and catch, allowing fishers that previously did not record all their catch to now do so. Thus, catch and bycatch might be mixed together and reported as one category. More investigation on the use of *Malapterus* and *Schilbe* after their arrival at the landing site is thus needed.

A very drastic shift of the industry to the smaller species (especially *E. bredoi* and *B. nurse*) seems to be happening. The decline and possible extirpation of other larger species, namely those that are not included in the 2019-2020 catch, are a good indicator that we are fishing down the food web at an uncontrolled speed. Although this shift was observed prior to my study, my results show that it does has not slowed down. The effort for the small sized pelagic species has increased by 6 or 8 times, which is dramatic, especially considering that the mass caught has not. This reenforces the finding that even small species body mass might be getting smaller and scarcer.

5.2. Causes of the fishing-down process

Although the decreased presence in large individuals of large-bodied species in the catch and the increased presence of small pelagic fish could be attributed to social and economic causes (Bennett et al., 2020; Mpomwenda et al., 2022; Nunan, 2006), it ultimately reflects in large part, the gear used. Indeed, most of the gear used on Lake Albert in both time periods is either illegal, uses illegal mesh sizes or an illegal number of hooks, or in the case of light fisheries, is simply unregulated, resulting in an unprecedented increase in their usage and the usage of small seines overtime.

Although the number of legal gillnets used in 2019-2020 has decreased compared to 2013-2014, the proportion of taxa caught with gillnets has also decreased; gillnets seem to have been largely replaced by small seines and light or other unregulated gears. The shift in the enforcement agent that has taken place in 2015 might be in cause; the Uganda Peoples Defense Forces (UPDF) has been in charge of the regulation since then (LVFO 2005). As their main objective was to act on the highly economically profitable Nile perch, which was in majority caught by gillnets, it is very likely that most of their efforts were put toward enforcing the use of legal gillnets. The decrease in the use of gillnets in 2019-2020 and the spike in the use of 5-inch mesh in the same time period shows that their methods were successful in most part. However, it created the problem of a shift to other illegal gears to catch Nile perch and other species. The interesting increase in the use of the illegal boat seines by 2019-2020 could be correlated with this higher enforcement of gillnet regulations. It could further indicate that many small individuals were caught, as there is no regulation on the size of the mesh of boat seines.

Hooks and long line usage stayed similar between 2013-2014 and 2019-2020, as did the amount of boats using the legal number of hooks on a line. However, in 2019-2020, more boats have been using a large number of hooks (between 18 and 25) than was the case in 2013-2014. This might explain the increase catch rate for certain species (as *Lates* and *Malapterus),* which were mostly caught with long lines in 2019-2020, as well as the increase in the total relative mass caught for species captured with long lines and hooks and lines, since it is probable that many were captured at the same time, yet with less efforts. To come back to the issue of both the catch rate and the effort that have decreased for Nile perch, a possible explanation might be the new trend of using multiple hooks for Nile perch and less gillnets, which were really effective in catching this taxa. The UPDF efforts to regulate gillnets thus has had cascading repercussion on the food web.

The increasing number of lights used in 2019-2020 relative to 2013-2014 and the increase in the proportion of fish gear comprised of small seines, is most likely a result of the quantity of fish being less and less available. Therefore, a larger effort (both time and material) must be put towards capturing the same quantity of fish. Indeed, the relative mass of the small pelagic species (i.e., *E. bredoi* and *B. nurse*) have decreased slightly, while still comprising the majority of the total catch. The proportion of small seines used to catch them has significantly increased as have the number lights used. It is possible that the use of more lights does not attract more fish, or it might be that the small pelagic fish are actually scarcer.

The violation of gear regulations possibly demonstrates four ideas; (1) the actual regulations are not appropriate to the current characteristics of the fishery, (2) the enforcement is not done in a manner that either reaches the fishers or that they understand, (3) if the regulations were effectively enforced, they might lead to negative social and economic impacts as the community surrounding the lake are dependent on the fishery for food and income, and (4) on a more positive note, both CAS and e-CAS do not restrict fishers from being truthful as to which gear (legal or not) they are using.

5.3. Implications for biodiversity of the lake

Fishing-down the food web of a lake-system often results in extinctions and extirpations. Although there is not enough data to evaluate if this has been the case yet, many studies suggest that it is only a question of time (Chapman, Nyboer, and Fugère, 2022; Bennett et al., 2020; Sumaila, Bellmann, and Tipping, 2016). This could create trophic cascade effects and impact the whole ecosystem. The lake would thus be increasingly vulnerable to external stressors as climate change or human development and would be at risk of collapsing (Pauly et al., 2005).

5.4. Limitations

The most important limitations of this study originated from the datasets used. Indeed, the CAS and the e-CAS are overall similar enough to be compared, but do not have the same resolution. Much more data was available for 2019-2020. While this is a great confirmation that the e-CAS system is efficient at collecting a much more representative data set, there is less precision of the species caught in the e-CAS; some species were group together (i.e., tilapias). As fishers usually know exactly which species they have caught, it would be a necessary improvement to have the precision of the exact species. In both CAS and e-CAS, species or taxa are reported with scientific names and not local names. Data would have more accuracy and would better represent the actual catch if fisher used regional and local names as they enter data in the app. Also, while it is very clear in the 2013-2014 CAS if the data come from Lake Albert or Albert Nile, it is less clear in the 2019-2020 e-CAS, which leaves more place to interpretation, especially since the diversity of species at both locations is said to be different. Finally, the results presented here only include the catch of boats that arrive at landing sites and that have a regulated licence. However, there might be an important proportion of fishers that take an unknown, maybe important, quantity of fish from the lake that do it illegally (Mbabazi et al., 2012). This would change the proportion of the catch found here. We also need to consider that 46% of the Lake is under the regulations of the DRC, so it is important to recognize that the data reported here represent about half the lake only.

5.5. Recommendations

From the results of this study, I offer the following recommendations concerning the management of Lake Albert. They have for objective to decrease the speed of the fishing-down process, in order to bring the fishing industry back to a sustainable level over the long-term catch.

(1) Gear regulations must be adapted to subsistence fisheries and to the context of Lake Albert. More investigations and more consultation with the population is needed to produce those. Regulations should be grounded in the community and the use of focus groups composed of a diversity of actors from the fishing industry are proposed (Mpomwenda et al., 2022).

(2) Regulations should be imposed on all the gears used, even the ones that are currently illegal, in order to allow each fisher to fish in a sustainable way with the fishing gear available to them, but to still control the size of the gear used.

(3) Regulations should include a quota of each species per day or per week, which should be determined using both the input from research on the sustainable population of each species and on the outcome of focus groups. This would allow for a two-way control. This management solution has proven to be more sustainable in communities all around the world (Bennett et al., 2020; Castello et al., 2013; Costanza, 1987).

(4) There needs to be a shift in the enforcement of the regulations. I propose to explore the idea of bringing back BMUs, which should be community-based and community-managed. This idea should however be discussed in an eventual focus group. If BMUs are found to be a not sustainable idea over time, the regulation agent should still be community-based. This management solution has proven to be more sustainable in communities all around the world (Bennett et al., 2020; Castello et al., 2013; Costanza, 1987).

(5) This new management should be also supported by education at landing sites to promote the use of legal gear sizes and legal quotas. This would allow all the players in the industry to encourage each other to promote sustainable fisheries and to understand why there is a need to reenforce regulations. It should also be enhanced from insurance, institutional support to the fishers and alternative-livelihood opportunities (Costanza, 1987; McClanahan et al., 2005).

(6) Long term monitoring by NaFIRRI needs to be continued. As proven earlier, the methods to get data seems to be efficient in term of the veracity of the data collected from the fishers using the e-CAS system. This is a very positive outcome to this study, as it shows that e-CAS has the potential to be a very efficient monitoring system. However, there is a need for more precision in the e-CAS. The fish need to be differentiated by species (both local and scientific names), instead of by taxon and group. This will allow for a greater understanding of the mechanisms at play at the ecosystem level (i.e., of the impacts of the fishing down on endemic species). Moreover, a category that should be added in the e-CAS is whether the fish was caught intentionally or as a bycatch. This will give more indications on the shift in the use of some species.

