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THE DEVELOPMENT AND EFFECTS OF THE GILLNET MESH SIZE REGULATION ON LAKE VICTORIA, UGANDA. CASE OF THE NILE PERCH FISHERY

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ABSTRACT

Prior to the introduction of Nile perch various selectivity studies have been undertaken to establish the minimum mesh size regulation of gillnets ranging from 5 inches to the currently emphasized 7 inches as per the 2009 council of ministers' directives. However, few studies on the minimum mesh regulations have been carried out to show how the fishery has developed in relation to the regulation. Therefore, the study employed various statistical tests in SAS to relate development and effect of gillnet mesh size effect on the landed catch by fishers based on craft using engines (motorized) and paddles. Using Catch assessment studies, the data were sorted according to craft using gillnets resulting in 10800 samples for motorized craft and 8021 cases for paddled craft over a period of 8 years adjusted to a linear scale to represent a period from 2005 to 2015. Study findings indicated the growing use of motorized craft over the past decade with 90% of their nets above the minimum mesh size 5 with a concentration on mesh size 6 since 2005, and a growing increase in the use of 5.5 inches since 2010. Their estimated catches, however, indicated declines; from 30kg of Nile perch per boat sampled in 2005 to 19 kg in 2015 and a corresponding decline in CPUE from 3 kg per hour to less than 2 kg per hour in 2015. This in turn has led to an ever-increasing price premium with the large sized fishes earning 4 times the price per kilogram compared to the small sized fishes. This was not the case with the paddled craft who were considered uncommon in the fishery. However, there was a steadily growing composition of meshes below the minimum from 31% in 2005 to 69% in 2015. This paper therefore, provides a baseline on understanding how imposing minimum size regulations affects harvesting patterns in the fishery and fisher's behaviour as they exclusively target large sized species. Therefore, management decisions on future selectivity studies should consider societal and economic implications that might trigger situations such as size selective fishing.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

BMU	Beach Management Units
CAS	Catch Assessment Survey
CPUE	Catch per Unit Effort
DFR	Directorate of Fisheries Resources
FS	Frame survey
IFMP	Implementation of fisheries Management Plan
LVEMP	Lake Victoria Environmental Management Project
LVFO	Lake Victoria Fisheries Organization
NaFIRRI	National Fisheries Resources Research Institute
SOPs	Standard Operating Procedures

1 INTRODUCTION

1.1 Background

Gillnetting is of special interest for artisanal fisheries because it is does not demand large investment. Specialised vessels are not needed, and a small crew can be used when using a relatively small number of gillnets (Brandt, 1984).

The gillnet is the most important and widespread fishing gear in Lake Victoria Uganda where it makes up 30% of the total fishing gears followed by longlines (22%) and small seines (15%) (DFR, 2014). There are three types of gillnets which include the monofilament, the twine twisted nylon, and the hand woven. Gillnets have different mesh sizes and range in length from 20 to over 100 m. In Lake Victoria the size of the nets depends on the fisher's choice (Okeyo, 2014). One vessel with a crew of at least three carries a total of up to 100 or more gill nets tied together. Gillnets with smaller mesh sizes are spread in the nearshore areas up to 20 m depth to target Nile tilapia and the bigger net sizes are set offshore in deep waters up to above 20 m deep areas to target Nile perch. Gill-nets are set late in the afternoon and hauled at dawn the next day (Okeyo, 2014).

Gillnetting is practiced around the world and can be considered as a typical small-scale fishery method which can be very effective with a few nets (Brandt, 1984). They are selective with each mesh size catching a specific size range of a particular species (Ogutu-Ohwayo, *et al.*, 1990) and usually have less environmental impacts than active fishing gears (Uhlmann & Broadhurst, 2015).

The use of gillnets on Lake Victoria started in the Kenyan waters of Lake Victoria in 1905 targeting two indigenous tilapia species, *Oreochromis esculentus* and *Oreochromis variabilis*, other large species like catfishes, mormyrids and lungfish were also caught (Fryer, 1960).

Commercial fishing was caused by a boom in trade opened during the construction of the East African railway which opened markets for trade (Okeyo, 2014). Decline in stocks of *Oreochromis esculentus* which of the formed most important part of the commercial fisheries on Lakes Victoria and Kyoga was caused by the increasing fishing pressure on the indigenous tilapia species. This led to a decline in catches from about 25 to 5 fish per net leading to the recommendation to introduce a 5 inch (127 mm) minimum mesh size (Graham, 1929).When the mesh size regulation was removed, there was a shift to smaller meshes which targeted immature fish leading to the collapse of the fishery (Ogutu-Ohwayo, *et al.*, 1998).

The introduction of Nile perch exposed the lake to various ecosystem changes including the major changes in fish stocks in the lake where over 60% of the 500 and so native species in the Lake are believed to have been exterminated (Witte, *et al.*, 1992; Taabu, 2014).

It should be noted that the introduction of Nile perch was also followed by a dramatic increase in the total fish landings from about 100,000 tonnes in 1980 to 500,000 tonnes in 1989 (Reynolds, *et al.* ,1995) and one million tonnes in 2010 (Marshall & Mkumbo, 2011; Taabu, 2014) in Lake Victoria and a corresponding to the increase in fishing effort.

However, total biomass of Nile perch as measured by the hydro acoustic survey decreased from 1.4 million tons 92% of total biomass in Lake Victoria in the early 1990s to about 250,000 t (14.9%) in the mid-2000s and has since remained constant (Mkumbo and Marshall, 2011;

Taabu, 2014). In contrast, the only native species to flourish after the introduction of Nile perch is the pelagic cyprinid Rastrineobola argentae locally known as Mukene which rose from a relatively insignificant commercial species in the 1960's to become the largest component (> 50%) of the catch by weight in the total ladings since 2005 (Taabu, 2014).

In addition to the decline in Nile perch stocks, Mkumbo and Marshall (2011) provided data that indicated a reduction in the proportion of fish > 50 cm in the catch from 65% in the period 1980 to early 2000s to 15-20% by the mid 2000's. Nile perch below 50 cm TL is also reported to make up to 40% of the total landings recorded in the catch assessment surveys (LVFO, 2014). Therefore, the decline of the large sized Nile perch in the catches is a cause for concern.

Efforts put by the Lake Victoria Fisheries Organization to reduce fishing pressure on Nile perch among others have been set towards eliminating gears that are attributed to harvesting juveniles, the small sized gillnets of less than 5 inches (Kariuki, 2012).

Besides the frame survey, few studies nationally and regionally have attempted to describe or quantify the development and effects of gear regulations, including minimum mesh size regulation on Lake Victoria. Frame surveys have documented a significant (> 90%) increase in craft using gillnets with meshes above the minimum mesh size between 2004 and 2014 (DFR, 2014) but this still has not eased in the reported declining stocks of large sized Nile perch catches.

The study, therefore, sets to quantify the development and the effect of the gillnet mesh size regulation, explaining the probable causes in the given trends using the fishermen's landing with respect to the fishing gears (gillnets) of the sampled boats from the Catch Assessment surveys.

1.2 The Gillnet mesh size regulation fisheries on Lake Victoria

Management decisions on the Lake Victoria fishery began with the native gillnet fishery of *Oreochromis variabilis and Oreochromis esculentus,* where a minimum gillnet mesh size regulation of 5 inches was adopted due to intensive fishing pressure in the late 1920s by nylon gill nets (Graham, 1929). A minimum gillnet mesh size regulation to protect the indigenous Tilapines was set at 5", which was later adopted to protect the large exotic predatory species, Nile Perch (*Lates niloticus*). This was done through studies by Ogutu-Ohwayo *et al.* (1990); Schindler *et al.* (1997) on gillnet selectivity studies based on experimental studies.

The advent of gears (gillnets) started on the Lake started in the Kenyan waters in 1905 targeting two indigenous tilapia species, *Oreochromis esculentus* and *Oreochromis variabilis*, other large fishes like catfishes, *mormyrids, propterus aethiopicus* were also caught (Fryer, 1960). Increasing fishing pressure on the indigenous tilapia species led to a decline in catches from about 25 to 5 fish per net (Graham, 1929) and reduction in fish size. This sparked management decisions on the Lake Victoria fishery where a minimum gillnet mesh size regulation of 5 inches was adopted due to intensive fishing pressure in the late 1920s by nylon gill nets (Graham, 1929). This was to protect the indigenous juvenile Tilapines and the regulation was later adopted to protect the large exotic predatory species, Nile Perch (*Lates niloticus*).

In 1947, a Lake Victoria Fisheries service (LVFS) was established to enforce the gillnet mesh size, however, local communities were not subjected to this law because they thought that they would disapprove of it as they would find it legitimate (Onyango, 2015).

Much of the management issues on the lake where unclear since then until the formation of the Lake Victoria Fisheries Organisation (LVFO). This was established through a convention agreed by the East African Community partner states (Kenya, Tanzania and Uganda) to coordinate and harmonize efforts towards sustainable utilization of the Lake Victoria. The organizations activities were then carried out under five programs and implementation of the gill net minimum mesh size regulation was one of the activities that was indicated under the Fisheries management program which is one of the five programs.

Besides that, implementation of the regulation has been reported in various policy documents such as the 2004 Regional Plan of Action to deter Illegal, Unreported and unregulated fishing (RPOA IUU), the 2005 strategy and action plan for monitoring, control and surveillance and the 2009 LVFO Council of Ministers directives for improved management of the fisheries of Lake Victoria.

However, the circumstances that led to adopting the 5" mesh size as the lower limit in subsequent years for the management of Nile Perch are not clear (Nunan, 2013; Taabu, 2014). Studies by (Msuku *et al.*, 2011) indicated that the 5" mesh size was dominated by immature catches (≥ 80%), therefore emphasis on recommending a shift from 5 to 7 by all member states (Kenya, Tanzania and Uganda).

This therefore was difficult to adjust the minimum mesh size from 5 inches to 7 especially in Uganda where frame surveys as well as catch assessment studies still consider the minimum legal mesh of gillnets as 5 inches. (LVFO, 2014), making the recommended of the 7-inch mesh size regulation redundant and unclear to the fishers' community.

1.3 Impact of gillnet regulations

Gillnet regulations are based on the notion that gillnets are usually very selective where certain catches of certain fish sizes correspond well to the chosen mesh size (Cochrane & Garcia, 2009). They are a form of measure based on biological fisheries management whose purpose is to protect young fish, spawners and habitats (Arnason, 2009) and they work efficiently under strict command and control management. Heikinheimo *et al.* (2006) analysed the impact of mesh size regulation of gillnets for the pikeperch fishery in Finland where minimum mesh size adjustment from 43-45 mm to 50 mm.They reported increased spawning population and protection of juveniles had positive effects but it would take the fishery 8 years to achieve the net present benefits.

A similar study by Msuku *et al.* (2011) on effectiveness of the gillnet regulation done in Tanzania recommended the 7-inch mesh compared to the 5-inch mesh which was earlier considered by (Ogutu-Ohwayo *et al.*, 1998).

However, a study on the effectiveness of the LVFO council of ministers' directives indicated that all fishers were aware about the directives but raising of the minimum legal mesh size from 5 to 7 inches was difficult due to the low catchability (NaFIRRI, 2012).

Establishing minimum mesh sizes predisposes fish stocks to size-selective harvesting where large individuals of a population are preferentially targeted (Fenberg & Kaustuv, 2007).

Various studies (Fenberg & Kaustuv, 2007; Kendall & Quinn, 2013; Hutchings & Baum, 2005) have raised concerns that size selective harvesting has negative effects on the demography, life history and the ecology of the large species. Selective exploitation can cause adverse ecological and evolutionary changes in wild populations and also affect sex ratios in the exploited population (Kendall & Quinn, 2013).

Species that have been subjected of size-selective harvesting for decades have been reported to adapt by reduction in body sizes, skewed sex ratios and changed behaviour on breeding grounds (Fenberg & Kaustuv, 2007).

Size selective fishing has also been extended to a number of subsistence and artisanal fisheries where harvesting has been given way to commercial exploitation (Fenberg & Kaustuv, 2007) due to expansion of markets including domestic and international markets. Under heavy harvesting pressure, even when it is not necessarily size selective, a truncation of the largest (oldest) size classes of a population is expected (Trippel, 1995; Fenberg & Kaustuv, 2007).

Therefore, it can be difficult to distinguish the effects of overharvesting per se from size-selective harvesting just by comparing size-frequency distributions.

It should be noted that management systems in small scale fisheries (including mesh size regulations) have been based on recommendations and models in developed countries (Kolding & Zwieten, 2011), some of which have faced selective fishing challenges. Therefore, an increasing number of species worldwide have been subjected to the effects of size selective harvesting including majority of small scale fisheries. However, this problem, is not recognised in most management plans for fish and marine invertebrates that are still mandated to minimum mesh size gear restriction (Fenberg & Kaustuv, 2007).

1.4 Objectives

The main objective of the study was to assess the development and effects of the gillnet mesh size regulation on the Nile perch Lake Victoria, Uganda. The specific objectives were:

- To identify and analyse the trends in gillnet mesh size composition in the Nile perch fishery on the Ugandan part of the Lake Victoria.
- To identify the probable causes of the given scale and trend in mesh size use in the Nile perch fishery.
- To identify the probable effects of the gillnet mesh size regulation on the Nile perch fishery on Lake Victoria.

2 MATERIALS AND METHODS

2.1 Study Area

The study focuses on 54 fish landing sites located along 15 Lake Victoria riparian districts in Uganda as illustrated in Figure 1. The Catch Assessment sampling sites represent 10% of the total landings in Uganda, therefore the catch statistics are based on surveys carried out at these landing sites.

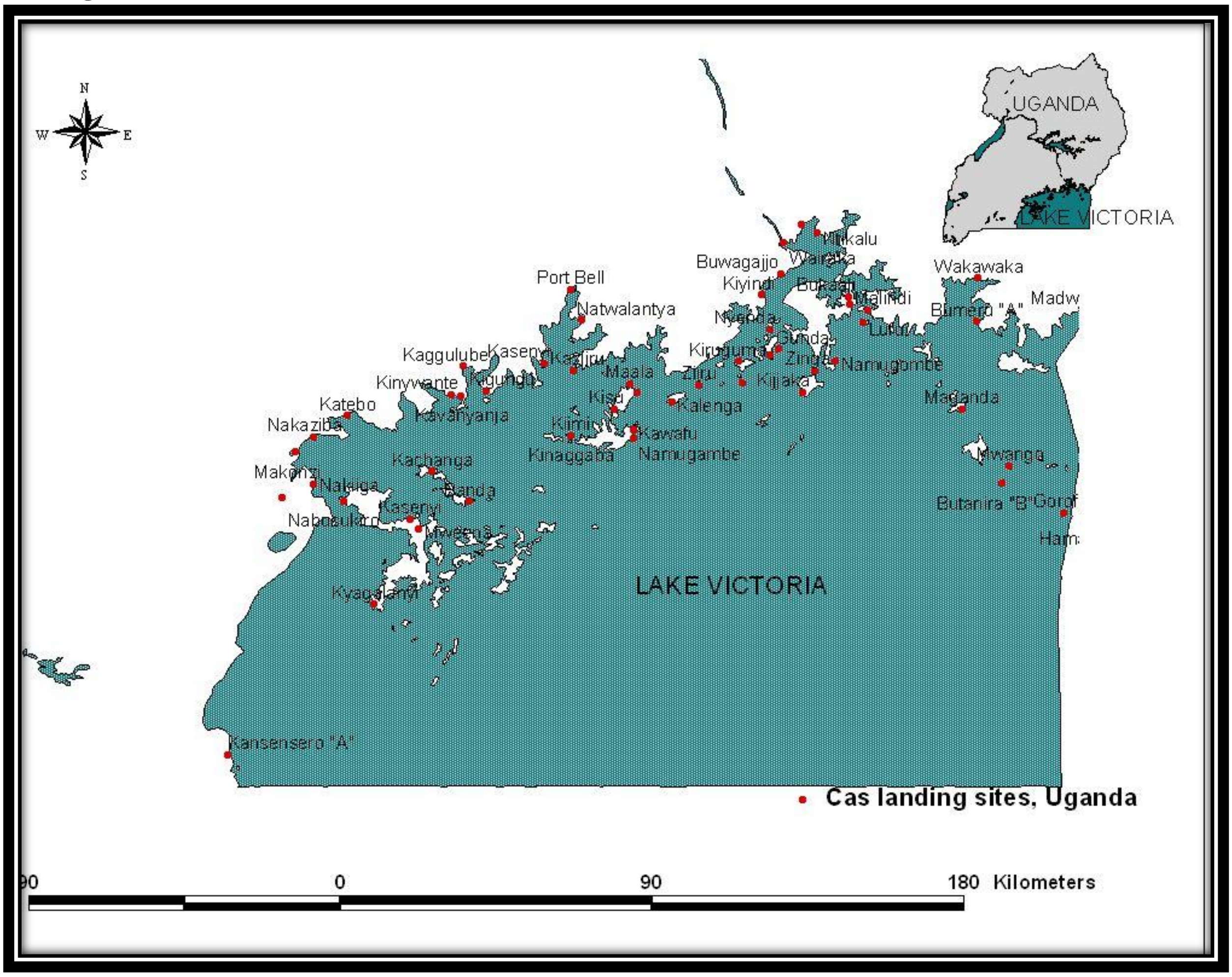

Figure 1: Catch Assessment Survey landing sites (source: NaFIRRI)

2.2 Available data sources

The data used in the study originated from the regionally organized Frame surveys (FS) and Catch Assessment Surveys (CAS).

Both studies are carried out under the coordination of the Lake Victoria Fisheries Research Organisation (LVFO) using regionally harmonized data collection forms.

2.2.1 Frame survey data

The frame survey data were obtained from the LVFO Frame Surveys reports from 2004 to 2014. The survey is conducted biennially to determine the overall fishing factors operating at all landing sites around Lake Victoria.

Before the survey is conducted, a planning meeting by the National Working Group (NWG) for frame survey is conducted to identify supervisors and enumerators who are mainly selected from the beach management units (BMUs) located at the landing sites. These undergo a one-day training session on how to collect data using standard training manuals developed from the Frame survey standard operating procedures.

During the surveys, enumerators directly record data on landing facilities and distribution of fishing effort for all landings using the regionally harmonized data collection forms and criteria for data collection according to the Lake Victoria Standard Operating Procedure.

The collected data are then entered and stored into Server based EAFish Information System/Database of LVFO and later analysed and reported. Therefore, the data obtained from the reports consists of these variables;

- Year
- Number of craft per boat propulsion
- The number of craft per propulsion mode targeting different species

This was done to establish which effort group was dominant in the Nile perch fishery for further analysis. Effort group in the study is defined as craft using gillnets in the different propulsion modes, for instance, craft using outboard engines, paddles or sails.

2.2.2 Catch assessment data

CAS data were collected from a total of 54 landing sites representing 10% of the total landings on the Ugandan side of the lake as shown in Figure 2. These landing sites are the primary sampling Units (PSU's) selected randomly with probability proportional to size (PPS) at the beginning of the surveys in 2005, where size referred to the total number of craft at the landing site.

Like the frame surveys, enumerators were identified from the BMUs and trained using harmonized training manuals form LVFO. During the survey, data on Craft-gear types, fish landings, and the ex-vessel price of fish per kilogram were recorded using the LVFO harmonized data collection form. The maximum sample per day was set at 20 craft. Each month during which the survey was carried out, sampling was done on four days, divided into two consecutive days in the first and third weeks of the month. From the data variables that were used for analysis included;

- Date: The date, month and year for which the data was sampled. The analysis aggregated data into year estimates for each effort group.
- Vessel propulsion: This indicated if a craft was using an engine, paddled or sailed.
- Gear: the name or code of the gear which was used to catch the species. The study limited its scope to gillnet.