6. Conclusions

This study concluded that there is a fishing-down process as described by Castello et al., 2015 going on in Lake Albert, Uganda, and it seems to have been accelerating between 2013 and 2020. The composition of the catch did change, as four species previously captured were not observed in the 2019-2020 catch data, and two species that were previously seen as bycatch are now part of the catch. It is unknown if the total biomass taken out of the lake is similar in both time periods, but the proportion of each species changed significantly. By 2019-2020, the majority of the catch biomass was comprised of small pelagic species caught by small seines and monofilaments. A relationship was evident between the size of the catch and the change in the gears used, the species, and the length of each species. Indeed, the shift away from gillnets and toward small seines and lights might have contributed to the decrease in certain species and the in the total length of them. Fishing effort has generally increased, while the catching rate has generally decreased, suggesting that fish are scarcer in the lake or that their individual mass is smaller. Further research is needed to assess the actual impacts of this phenomenon on the biodiversity of the lake, although other studies have shown that the fishing-down process often leads to ecosystem-wide impacts.

The different recommendations proposed must all be based in the community and supported by country-wide politics to work. Indeed, the idea of grassroot project to regulated the fisheries has been shown to work in many other industries in East Africa and elsewhere on the planet. In the next years, close monitoring of the catch and of its evolution through time must continue to happen through NaFIRRI. This is essential to the well-being of an endangered industry as the fisheries on Lake Albert (Wandera & Balirwa, 2010).

In terms of research, the next steps need to be a study of the economic impacts of the fishing-down process in Lake Albert. CAS and e-CAS contains the necessary data to do so, but it was beyond the scope of this study. There is also the need to further explore how each species is uses and what are the cultural impacts of losing certain species. Lastly, an analysis of the data collected on the DRC shores of Lake Albert (if any), is needed to understand if the fishing down process is found in the whole lake.

7. Acknowledgements

Permission for this project was granted by the Bieler School of Environment at McGill University. I acknowledge my positionality as a white settler living in Tiohtiá:ke, which is situated on the traditional territory of the Kanien'kehà:ka people. This study was completed on Turtle Island, and I have never been physically to Lake Albert. Even though I am as informed as I can, I acknowledge that my recommendations might not be adapted to the cultural, social, political and economic realities of Uganda and of the population surrounding Lake Albert.

I would like to thank Dr. Lauren Chapman from the Department of Biology at McGill University for her outstanding guidance, advice and support throughout the preparation of this thesis as my Honours thesis supervisor. I would also like to thank Mr. Herbert Nakiyende from NaFIRRI for his amazing help in understanding the data and the reality of Lake Albert, as well as for his input throughout my process. Thank you to the members of the Chapman Lab for their inputs on my presentations. Finally, I would like to thank the Field Studies & Internship Office and the Africa Field Study Semester (AFSS), which sparked my interest in such research by allowing me to spend 3 months learning in East Africa in Kenya and Tanzania.

8. Tables

Table 1- Body size, IUCN status, and geographical range of fish species comprising >85% of the catch of the fishing industry in 2012 in Lake Albert, Uganda.

		Life History			
Scientific Name	**Common name**	**Size**	**IUCN Status**	**Geographical range**	**Photography**
Alestes baremose	Silversides	Adult fishes range between 30-55 cm long	Least concern	Not endemic, native	
Bagrus bayad	*Black Nile Catfish*	Most individuals are about 40 cm long	Least concern	Not endemic, native	
Barbus bynni	*Niger barb*	The maximum recorded specimen was 82 cm, but there is no available information on the life-history aspects of the species in Uganda.	Least concern	Not endemic, native	
Engraulicypris bredoi	none	Max length : 4.5 cm TL male	Not evaluated	Endemic, native	
Hydrocynus forskali	Tiger fish	Max length : 78.0 cm SL male/unsexed	Least concern	Not endemic, native	
Lates macrophatlmus	Albert lates	Max length: 29 cm TL	Vulnerable	Endemic, native	
Lates niloticus	Nile perch	52-54 cm TL for males and 58-62 cm TL for females	Data deficient	Not endemic, native and introduced	
Mormyrus kanume	*Elephant-snout fish, Bottlenose*	size range of adult fish is usually between 40-60 cm	Least concern	Not endemic, native	
Oreochromis niloticus	Nile tilapia	22-25 cm TL for females and 31-35 cm TL for males	Least concern	Not endemic, native and introduced	
Brycinus nurse	Nurse tetra	12.20-22.60 cm T.L	Least concern	Not endemic, native	

Table 2- Comparison between the catch assessment survey (CAS) of 2013-2014 and the electronic catch assessment survey (e-CAS) of 2019-2020 of fishes of Lake Albert, Uganda.

	2013-2014	2019-2020
Number of species group	39	18
Total number of entries	4 055	11 076
Total weight of catch (kg)	138 199.6	334 364.7
Recorded time spent fishing (total hours)	5 076.6	22 697.4
Total number of fish caught	71 882	418 710

Table 3- Proportion of fish captured (percent mass) in different gears used in 2013-2014 and 2019-2020 in the fishing industry of Lake Albert, Uganda. The legal status of the gears is also presented.

		% of catch by weight caught by each gear		
Gear used	**Gear code**	**2013-2014**	**2019-2020**	**Legality**
Boat Seines	BOS	0.3	6.8	No
Cast Nets	CN	0.6	1.6	No
Gillnets	GN	10.4	6.7	Yes (>4 inches nets)
Hooks and Lines	HL	0.1	0.1	Yes (< 9 hooks)
Long Lines	LL	1.6	5.9	Yes (< 9 hooks)
Small Seines	SS	86.7	64.9	Yes (< 8 mm nets)
Traps	TR	0.3	2.0	No
Beach Seines	BES	0.0	0.9	No
Monofilaments	MF	0.0	11.0	No
Others	OT	0.0	0.0	No

9. Figures

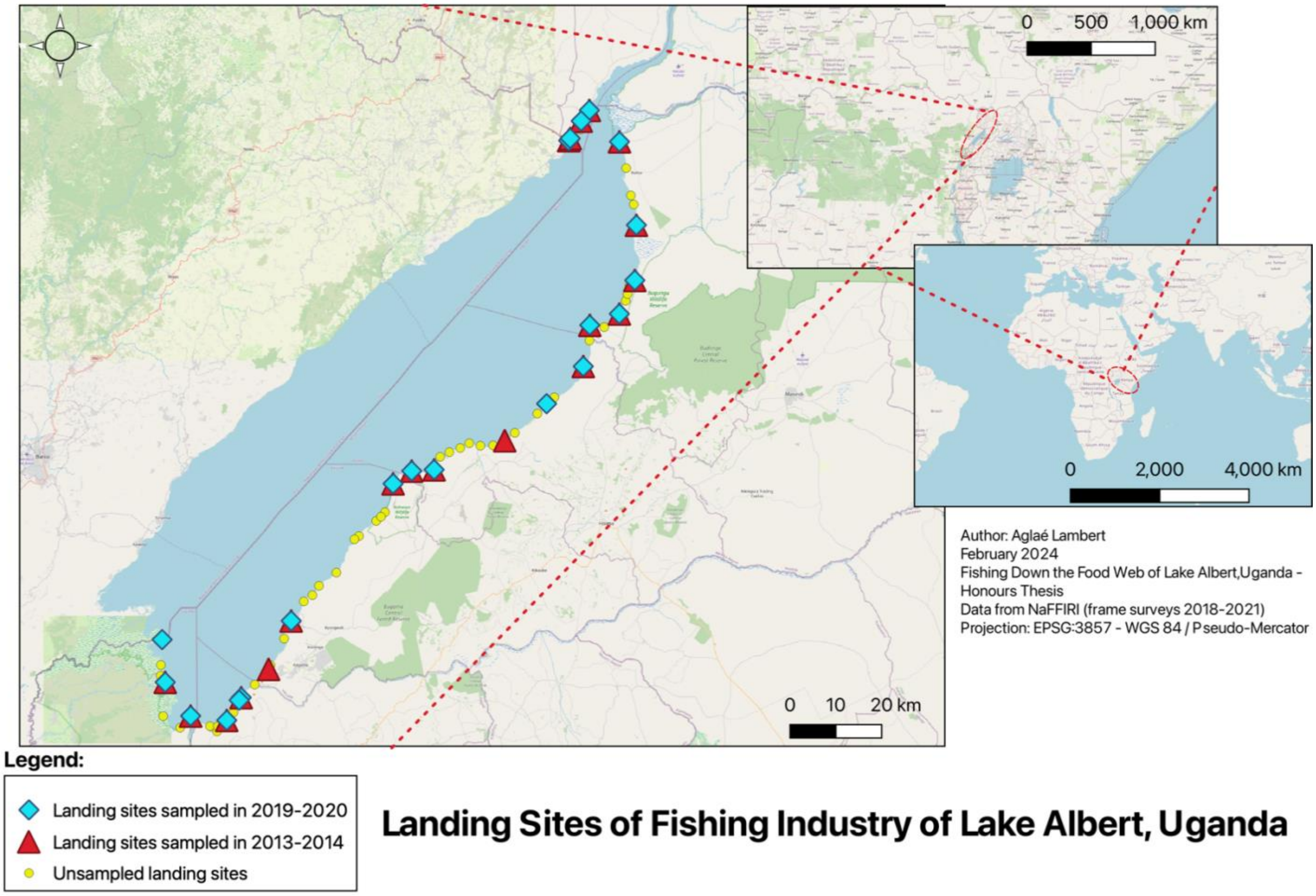
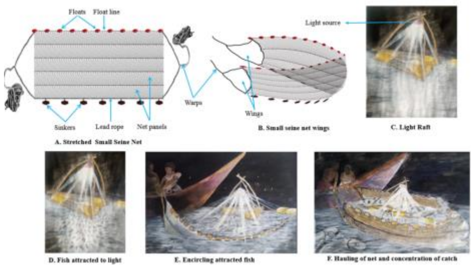