- Gillnet size: During data collection, the number of units used by a craft are recorded corresponding to the gillnet mesh size provided for in the excel data entry template. Mesh sizes range from less than 2.5 inches to 10 inches
- Fish numbers and weight per fishing craft.
- Fish price data corresponding to the weight. The price recorded is per kilogram irrespective of the weight of fish.
- Vessel length.
- Hours fished.

Data that were available for analysis was collected for the years 2005, 2006, 2007, 2008, 2010 and 2011 funded by the IFMP project, 2014 to 2015 funded by the LVEMP 2 and coordinated by the LVFO.

2.3 Analysis of data

Before the analysis, the primary data were organised by sorting out craft that used gillnets and the sorted data were saved in a new sheet for further analysis.

The data were then organised in groups based on their mode of propulsion (engines, paddles or sails) and using gillnets with different mesh sizes. The study considered boat propulsion mode because it influences the gillnet mesh size, how far from the shore the boat can fish, and the gillnet mesh size used.

2.3.1 Analysis of the trends in the gillnet mesh size composition in the Nile perch fishery

The trend in gillnet mesh sizes for the sampled years was obtained through:

- Sorting the data into different vessel groups analyzing separately.
- Proportions of meshes in each craft was calculated as; Number of gillnets in each given mesh size / total number of nets in a craft.
- The individual craft proportions were combined into year proportions to obtain the average of gillnet mesh size composition for craft in given groups.
- The data generated were then plotted into interpretable graphs in excel to show trends in gillnet mesh size use and compared to the readily available trend according to the Frame survey.

2.3.2 Causes of the trends in the gillnet mesh size composition in the Nile perch fishery.

Nile perch length composition was obtained from three data variables that is; weight of the fish in kilograms, number of fish and Mesh size composition of an individual craft and these were aggregated in years to analyse for each effort group. It should be noted that some craft had combinations of different mesh sizes. In those cases, the mesh size with the high number of nets was considered and tallied with the length to be calculated.

To obtain the length of fish in the different gillnets, the average weight of Nile perch caught by a specific mesh size in each craft was obtained by dividing the weight of the catch by the total number of Nile perch specimens.

The average weight per craft was then converted into an average length, using the length - weight relationship formula given by W = aL^b where W is the weight of the fish in grams, and L is the total length of fish in cm. The constants a= 0.0042 and b=3.26 as the formula parameters (LVFO, 2008), the same length-analysis for commercial catches was used by (Msuku *et al.*, 2011) for the Tanzanian data.

The length values generated were then analysed in the SAS © statistical software using various modelling approaches (*full results shown in Appendix1 and Appendix 2*) to determine the effect of gillnet mesh size in the different vessel categories (motorised and paddled) on the length of fish.

The effect of mesh size on the length of the fish was obtained through the GLM formula demonstrated as,

$$L_{it=AL_{it}} + \beta \qquad (1)$$

Where L_{it} is the resultant Length effect at landing i in a given time t
AL_{it} the average Length at a time at landing i in a given time t (Year*Month)
β is the effect of mesh size on length

The combined mean length for all the years was then obtained from Excel by dividing the total resultant length by the number of years (8 years from 2005 to 2015 with exception of 2009, 2012 and 2013). A graph showing Length of the fish in cm against gillnet mesh size was generated in excel at a given standard error to indicate the length-mesh size relationship for Nile perch.

2.3.3 *Estimation of the effects of trends in the gillnet mesh size composition in the Nile perch fishery*

Average quantity fished per propulsion type

The weight values for the estimated annual quantity were raised from sampled catch data for the effort groups and averages summarised in Excel for the 8 surveys.

The average quantity fished per group was calculated in Excel through:

$$AQ_{et} = \sum (\text{Total quantity of landings}_{et}) / \text{Number of craft}_{et}$$

Where; AQ_{et} = Average quantity fished in a given craft group at time t.

Catch per unit of effort

Catch per unit of effort for the defined effort groups in each of the survey years were analysed to determine their trend for the eight Catch Assessment Survey years.
CPUE was calculated as:

$$CPUE_{et} = AQ_{et} / \text{average hours fished per day}_{et}$$

Where, $CPUE_{et}$ is the Catch per unit effort for a given effort group at a given survey period t.
AQ_{et} is the average quantity fished per boat in a given effort group at a given survey period t.

The price effect

Ex-vessel prices at the landings were used, these were based from the catch data corresponding to the price per kilogram (also were considered for the corresponding fish length calculated earlier) per individual fishing vessel. These were analysed in the SAS © statistical software using various modelling approaches (*full results shown in Appendix 3*) to determine the price of fish at various length. Fish length were set from 10cm to represent the rounded value of the minimum length of fish in the sample size and 90 cm to represent the maximum rounded length of fish from the sample.

$$P_{et} = \alpha + \beta L_{et} + \gamma L^2_{et} \qquad (2)$$

Where P_{t}- Price at time t
L- Length of fish in landing i at time t
α, β, Ɣ- constants to be estimated.

The parameters α, β, Ɣ were obtained from the model per given year and month period and the price of fish was determined from the above formula at given length categories in the corresponding years. The resultant Price- Length relationship was plotted to indicate the price effect on length in each year period.

3 RESULTS

3.1 Trends in fishing in the Nile perch fishery

3.1.1 Fishing craft and their propulsion.

The number of paddled craft increased noticeably from 12,506 crafts in 2004 to 17,475 in 2006, and there has been no increase since 2006 (Figure 2). The number of crafts using sails has been low throughout the period of the study with a decline of sailing boats from 1096 in 2004 to 856 in 2015.

The number of crafts using outboard engines increased 3-fold from 3173 in 2004 to 10,059 crafts in 2014. Because of the relatively low and constant use of the sailed boats over the period, the study considered paddled and motorized boats.

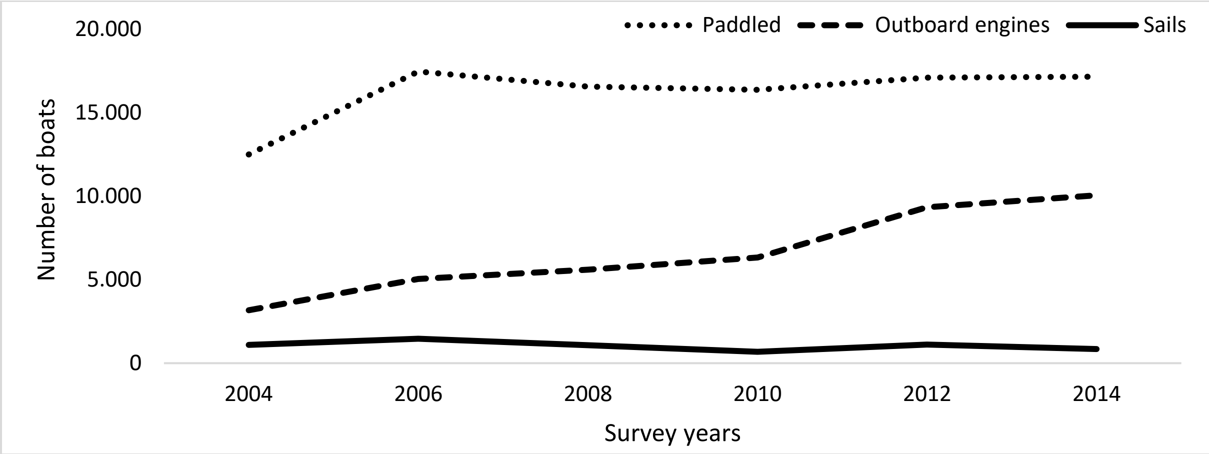

Figure 2: The total fishing craft in three effort groups on Lake Victoria from 2004 to 2014. (*Source Frame survey*)

3.1.2 Target species in relation to boat propulsion

Motorized boats

The Nile perch dominates among all fish species targeted by motorized boats. This is indicated by an increasing number of craft from 5808 in 2010 to 8088 in 2014 (Figure 3).

The number of crafts targeting Mukene increased from 380 in 2010 to 1793 in 2014. Tilapia and other species, however, are not commonly fished in motorized craft as they indicate very low numbers.

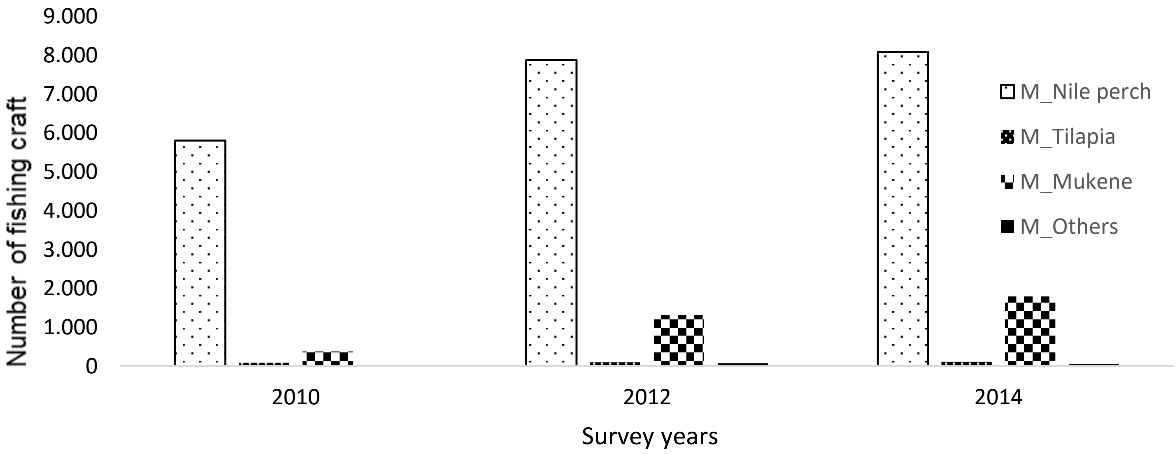

Figure 3; Number of motorized craft per target species. (Source, *Frame survey reports 2010, 2012 and 2014)*

Tilapia dominates the target species in paddled boats, however, the number of crafts targeting the species has declined from 8103 (51%) in 2010 to 7468 (45%) in 2014 (Figure 4). Craft targeting Nile perch on the other hand have shown a slow increasing trend from 5534 (35%) in 2010 to 6427 (39%) in 2014.

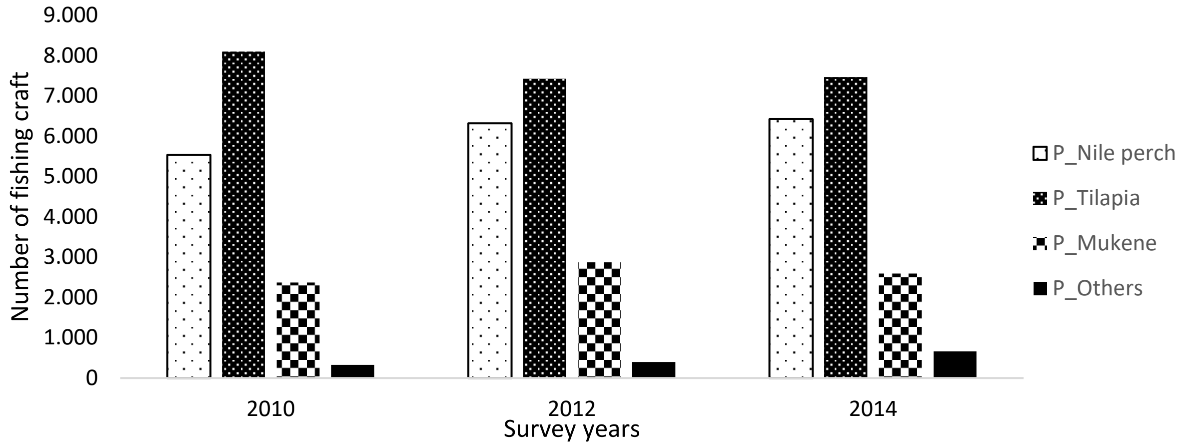

Figure 4: Number of paddled craft per target species. (Source, Frame survey reports 2010, 2012 and 2014.

3.1.3 Sample composition per boat propulsion type

The total number of boats sampled was 19847, representing the overall number of boats that used gillnets and had Nile perch catches in their landings. The sample crafts are dominated by motorized boats (10800), followed by paddled boats (8021) then sailed boats (1026).

The highest number of boats sampled was in 2005 and the lowest in 2015 for all boat groups as shown in Table 1. This is because in 2005, surveys were carried out in four months and for one month in 2015.

For purposes of analysis, the study considered analysing data for boats using paddles and engines neglecting sails due to their small sample number.

Table 1: Total boats sampled using gillnets in the different propulsion mode for the given study years. (Source Catch Assessment data.)

YEARS	PADDLE	MOTORISED	SAILED
2005	2165	2324	363
2006	1723	1915	257
2007	1182	1553	130
2008	1021	1518	96
2010	463	778	30
2011	463	1061	44
2014	425	753	74
2015	579	898	32
TOTAL	8021	10800	1026

3.1.4 Gillnet mesh size composition

Mesh size composition in motorized craft

The five-inch gillnets contributed 17% of all gillnets used by motorized boats in 2007, but declined considerably by 2010 to 8%, the trend further indicates that these nets are rarely used by the motorized boats (Figure 5). Gillnets of mesh size 5.5 to 6.5 dominate in boats for all the years and this has increased over the last 5 years from 52% in 2010 to 81% in 2015.

Gillnets of mesh sizes 7 inches and above show smaller proportions with a slight increase to 28% in 2008, followed by a declining trend composing 9% in 2015 (Figure 5). There has been a continuous decrease in the proportion of the use of gillnets of 7 inches and above since 2008, indicating reduced abundance of largest Nile perch.

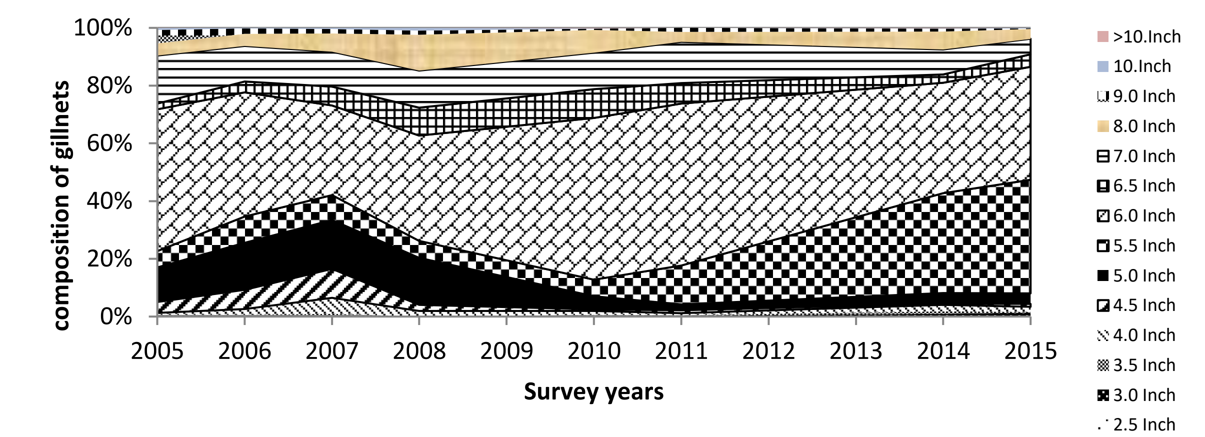

Figure 5: Composition of Gillnet mesh in motorised craft. (Source: *Catch Assessment data survey).*

Mesh size composition in paddled boats

In 2005 and 2006, 32% of gillnets used by paddled boats was 5-inch mesh sizes but reduced to 11% in 2015. The use of 3.5 to 4.5-inch mesh size was 25% in 2005 and increased to 47% in 2007, however, this was followed by a decreasing trend from 33% in 2007 to 28% in 2015. The case of gillnets of 3 inches and below shows an increasing trend from 5% in 2010 to 40% in 2015. This indicates an increased use of gillnets below the minimum required mesh size of 5 inches in paddled boats from 30% in 2005 to 68% in 2015 (Figure 6).

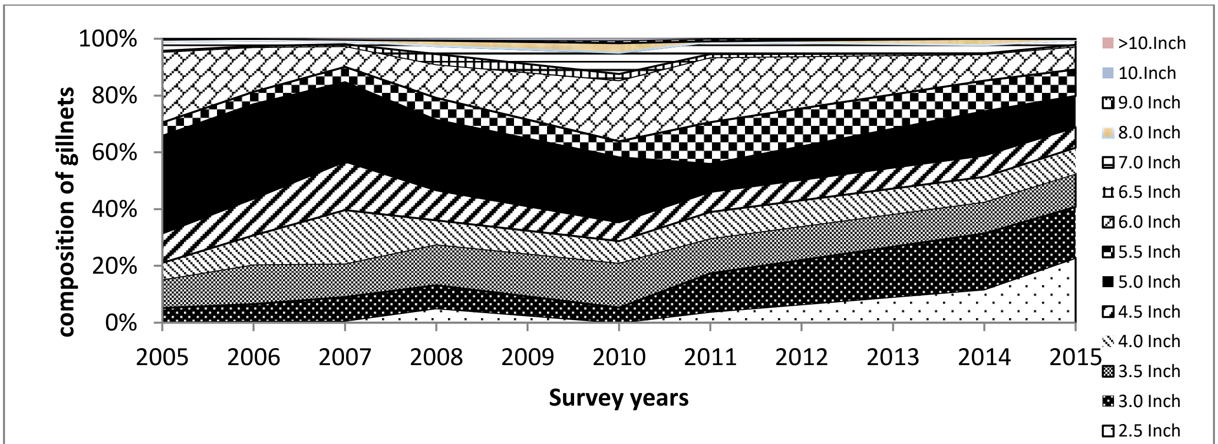

Figure 6: Composition of gillnets in the sampled paddled boats. (*Source Catch Assessment data)*

3.2 Fish length per boat propulsion type.

The average length for Nile perch caught in motorized craft has remained steadily constant over the period for 2007 when the average length of 49.06 cm TL is recorded. In other years, the average length has ranged from 50 to 54 cm TL (Figure 7).

The average length of Nile perch caught by paddled boats on the other hand is consistently below the minimum size of 50 cm TL. In the last six years, there has been a continuous decline from 42.93 cm in 2010 to 33.7 cm in 2015.

In general, the Total length of Nile perch catches in motorized craft are higher than those in paddled craft because they can easily access offshore areas of the Lake for larger catches unlike the paddled craft that are normally bound to areas near the shore.

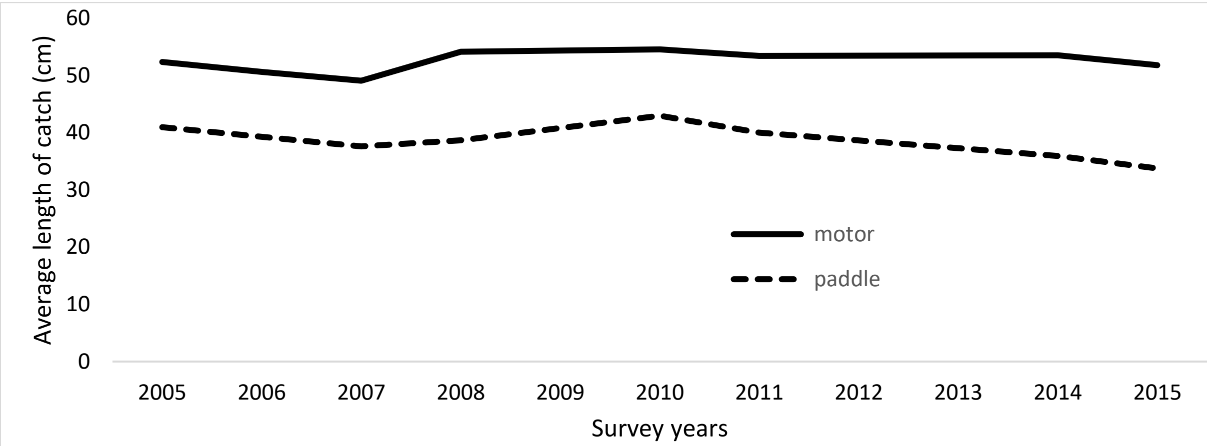

Figure 7: Average length of Nile perch caught in gillnets used for both the paddled and motorized craft between 2005 and 2015.