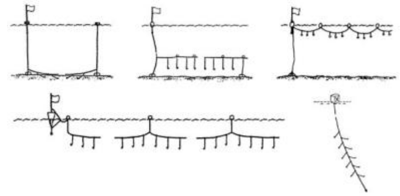
Figure 1 – Map of landing sites sampled for catch assessment surveys in 2013-2014 and 2019-2020 of Lake Albert, Uganda. The map was created with the software QGIS, using data from NaFFIRI

a) Gillnets - Designed to allow fish to get only their head through the netting but not their body. The fish's gills then get caught in the mesh as the fish tries to back out of the net. As the fish struggles to free itself, it becomes more and more entangled (NOAA, 2023)

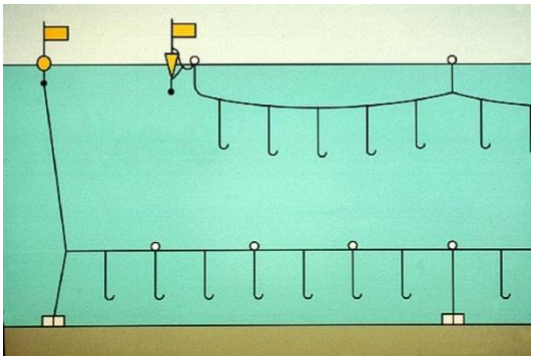
b) Seines- very long net, with or without a bag in the centre, which set either from the shore (beach seines) or from a boat (boat seines) (FAO, 2022)



c) Small seines and light fisheries (Nakiyende et al., 2023)

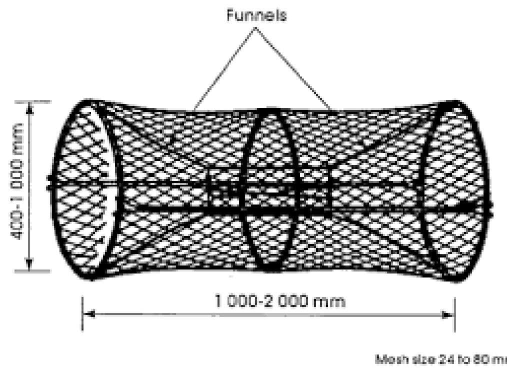


d) Hooks and Lines - fish is attracted by a natural or artificial bait (lures) placed on a hook fixed to the end of a line or snood, on which they get caught (FAO, 2023)



e) Long lines - mainline and snoods with baited (occasionally unbaited) hooks at regular intervals and which is set, in general, on or near the bottom (FAO 2023).

f) Castnets - constructed from a series of tailored netting sections joined together to produce a cone-shaped net with weights and a drawstring attached to the perimeter and cast by a fisher to catch fish (FAO, 2023).



g) Fish traps - fish enter the trap by one or several entrances or funnels and are prevented from escaping (FAO, 2023).

Figure 2 - Legal and illegal fishing gears used in the fishing industry of Lake Albert, Uganda. Photos and graphics were downloaded from Food and Agriculture Organisation of the United Nation (FAO, 2023).

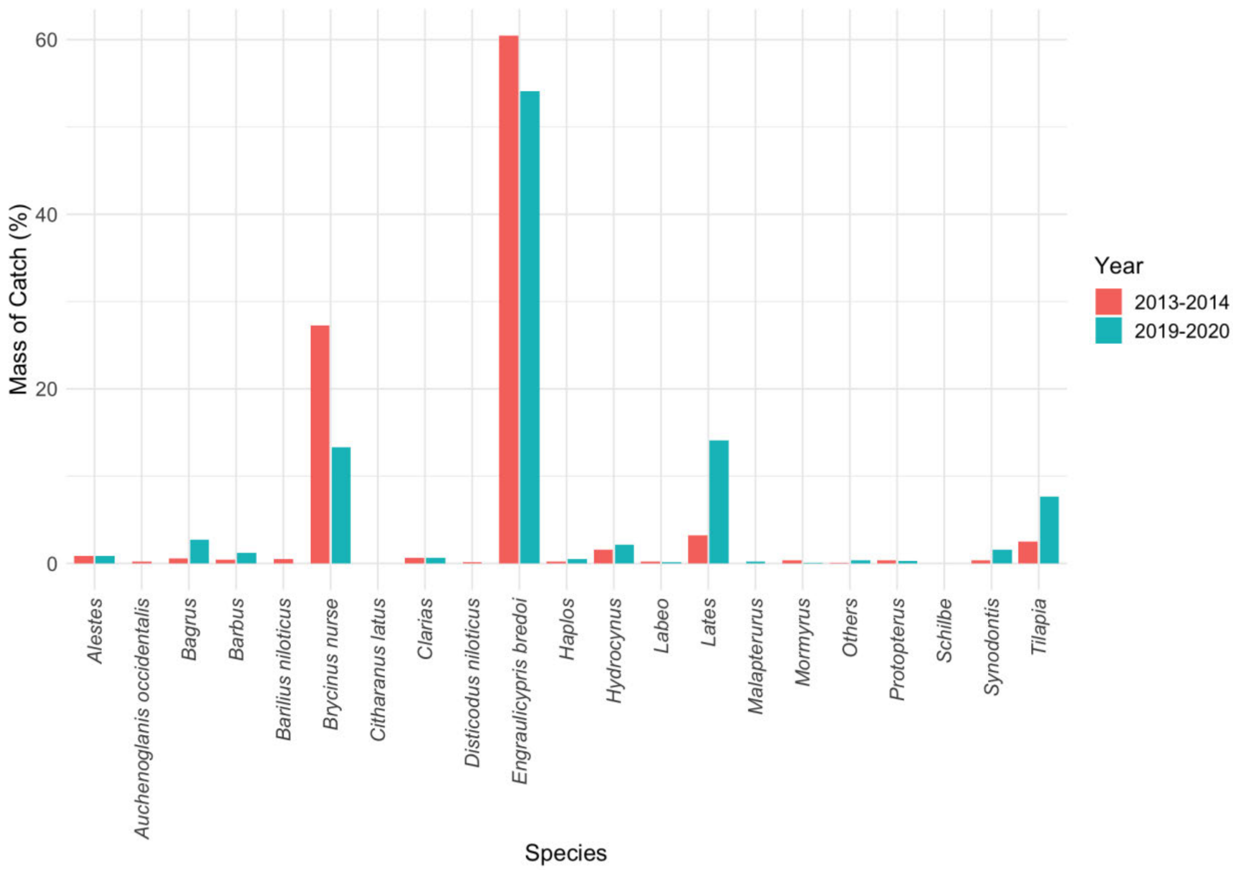


Figure 3- Proportion of the catch by mass per fish taxon in 2013-2014 and 2019-2019 in Lake Albert, Uganda. Data were derived from catch assessment surveys carried out in 2013-2014 and electronic catch assessment surveys carried out in 2019-2020.