3.2.1 Nile perch length in motorized craft

A regression model was used to determine the effect of the different mesh sizes on the length of Nile perch (Table 2). The mean length of Nile perch increases as bigger mesh sizes are used. The lowest length estimate in the different mesh sizes is observed from gillnets 2.5 inches where the length of fish that was caught using this mesh size was 18.5 cm smaller than the average length estimates in each year.

The highest length estimate is observed with gillnets of mesh size 10 inches where the length of fish caught in a given year was 26.8 cm longer from the mean year estimate as shown in the table 2.

The discrepancy for the gillnet mesh size <2.5 was due to the small sample size for mesh sizes in the craft and might also be due to the entanglement of a large sized fish captured in such a net from the small sample analysed. Tangling is less dependent on mesh size since gillnet selectivity which is mainly based on fish which is gilled or wedged (Msuku *et al.*, 2011).

Table 2: Regression model for average length of fish per gillnet mesh size of sampled motorised craft from commercial catches from surveys conducted in 2005 to 2015. (Source: Catch Assessment survey data).

Source	DF	Sum of squares	Mean square	F value	Pr>f
Model	25	29051532.79	1162061.31	24088.20	<.0001
Error	10489	506008.67	48.24		
Uncorrected total	10514	29557541.46			
R-Square		Co-efficient variance	Root MSE	Length mean	
0.50		6.95	13.33	52.11	
Parameter	Estimate	Standard error	t value	pr>t	
2005	46.36	0.81	57.56	<.0001	
2006	46.17	0.81	57.07	<.0001	
2007	45.48	0.82	55.23	<.0001	
2008	47.41	0.82	57.70	<.0001	
2010	47.44	0.86	55.46	<.0001	
2011	47.14	0.83	56.96	<.0001	
2014	48.50	0.86	56.56	<.0001	
2015	47.62	0.84	56.67	<.0001	
gn < 2.5	4.20	6.97	0.60	0.5465	
gn_2.5	-18.47	2.70	-6.84	<.0001	
gn_3.0	-17.27	1.51	-11.44	<.0001	
gn_3.5	-19.49	1.39	-14.04	<.0001	
gn_4.0	-14.07	0.82	-17.18	<.0001	
gn_4.5	-12.28	0.73	-16.92	<.0001	
gn_5.0	-5.59	0.65	-8.55	<.0001	
gn_5.5	-1.43	0.65	-2.19	0.0283	
gn_6.0	2.83	0.63	4.52	<.0001	
gn_6.5	5.43	0.69	7.85	<.0001	
gn_7.0	8.44	0.65	12.98	<.0001	
gn_8.0	16.12	0.69	23.49	<.0001	
gn_9.0	11.67	0.86	13.61	<.0001	
gn_10	26.83	1.33	20.11	<.0001	

The effect of mesh size on the average length of fish per year is obtained by the summation of the individual year estimate and the mesh size estimate (Table 2). For instance, in 2005, there was a significant (p<.0001) resultant effect of crafts using 5-inch mesh size on the length of Nile perch caught. This can be obtained by 46.36+ (-5.59) cm TL.

The combined average length of fish for all the years is shown in the Figure 8. This is obtained from the computation from table 2 above.

Considering the minimum-slot size of Nile perch of 50 cm TL, gillnets of size 7 inches achieved the recommended slot size with an average total length of 54.94 cm captured by the motorized craft. This is in line with research conducted by Msuku *et al.* (2011) that reccomended raising of the minnimum mesh size from 5 inches to 7.

The highest average length obtained size of 72.84 cm TL is observed in mesh size 10 inches. (Figure 8)

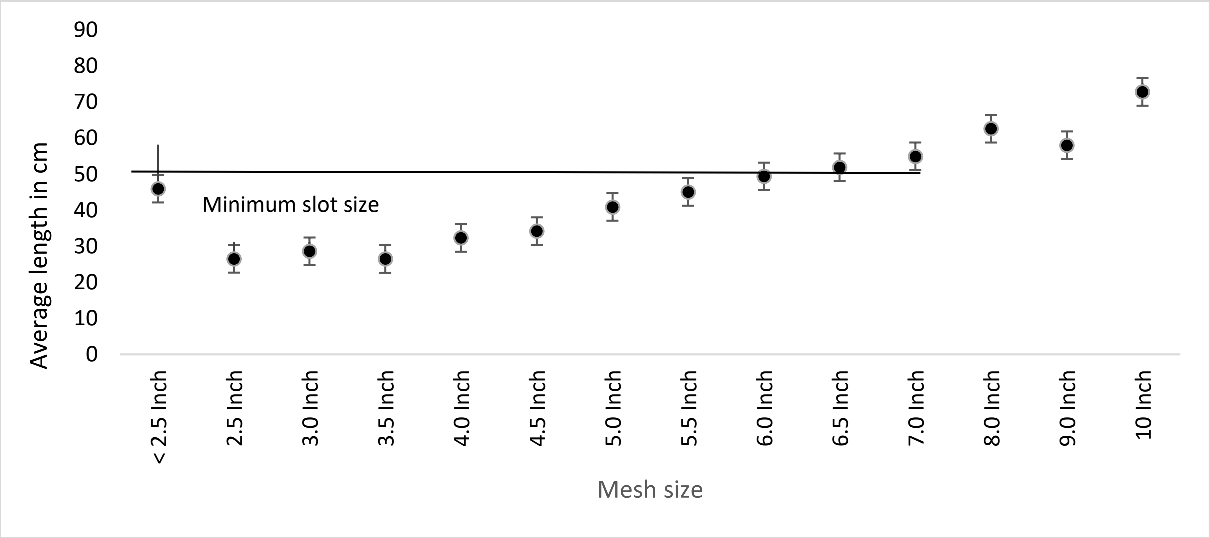

Figure 8: Average length of Nile perch in gillnets of sizes < 2.5 inches to 10 inches for motorized craft. (*Source; Catch assessment survey data*).

3.2.2 Nile perch length in paddled craft

Length of fish increases with an increase in mesh size. Nets of less than 2.5 captured fish of 14.75 cm less than the average length estimation in a given year. Like in the motorized boats, the large sized Nile perch is captured in gillnets of 10 inches with a 24.17 cm increase on the estimated average length parameter in a given year say in 2005 it will be given as 36.82+24.17.

The combined effect of length-frequency distribution for Nile perch in the different gillnet meshes of paddled craft is shown in Figure 9. Gillnet mesh sizes less than 8 inches capture Nile perch below the minimum size slot of 50 cm TL as shown in the (Figure 9).

It should be noted that paddled boats fish in areas near the shore where most small sized fish is found thus contributing to the smaller mean length of fish harvested than by the motorized boats.

3.3 Nile perch catch per craft propulsion mode

3.3.1 Average quantity of Nile perch

The average quantity fished per boat sampled was high for motorized boats than paddled boats throughout the survey period. The average quantity of Nile perch fished was highest in 2005 than in other years, this could be attributed by the large size of boats sampled (n= 4489 craft) and might also be due to the high fish catches obtained by fishers during that year compared to other years (Table 4).

Table 3: Regression model for average length of fish per gillnet mesh size of sampled craft using paddles in commercial catches from surveys conducted in 2005 to 2015. (Source: Catch Assessment survey data)

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	25	12328915.1	493156.6	5608.3	<.0001
Error	7743	680871.2	87.9		
Uncorrected Total	7768	13009786.3			

R-Square	**Coeff Var**	**Root MSE**	**Length Mean**
0.43	24.04	9.38	39.00

Parameter	Estimate	Standard Error	t Value	Pr > |t|
2005	36.82	0.97	37.98	<.0001
2006	36.89	0.98	37.75	<.0001
2007	36.65	1.00	36.47	<.0001
2008	36.53	1.01	36.16	<.0001
2010	37.94	1.07	35.54	<.0001
Parameter	Estimate	Standard Error	t Value	Pr > |t|
2011	36.79	1.07	34.41	<.0001
2014	35.10	1.12	31.37	<.0001
2015	36.20	1.05	34.55	<.0001
gn<2.5	-14.75	1.31	-11.27	<.0001
gn_2.5	-13.50	1.01	-13.39	<.0001
gn_3.0	-11.35	0.87	-13.07	<.0001
gn_3.5	-9.42	0.83	-11.37	<.0001
gn_4.0	-5.48	0.85	-6.43	<.0001
gn_4.5	-3.42	0.84	-4.06	<.0001
gn_5.0	1.01	0.80	1.26	0.2061
gn_5.5	4.53	0.90	5.02	<.0001
gn_6.0	8.78	0.82	10.72	<.0001
gn_6.5	11.55	1.38	8.39	<.0001
gn_7.0	13.61	1.06	12.86	<.0001
gn_8.0	22.06	1.45	15.18	<.0001
gn_9.0	9.23	2.39	3.86	0.0001
gn_10	24.17	3.96	6.10	<.0001