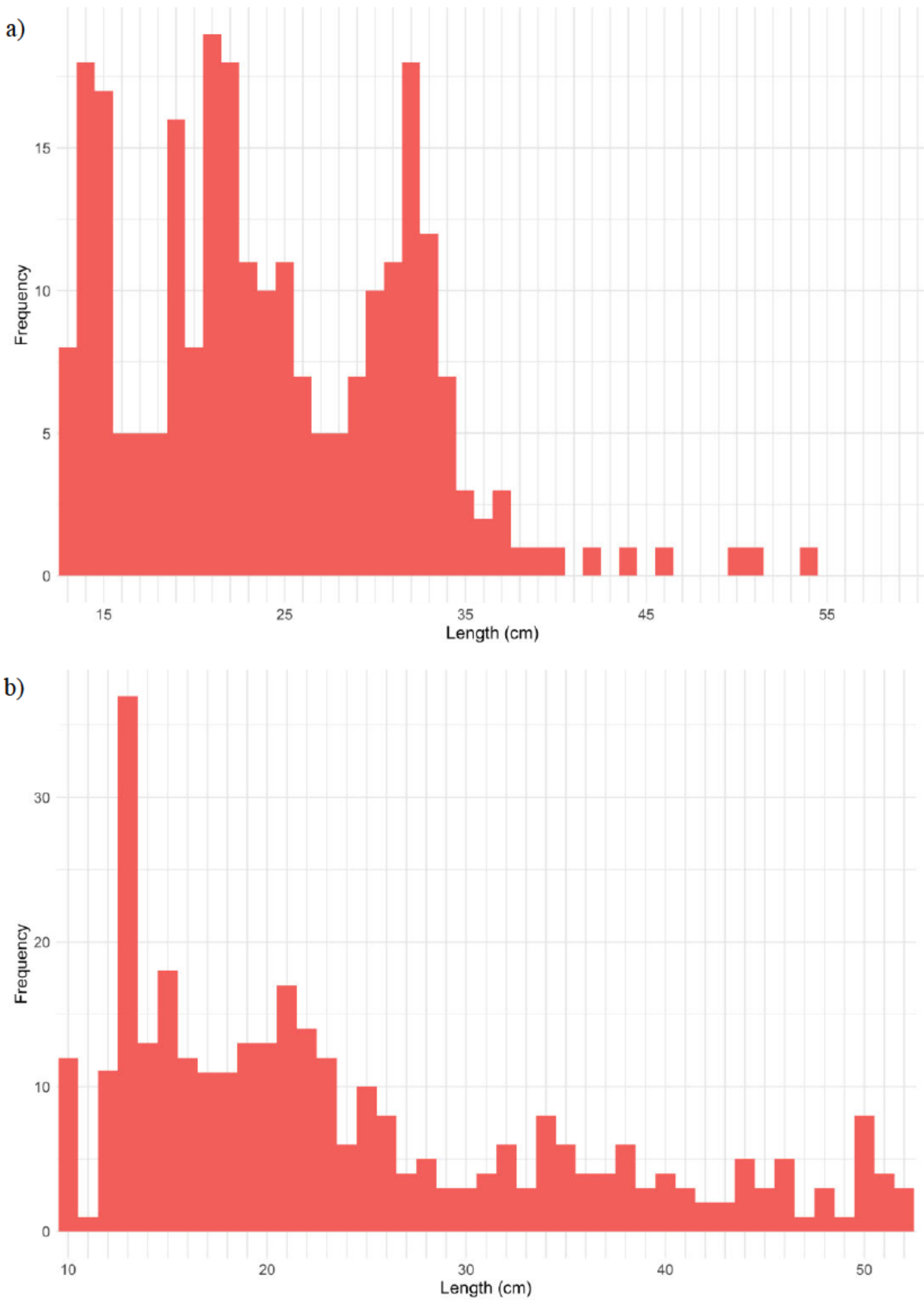


Figure 4 – Length frequencies of two fish species harvested in the fishing industry of Lake Albert, Uganda, in 2013-2014. a) *Alestes baremose*; b) Nile Tilapia (*Oreochromis niloticus*). Data were derived from catch assessment surveys carried out in 2013-2014.

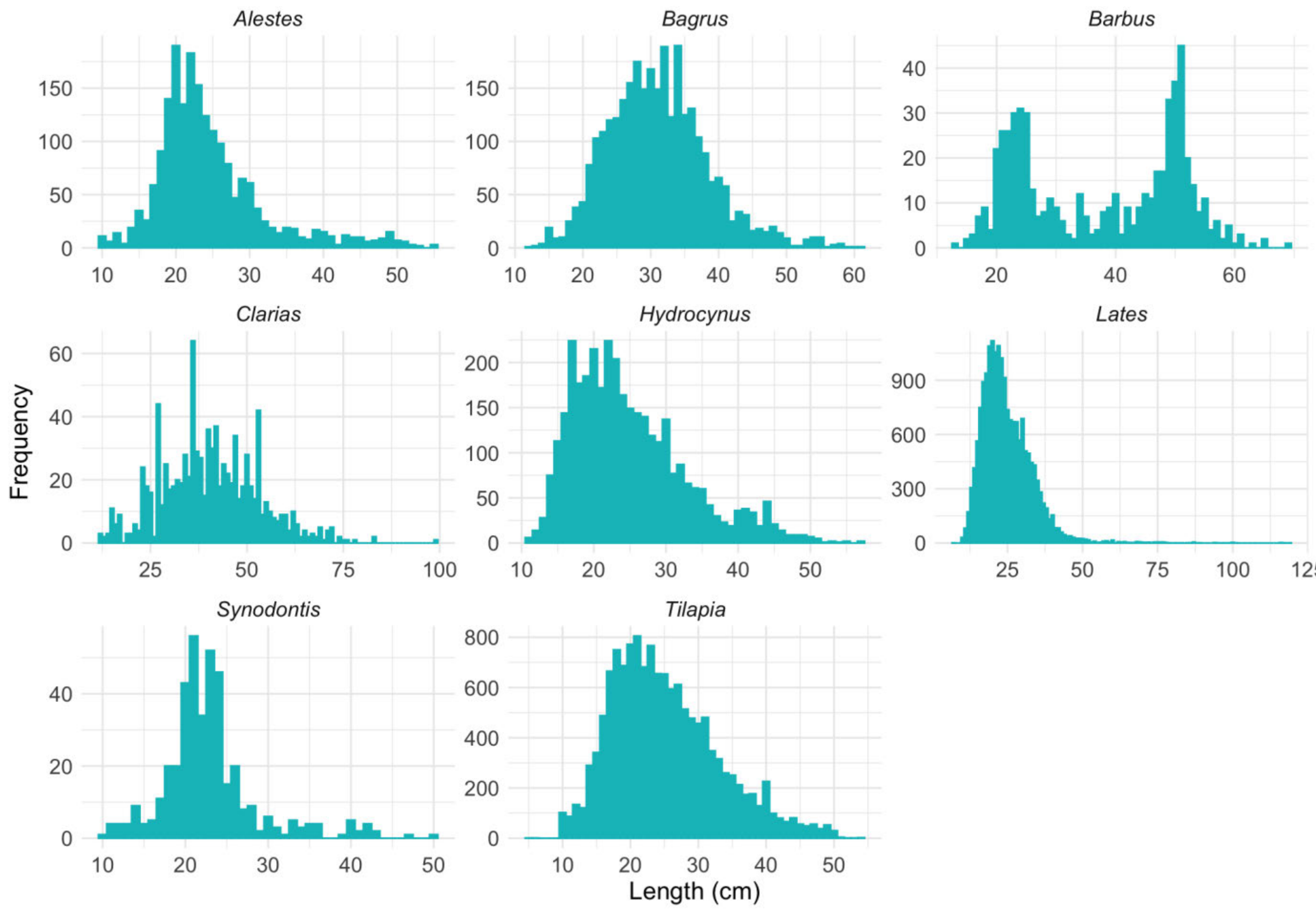


Figure 5 – Length frequencies of eight fish taxa harvested by the fishing industry of Lake Albert, Uganda, in 2019-2020. Data were derived from electronic catch assessment surveys carried out in 2019-2020.

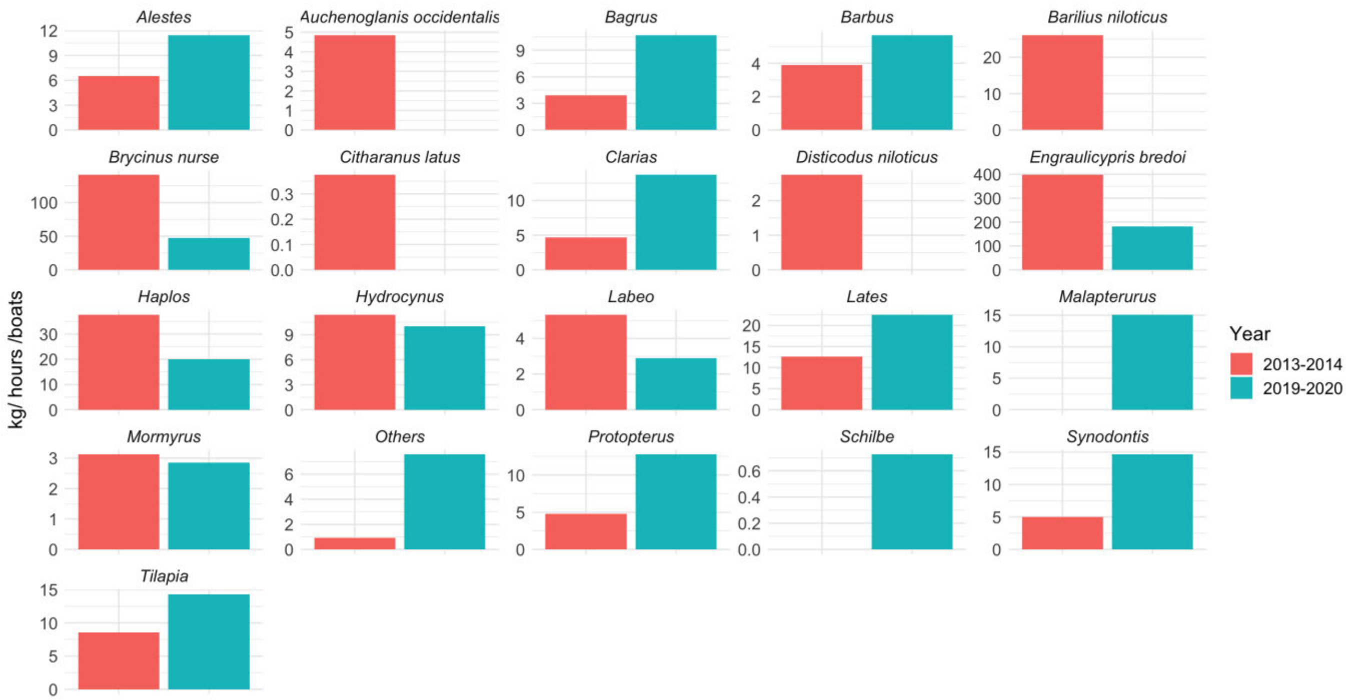


Figure 6 – Fish catch rate in mass (kg) per hour per boat per fish taxon, on average for 2013-2014 and 2019-2020, for the fishing industry of Lake Albert, Uganda. Data were derived from catch assessment surveys carried out in 2013-2014 and electronic catch assessment surveys carried out in 2019-2020.

Figure 7- Effort (time spent on a boat) on average per day per fish taxon, for 2013-2014 and 2019-2020, for the fishing industry of Lake Albert, Uganda. Data were derived from catch assessment surveys carried out in 2013-2014 and electronic catch assessment surveys carried out in 2019-2020.

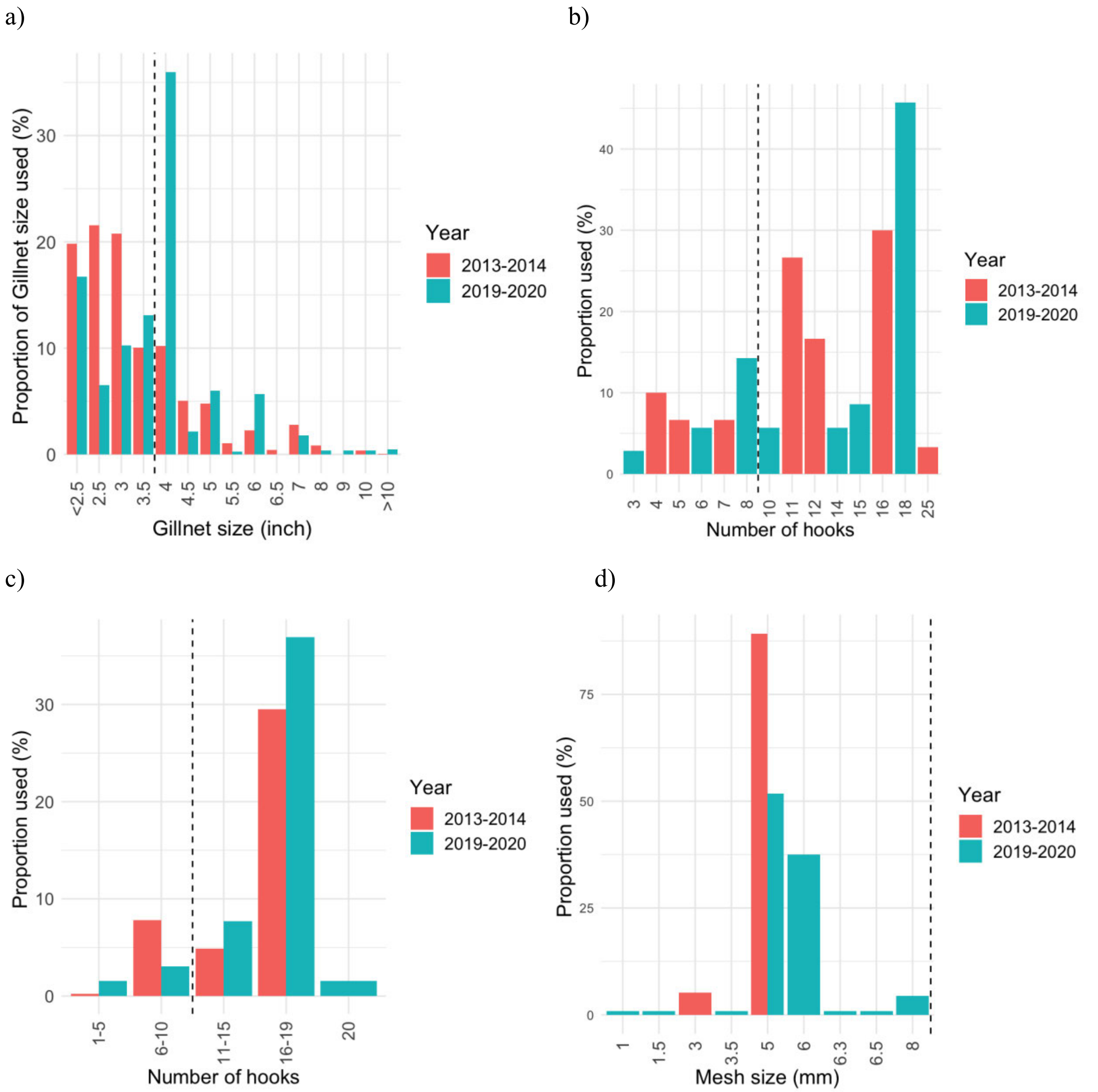


Figure 8- Proportion of fishing gear per mass of catch used in 2013-2014 and 2019-2020, for the fishing industry of Lake Albert, Uganda. Data were derived from catch assessment surveys carried out in 2013-2014 and electronic catch assessment surveys carried out in 2019-2020.

a) gillnets, the right of the dotted line is legal- sized mesh; b) hooks and lines, the left of the dotted line is legal number of hooks; c) long lines, the left of the dotted line is legal number of hooks and d) small seines, the right of the dotted line is the legal-sized mesh (none are recorded as legal).