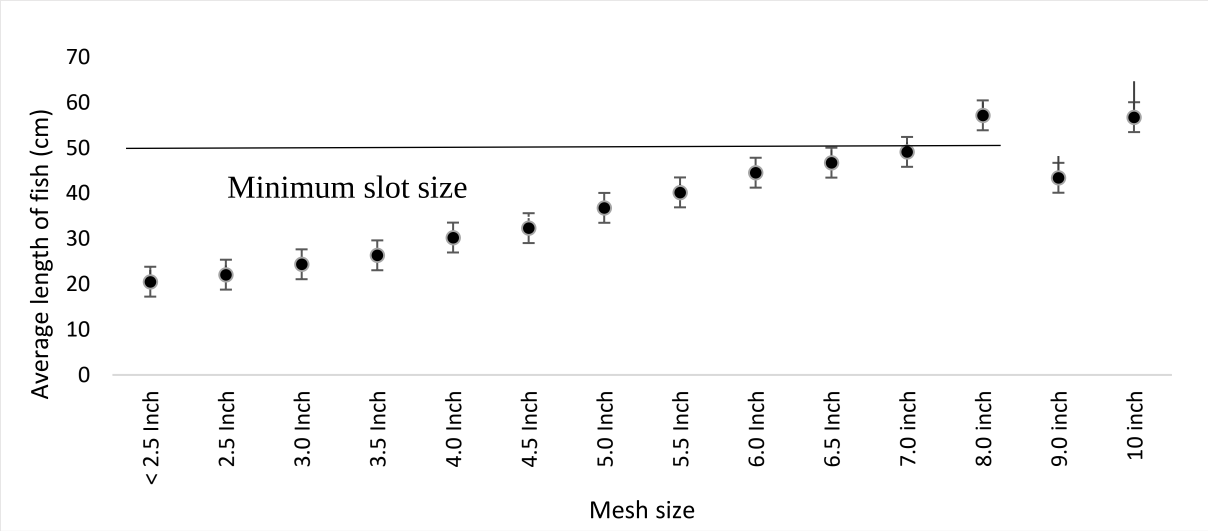

Figure 9: Average Nile perch length in gillnets of sizes < 2.5 inches to 10 inches for paddled craft. (Source; Catch assessment survey data).

Table 4: The estimated weight and average quantity (kgs) of Nile perch from sampled boats in kg per boat in a given year for the given boat propulsion. (Source: Catch Assessment survey data)

	Frequency (n)		Weight of fish (kg)		Average quantity fished (kg/boat/year).	
Year	Engines	Paddles	Engines	Paddles	Engines	Paddles
2005	2324	2165	68646	30442	29.54	14.06
2006	1915	1723	54135	28118	28.27	16.32
2007	1553	1182	40956	14767	26.37	12.49
2008	1518	1021	38692	13198	25.49	12.93
2010	778	463	21546	7316	27.69	15.80
2011	1061	463	24245	6520	22.85	14.08
2014	753	425	15219	4858	20.21	11.43
2015	898	579	16485	6648	18.36	11.48

Generally, the average quantity of Nile perch per boat was higher in motorized boats than the ones using paddles for all the survey years (Figure 10). Motorized boats harvest large sized fish (mean = 52.11 cm TL) which weighs more than that harvested in paddled craft with a mean of 39.00cm TL.

However, there is a continuous decline in catches for the motorized boats with a 38% decline in average quantity harvested per day by these craft since 2005. Paddled boats on the other hand do not show a decreasing trend over the period of the study.

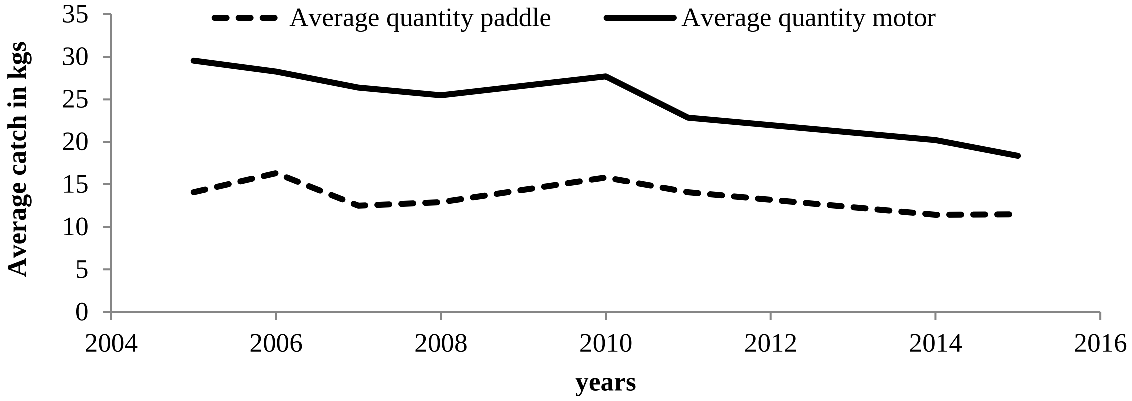

Figure 10: Average quantity of fish harvested by the sampled motorized and paddled boats from 2005 to 2015 *(Source: Catch Assessment survey data)*

3.3.2 Catch per Unit effort

The CPUE in kilograms per hour for the craft groups corresponds with the average quantity that has previously been described. With the highest CPUE estimate of 3.91 kg/hour in 2005 for the motorized craft dropping to 1.90 kg/hour in 2015. CPUE for paddled craft on the other hand is lowest in 2005, the low estimates in paddled boats are attributed to the fact that these boats capture small sized Nile perch in the near shore areas, thus the low CPUE estimates.

However, from 2014 there is an increase in CPUE, from 1 kg/hour in 2014 to 1.6 kg/hour in 2015 which might also be attributed to the high number of craft landing large quantities of juvenile Nile perch in the Lake Victoria. (Figure 11).

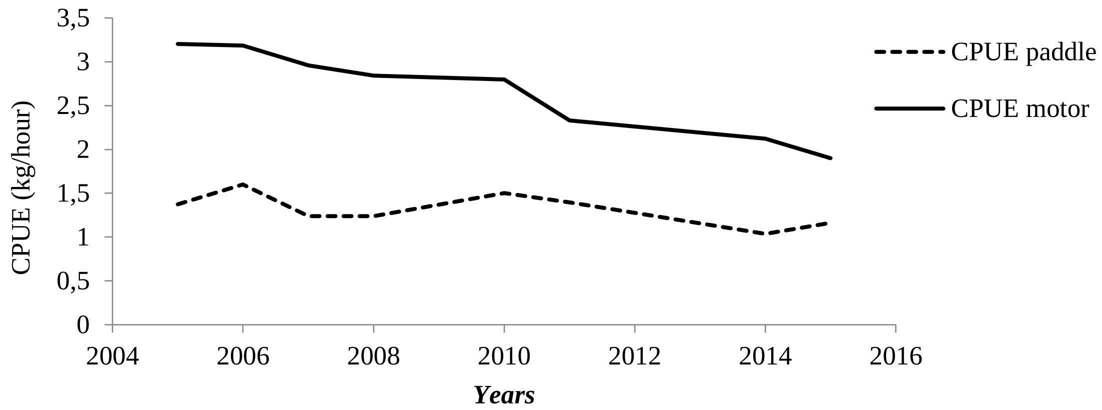

Figure 11: CPUE for the sampled motorised and paddled craft for the years 2005 to 2015. (*Source Catch Assessment survey data*).

3.4 The price development of Nile perch.

3.4.1 The price per boat propulsion

The price of fish from both groups has increased over time since 2005, the lower prices observed in 2005 are characterised by a small price difference in Nile perch catches from both the motorized (UGX 1929) and paddled craft (UGX 1591) as shown in Figure 12.

In general, there is an increasing trend in the prices of fish, with a high increase indicated in 2015. A growing deviation in the price of catches for the motorized and paddled craft is observed from 2007, which has since risen and almost doubled in motorised craft (7697 UGX) as compared to paddled craft (UGX 4637) in 2015 (Figure 11). This might be due to the scarcity of large sizes Nile perch, which is a key raw material of fish factories, thus commanding the high prices.

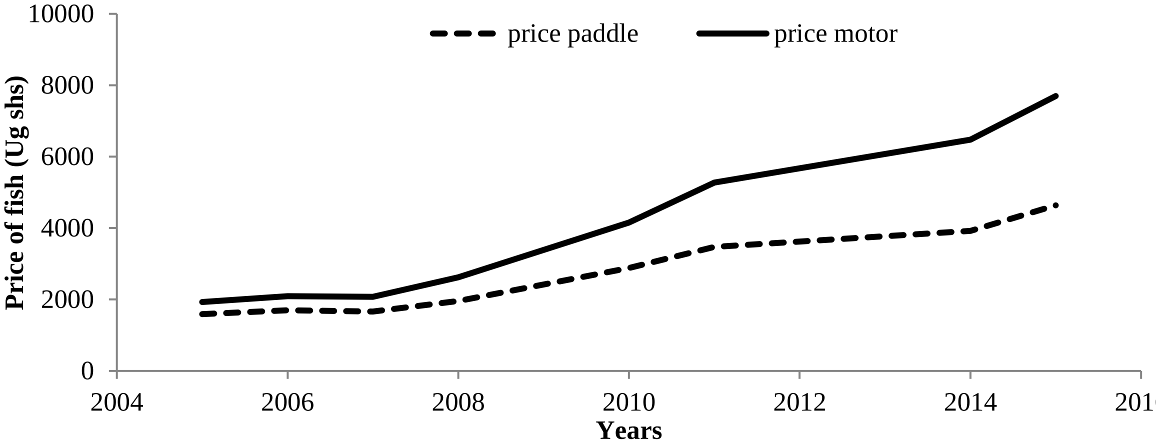

Figure 12: Price of fish from the different boat propulsion (*Source Catch Assessment survey data*).

3.4.2 The price-length interaction of Nile perch

Since 2008, fish prices have increased, and the increase has been greatest for the larger fish (Figure 13). In 2015, for instance 10 cm fish commanded a lower price UGX 1470 compared to the 90 cm fish that costs UGX 9643.

The prices of fish were low and constant from 2005 to 2008. This might be attributed to the global financial crisis characterized by low prices accrued from fish exports from processing industries.