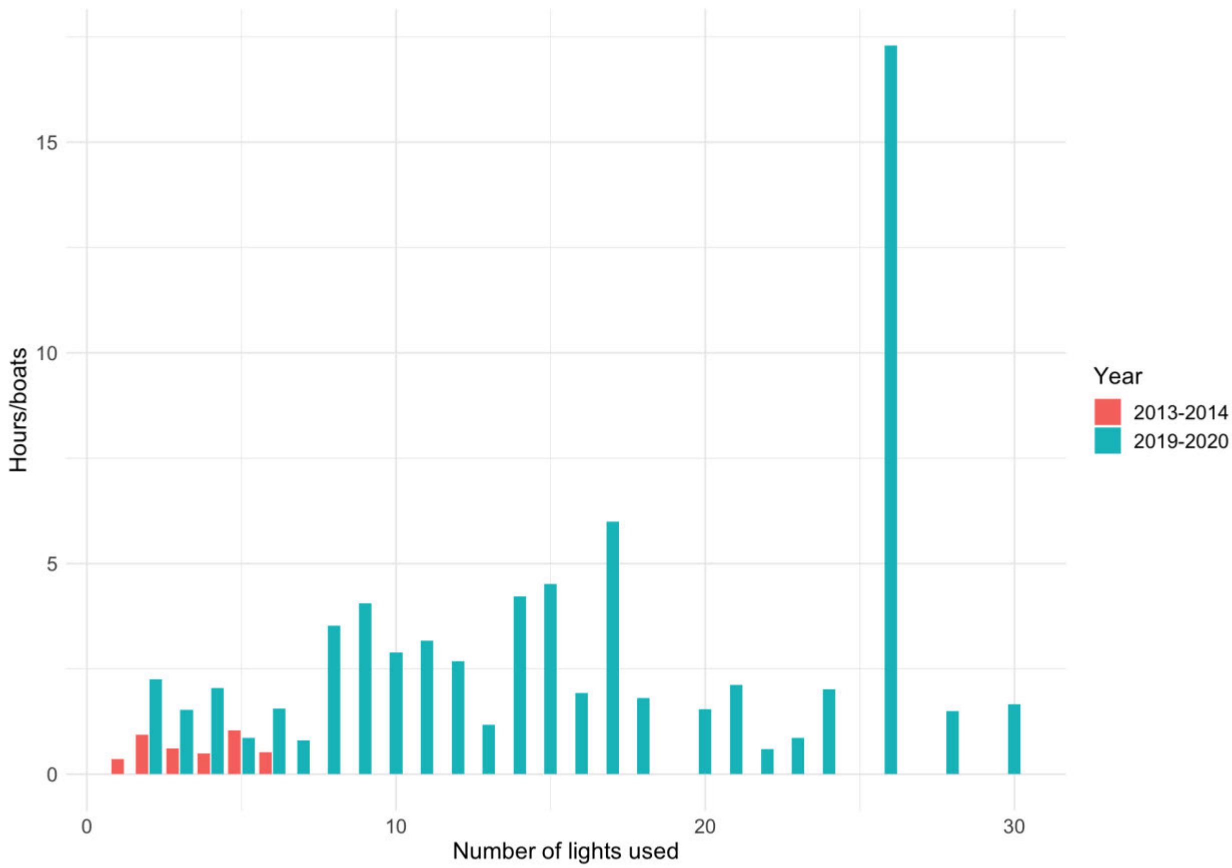
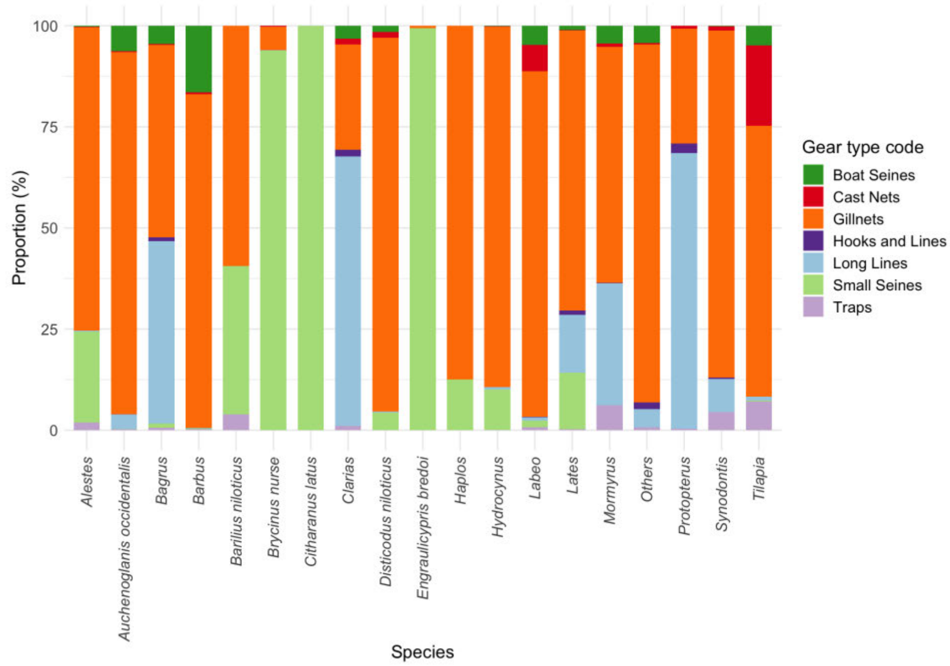


Figure 9 - Effort (time spent on a boat) on average per day for all fish species group using the fishing gear small seines and a certain number of lights, for 2013-2014 and 2019-2020, in the fishing industry of Lake Albert, Uganda. Data were derived from catch assessment surveys carried out in 2013-2014 and electronic catch assessment surveys carried out in 2019-2020.

a)



b)

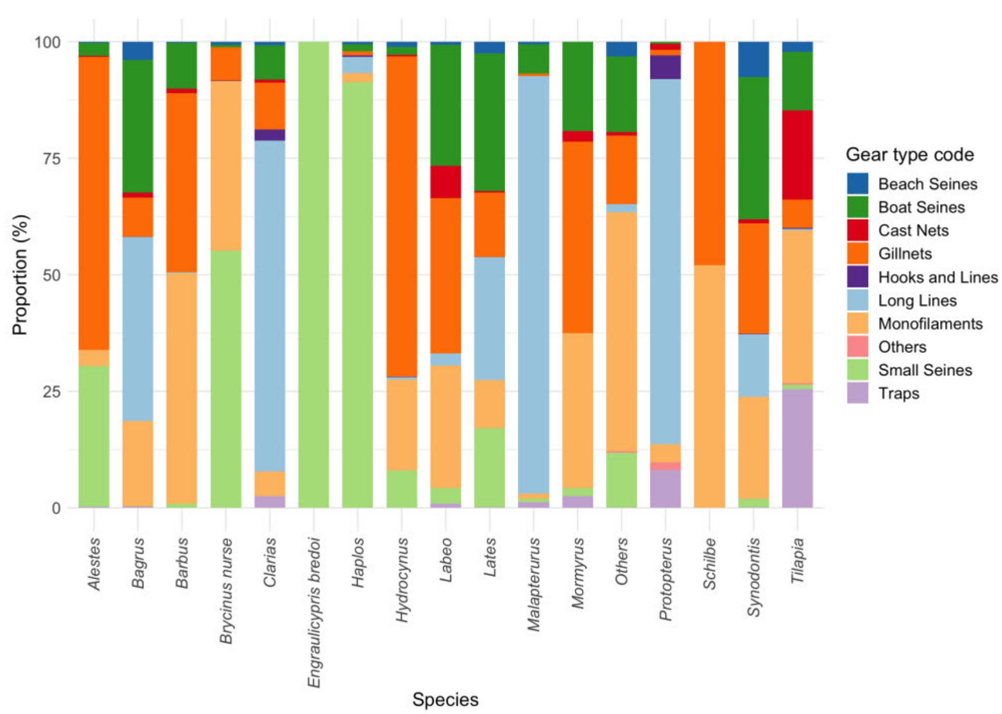


Figure 10 – Comparison of the mass proportion (kg) of legal and illegal fishing gears used to catch each fish taxa in the fishing industry of Lake Albert, Uganda. Data were derived from catch assessment surveys carried out in 2013-2014 and electronic catch assessment surveys carried out in 2019-2020.

a) is 2013-2014; b) is 2019-2020.