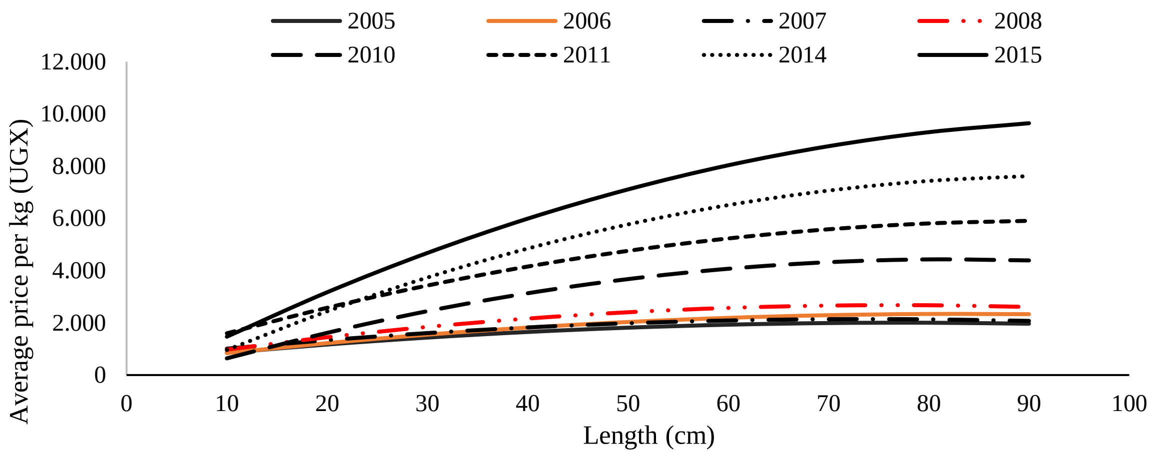

Figure 13: Average price of fish per cm from 2005 to 2015. (*Source Catch Assessment survey data*).

Three length categories were selected (authors own estimates) 20 cm, 50 cm and 80 cm. 20 cm was assumed to represent juvenile Nile perch, 50 represented the required slot size for harvesting, and 80 cm Nile perch represented the largest individuals sampled.

Large sized individuals (50 and 80 cm) command higher prices as compared to small sized individuals (20 cm) for all years (Figure 14).

There was a small price difference for the three selected fish sizes from 2005 to 2007 say in 2005, 20 cm commanded 1169 UGX, 2004 UGX for 50 and 80 cm fish.

However, the significant price differences for the selected fish size (length) was recorded from 2008 to 2015 with the highest in 2015 such that 20 cm fish commanded 3169 UGX, 7106 for 50 cm fish and 9300 UGX for the 80 cm fish.

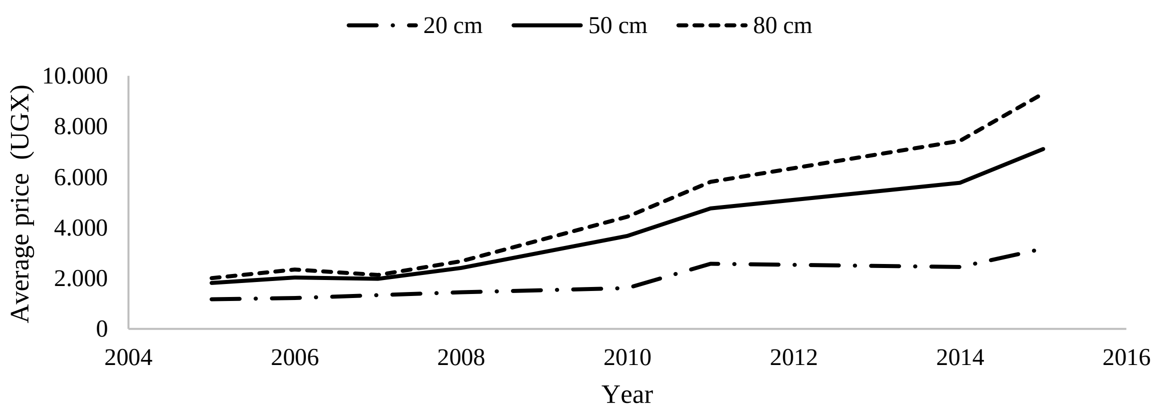

Figure 14: The price development for different size categories of fish (Catch Assessment survey; authors own estimates).

3.4.3 Relationship between average catch of Nile perch and price

Reduction in catch over time has been compensated with an increase in price (Figure 15). In 2005, the average catch per boat per day in motorized craft was 29.54 kg commanding price per kg approximately UGX 2000. In 2015, the average catch had declined to 18.36 kg commanding UGX 8000 per kg, which is 4 times higher than the price in 2005 (Figure 16).

This can be a scarcity indicator in the amount of fish harvested, thus leading to price increases and at the same time act as incentive for fishers to increase harvesting of Nile perch.

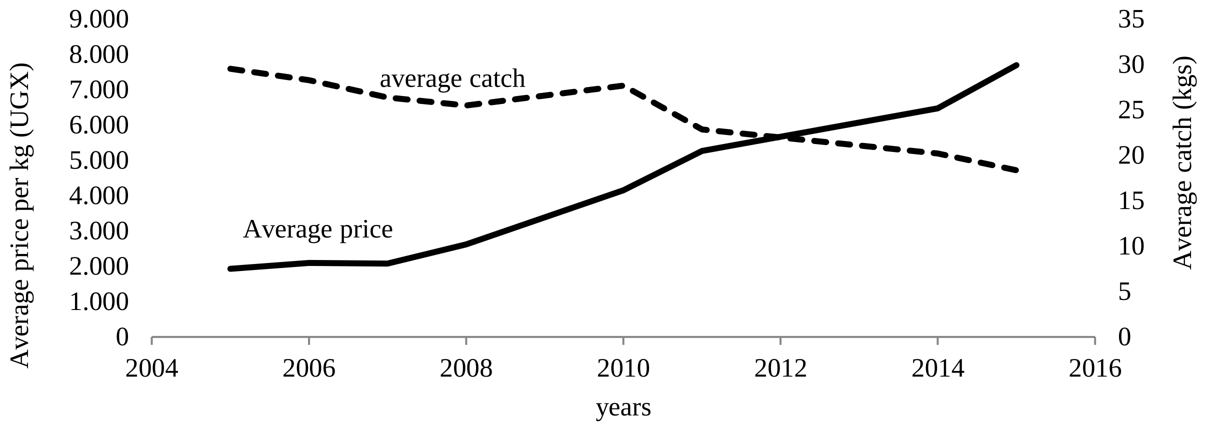

Figure 15: Relationship between average catch of Nile perch and price per kg in motorized boats from 2005 to 2015. (Source: Catch Assessment survey)

Catches in paddled craft commands lower prices than from the motorized craft but the trends are the same (Figure 16).

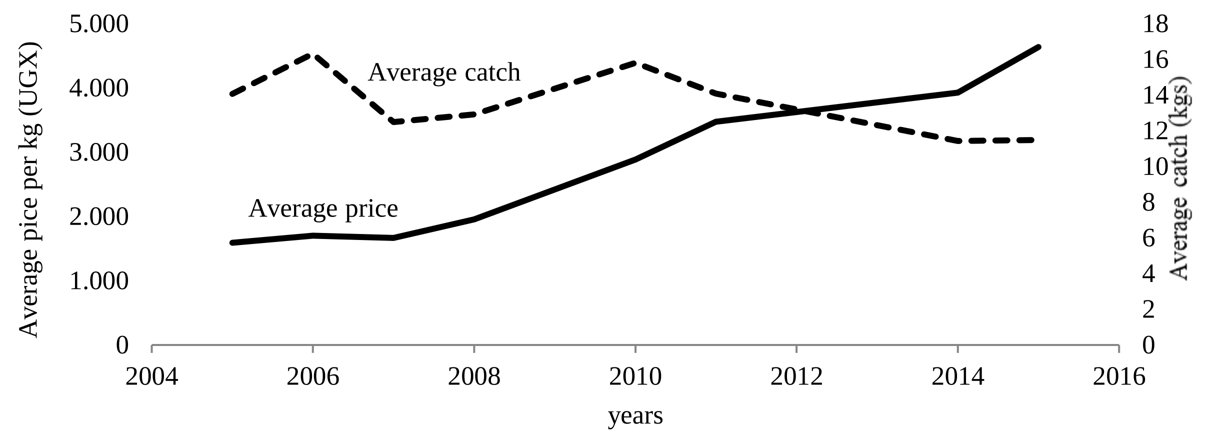

Figure 16: Price and quantity trend of fish for paddled craft (*Source Catch Assessment survey data*).

4 DISCUSSION

In the Lake Victoria on the Ugandan side, the fishing operations based on mode of propulsion are mainly carried out by craft using engines (motorized), paddles and sails (Figure 2). Motorized and paddled crafts dominate the fishery. Therefore, the study limited analysis to these two groups of fishing crafts as the number of sail boats indicated no significant part of the fishery. The reduction in the number of paddled crafts targeting Tilapia might be attributed to the declining Tilapia stocks in the lake indicating that these craft might be shifting from targeting Nile tilapia to Nile perch or mukene, which have relatively consistent landings (LVFO, 2014). This explains the dominance of motorized crafts (n=10800) than paddled crafts (n=8021) in the study results indicating an already established commercial fishery with abilities to invest in harvesting of Nile perch mainly for exports of Nile perch for factories, regional traders and fish maw traders (Atukunda & Ahmed, 2012). The study also indicates a greater composition of large mesh sizes above the minimum regulation 5 inch that are employed by these motorized craft.

The minimum mesh size is regulated to 5 inches in Lake Victoria. The results from this study indicate low levels of compliance among fishers using paddled craft where gillnets below the minimum mesh sizes 5 have increased from 30% in 2005 to 68% in 2015. This targeting of small size fish might be due to the growing regional and local demand for fish (DFR, 2012; Atukunda & Ahmed, 2012).