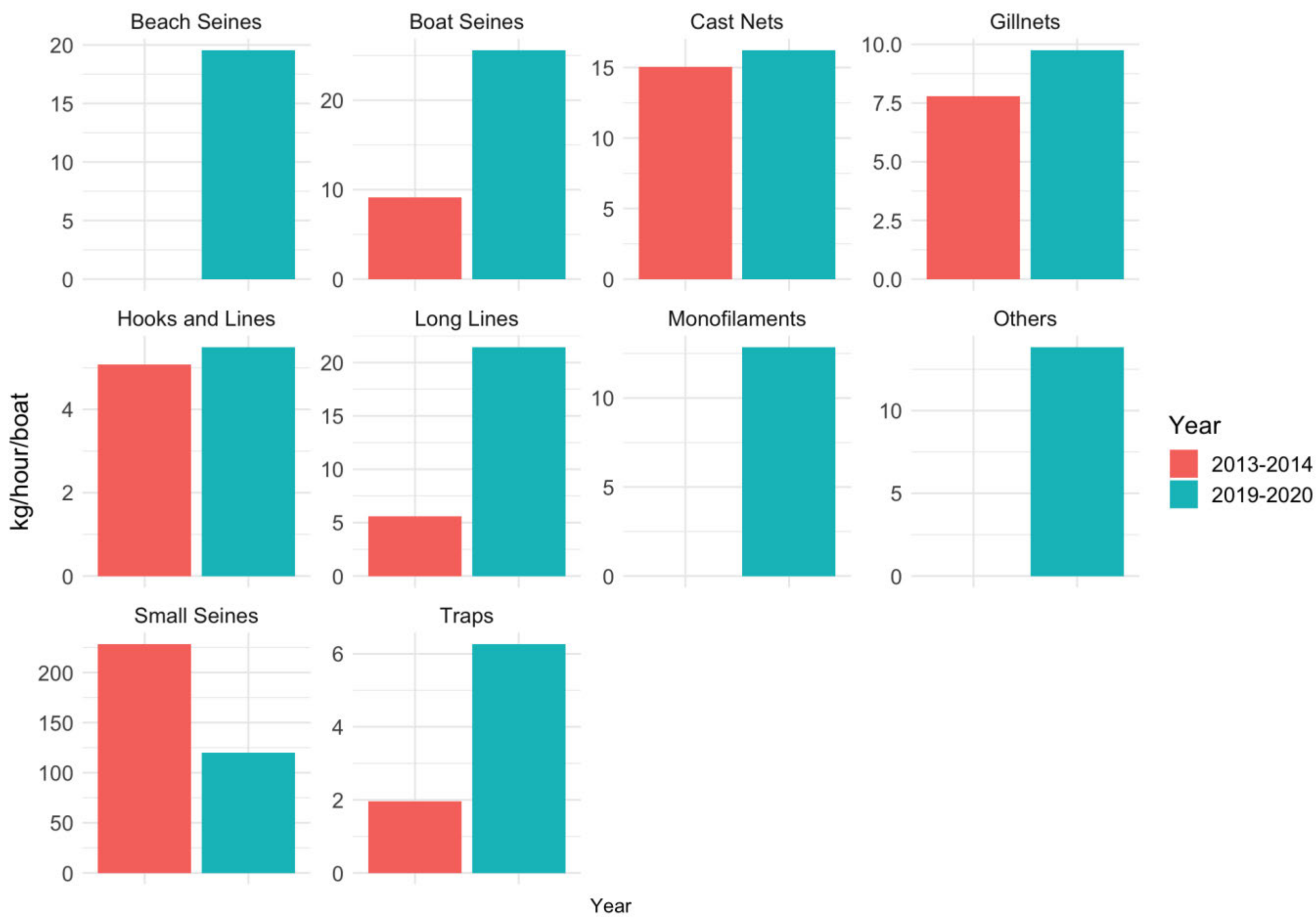


Figure 11- Fish catch rate in mass (kg) per hour per boat for each fishing gear (legal and illegal) used, on average for 2013-2014 and 2019-2020, for the fishing industry of Lake Albert, Uganda. An empty column for a time period means that the gear was not used during that year. Data were derived from catch assessment surveys carried out in 2013-2014 and electronic catch assessment surveys carried out in 2019-2020.

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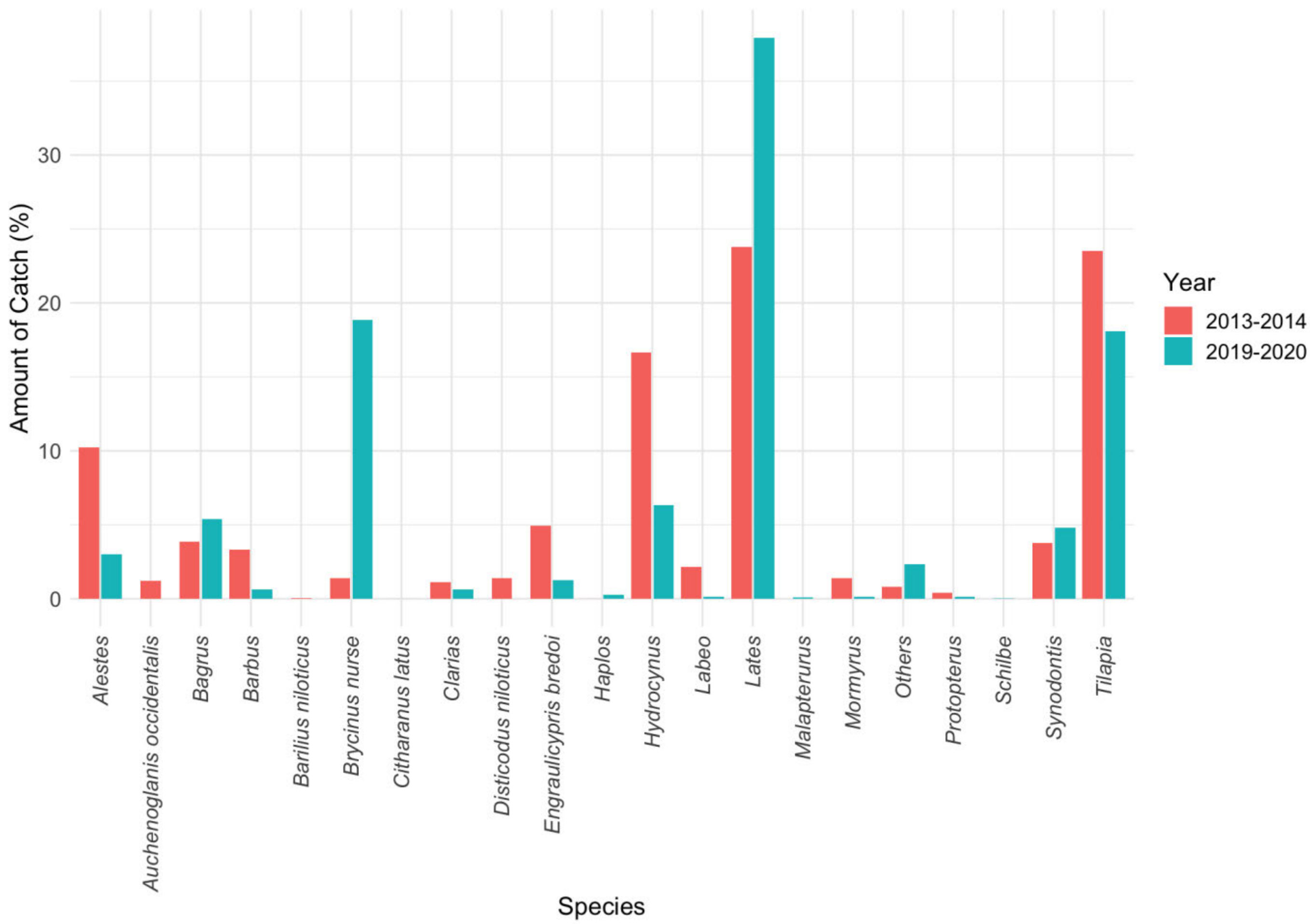
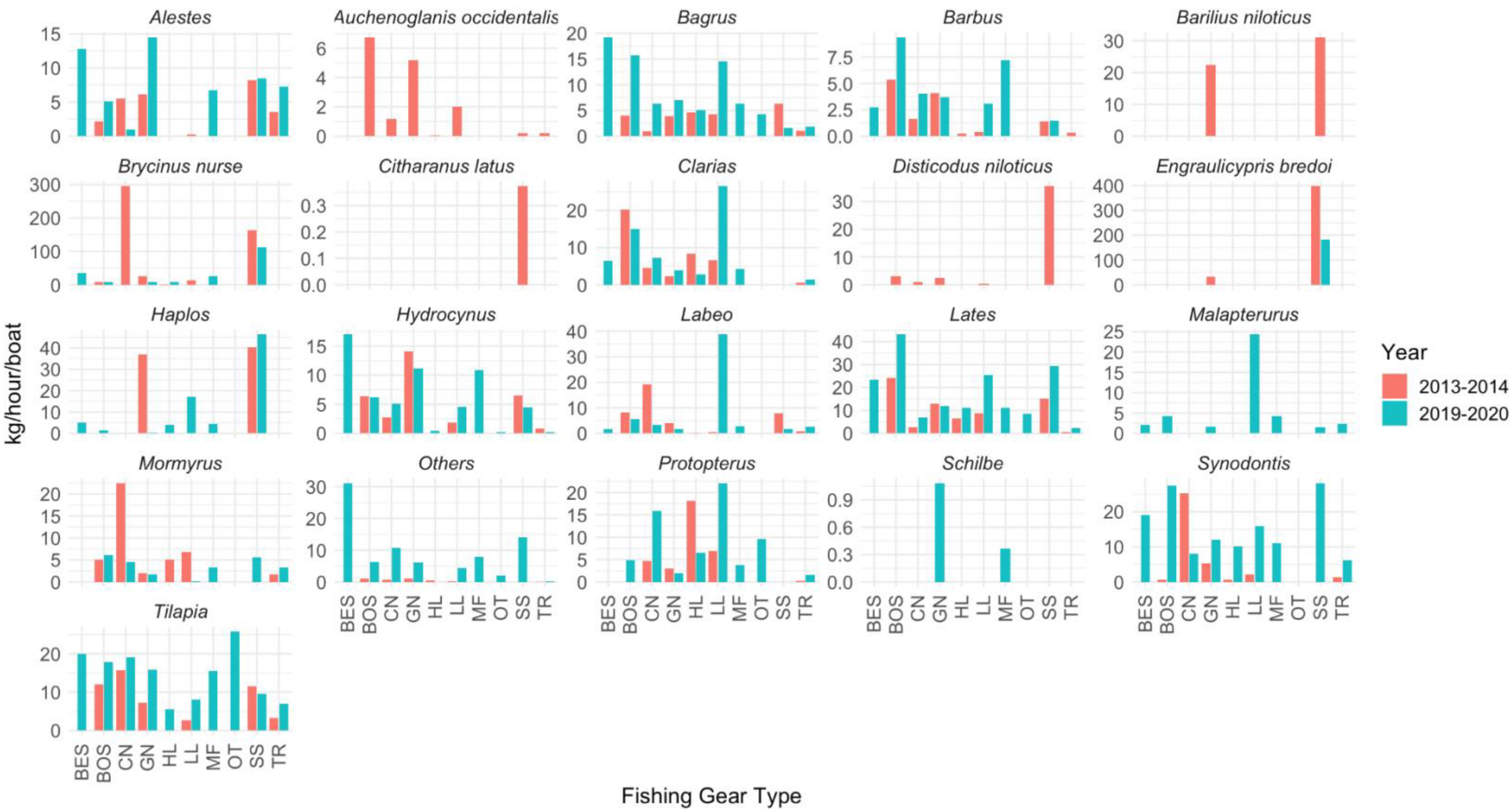
11.Supplementary materials

Supplementary figure 1 - Proportion of the catch (in number of fish or number of buckets) per fish taxon in 2013-2014 and 2019-2019 in the fishing industry of Lake Albert, Uganda. *B. nurse* and *E. bredoi* are presented in number of buckets. Data were derived from catch assessment surveys carried out in 2013-2014 and electronic catch assessment surveys carried out in 2019-2020.



Supplementary figure 2- Fish catch rate in mass (kg) per hour per boat for each fishing gear (legal and illegal) used and for each fish taxon, on average for 2013-2014 and 2019-2020, for the fishing industry of Lake Albert, Uganda. An empty column for a time period means that the gear was not used during that year. Data were derived from catch assessment surveys carried out in 2013-2014 and electronic catch assessment surveys carried out in 2019-2020.



Supplementary table 1- Classification of the fish catch recorded in 2013-2014 in the different species group (taxa) used in 2019-2020 in this study, and the importance of each fish species into a taxon and in the total catch mass (kg) for the fishing industry of Lake Albert, Uganda. Data were derived from catch assessment surveys carried out in 2013-2014.

Species	Group	Proportion of total weight caught (%)	Proportion of species group caught (%)
Alestes baremose	*Alestes*	0.83	99.07
Alestes macrolipidotus	*Alestes*	0.01	0.93
Bagrus bayad	*Bagrus*	0.50	90.10
Bagrus docmac	*Bagrus*	0.06	9.90
Barbus bynni	*Barbus*	0.43	99.75
Barbus perince	*Barbus*	0.001	0.25
Clarias gariepinus	*Clarias*	0.68	100.00
Haplochromines	*Haplos*	0.24	100.00
Hydrocinus forskali	*Hydrocinus*	1.61	100.00
Labeo coubie	*Labeo*	0.01	6.50
Labeo forskali	*Labeo*	0.03	14.67
Labeo horrie	*Labeo*	0.18	78.84
Lates macrophatlmus	*Lates*	0.55	17.17
Lates niloticus	*Lates*	2.68	82.83
Malapterus electricus	*Malapterus*	0.14	100.00
Gnathonemus longibarbis	*Mormyrus*	0.01	5.47
Gnathonemus victoriea	*Mormyrus*	0.01	5.31
Hyperopisus bebe	*Mormyrus*	0.02	9.55
Mormyrus anguilloides	*Mormyrus*	0.04	22.02
Mormyrus kanume	*Mormyrus*	0.11	51.97
Mormyrus macrocephalus	*Mormyrus*	0.005	2.42
Mormyrus niloticus	*Mormyrus*	0.01	3.26
Protopterus arthiopicus	*Protopterus*	0.35	100.00
Synodontis frontosis	*Synodontis*	0.04	10.34
Synodontis afrofischeri	*Synodontis*	0.17	44.54
Synodontis schasll	*Synodontis*	0.16	42.62
Synodontis victoriea	*Synodontis*	0.01	2.50
Oreochromis leucostictus	Tilapia	0.42	18.13
Oreochromis niloticus	Tilapia	1.92	81.84
Tilapia galilaea	Tilapia	0.0003	0.01
Coptodon zillii	Tilapia	0.0003	0.01
Brycinus nurse		27.23	100.00
Engraulicypris bredoi		60.47	100.00
Auchenoglanis occidentalis		0.23	100.00
Barilius niloticus		0.47	100.00
Citharanus latus		0.00	100.00
Disticodus niloticus		0.17	100.00
Others		0.04	100.00