The study results indicate lower prices for smaller sized fish which is caught in paddled boats, which is a disincentive to target small fish, however, hydroacoustic survey results indicate that small sized fish makes up 98.8 % of the fish population.

This might explain the less decline in average quantities harvested by paddled boats compared to that of the motorized boats.The shift towards even smaller mesh sizes in the small paddled vessels might be a response to keep up catches as a means of survival. Another reason could be demand for fish as bait for the long line fishery. Bait is captured using gillnets of less than 3 inches (Mkumbo & Mlaponi, 2007). Although this might cause significant catches of juvenile Nile perch in the nets which are set near the shore, these catches can still be sold to the local fish traders for human consumption.

The study findings indicate a growing commercial Nile perch fishery characterized by motorized craft having over 90% composition of gillnets above the minimum mesh size 5. It should be noted that Nile perch from Lake Victoria remains the major fish export accounting for 90% of all fish exports due to high consumer demands and its richness in Omega 3 fatty acids (Atukunda & Ahmed, 2012). According to Ikwaput (2004), the fish prices at the landings were highly driven by the export markets which led to fishers investing in larger boats, out board engines and large meshes sizes prior to the minimum size regulation. The minimum mesh size regulation was meant to protect juvenile fishes (< 50 cm TL) which was based on gillnet selectivity studies earlier conducted by (Ogutu-Ohwayo *et al.*, 1998). It should however, be noted that as the regulation-controlled fishing juveniles as one way of protecting the Nile perch stocks, the economic effect of this regulation was neglected. Bergmann (2002) explains that an overlooked issue in many selectivity studies is the likely uptake of new measures by the fishing industry, fishing is an economic activity and in order to make informed decisions, fishermen must understand the economic costs and benefits of using the most selective gear.

The high prices of large sized Nile perch (Figure 14) will affect fishermen's behaviour on their choice of gear thus increasing their targeted fishing effort in search of the largest individuals. This strong incentive is seen in Figures 13 and 14. As an example, the average price for 50 cm fish increased from about UGX 3600 Ug shs in 2010 to UGX 7100 in 2015. The low prices in earlier years before 2010 are attributed to the price fall during the global economic crisis (Atukunda & Ahmed, 2012).

Fenberg & Kaustuv, 2007 explains that when artisanal fisheries have been subjected to minimum mesh regulations in the pretext of making them economically viable they are subjected to the effects of size selective harvesting. This prediposes fish stocks to size-selective harvesting where large individuals of a population are preferentially targeted (Fenberg & Kaustuv, 2007). Various studies (Fenberg & Kaustuv, 2007; Kendall & Quinn, 2013; Hutchings & Baum, 2005) have raised concerns that size selective harvesting has negative effects on the demography, life history and the ecology of the large species which adapt by reduction in body sizes, skewed sex ratios and also changed behaviour on breeding grounds. This study does not indicate a clear biological effect on the size of the fish but clearly indicates that although larger fish is in high demand fishermen are shifting towards smaller mesh sizes and experiencing falling CPUE at the same time. Average catches of Nile perch caught by motorized boats fell from 29.53 kg per day in 2005 to 18.35 kg in 2015. At the same time CPUE fell from 3.20 to 1.9 kg/hr. The composition of mesh sizes for the gillnets in the motorized boats from 2010 to 2015 has been tilted towards the 5.5 inch mesh size rather than the dominant 6 in the early survey years. This is all consistent with overharvesting to large fish. This result is supported by hydro acoustic studies on Lake Victoria which have indicated reduction in the mean length of fish from 50 cm TL in 2006 to 25 cm TL in 2009 (Mkumbo & Marshall, 2015;Taabu, 2014). This has in turn affected processing industries as they operate 30 % below their installed capacity (DFR, 2012).

Another indicator of this can be observed from the rather constant catches in paddled boats which indicates that fishers might have taken advantage of the growing regional and local markets to exploit small sized fish to generate money for their livelihood.

With regards to the proposed minimum mesh size regulation by LVFO to raise the minimum mesh size from 5 inches to 7 inches, the implication would be that fishers will have to spend credible amounts of time, and increase on buying nets of the required size, spending on fuel in search for fish of the required slot size. This might not be economically viable to the fishers and to the government where huge sums of money will have to be invested in patrols to ensure fishers comply by the rule.

5 CONCLUSION

The gillnet mesh size regulation for Nile perch in Lake Victoria has been highlighted in most Nile perch regional plans like the RPOA-IUU (Regional plan of Action on Illegal, Unregulated and Unreported fishing), 2009 council of ministers' directives on management of Lake Victoria and the proposed species management plan for Nile perch. The results from this study indicate that most of the near shore paddled boats use predominantly gillnets below the minimum size and that the trend over time is towards smaller and smaller mesh sizes. The larger motorized vessels seem to follow the regulation better, although the trend there is also towards smaller mesh sizes. This trend goes against an ever-increasing price premium for large fish. It seems to be driven by falling catches, probably caused by overharvesting of larger fish. It is very important to look closely at the effects this development might have on fish stocks, as research shows a clear relationship between strong size selectivity and some negative evolutionary changes in fish stocks, such as age at maturity, gender composition and growth rates, etc. It seems clear from the study results that mesh size regulation is not achieving the goals set by managers, and new approaches are necessary to tackle management problems.

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APPENDICES

Appendix 1: Regression model for the gillnet mesh size effect on length in motorised craft.

Class Level Information		
Class	Levels	Values
year	8	2005 2006 2007 2008 2010 2011 2014 2015
district	13	Bugiri Buikwe Buvuma Jinja Kalangala Kalungu Kampala Mayuge Mpigi Mukono Namayingo Rakai Wakiso
Vessel propulsion	1	O

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	25	29051532.79	1162061	24088.2	<.0001
Error	10489	506008.67	48.24		
Uncorrected Total	10514	29557541.46			

R-Square	Coeff Var	Root MSE	Length Mean
0.50	13.33	6.95	52.11

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	8	28584476.99	3573060	74065.6	<.0001
gn < 25	1	13.73	13.73	0.28	0.5938
gn_2.5	1	2870.54	2870.54	59.5	<.0001
gn_3.0	1	10706.41	10706.4	221.93	<.0001
gn_3.5	1	14181.78	14181.8	293.97	<.0001
gn_4.0	1	61276.14	61276.1	1270.19	<.0001
gn_4.5	1	83226.09	83226.1	1725.18	<.0001
gn_5.0	1	101515.81	101516	2104.31	<.0001
gn_5.5	1	41248.98	41249	855.05	<.0001
gn_6.0	1	70147.57	70147.6	1454.08	<.0001
gn_6.5	1	11227.05	11227.1	232.72	<.0001
gn_7.0	1	12278.69	12278.7	254.52	<.0001
gn_8.0	1	11152.42	11152.4	231.18	<.0001
gn_9.0	1	2776.52	2776.52	57.55	<.0001
gn_10	1	19526.14	19526.1	404.76	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	8	168896.22	21112.00	437.63	<.0001
gn < 25	1	17.54	17.5391	0.36	0.5465
gn_2.5	1	2259.27	2259.27	46.83	<.0001
gn_3.0	1	6312.28	6312.28	130.85	<.0001
gn_3.5	1	9505.72	9505.72	197.04	<.0001
gn_4.0	1	14238.53	14238.5	295.15	<.0001
gn_4.5	1	13809.37	13809.4	286.25	<.0001
gn_5.0	1	3527.91	3527.91	73.13	<.0001
gn_5.5	1	232.18	232.179	4.81	0.0283
gn_6.0	1	984.58	984.581	20.41	<.0001
gn_6.5	1	2970.93	2970.93	61.58	<.0001
gn_7.0	1	8122.44	8122.44	168.37	<.0001
gn_8.0	1	26626.27	26626.3	551.93	<.0001
gn_9.0	1	8929.83	8929.83	185.11	<.0001
gn_10	1	19501.19	19501.2	404.24	<.0001

Parameter	Estimate	Standard error	t value	pr>t
2005	46.36	0.81	57.56	<.0001
2006	46.17	0.81	57.07	<.0001
2007	45.48	0.82	55.23	<.0001
2008	47.41	0.82	57.70	<.0001
2010	47.44	0.86	55.46	<.0001
2011	47.14	0.83	56.96	<.0001
2014	48.50	0.86	56.56	<.0001

2015	47.62	0.84	56.67	<.0001
gn < 2.5	4.20	6.97	0.60	0.5465
gn_2.5	-18.47	2.70	-6.84	<.0001
gn_3.0	-17.27	1.51	-11.44	<.0001
gn_3.5	-19.49	1.39	-14.04	<.0001
gn_4.0	-14.07	0.82	-17.18	<.0001
gn_4.5	-12.28	0.73	-16.92	<.0001
gn_5.0	-5.59	0.65	-8.55	<.0001
gn_5.5	-1.43	0.65	-2.19	0.0283
gn_6.0	2.83	0.63	4.52	<.0001
gn_6.5	5.43	0.69	7.85	<.0001
gn_7.0	8.44	0.65	12.98	<.0001
gn_8.0	16.12	0.69	23.49	<.0001
gn_9.0	11.67	0.86	13.61	<.0001
gn_10	26.83	1.33	20.11	<.0001

Appendix 2-Regression model for gillnet mesh size effect on length in paddled craft.

Class Level Information		
Class	Levels	Values
year	8	2005 2006 2007 2008 2010 2011 2014 2015
district	15	Bugiri Buikwe Busia Buvuma Jinja Kalangala Kalungu Kampala Masaka Mayuge Mpigi Mukono Namayingo Rakai Wakiso
V Propulsion	1	P

Number of Observations Read	8021
Number of Observations Used	7768

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	25	12328915.12	493157	5608.27	<.0001
Error	7743	680871.2	87.93		
Uncorrected Total	7768	13009786.32			

R-Square	Coeff Var	Root MSE	Length Mean
0.43	24.04	9.38	39.00

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	8	11859592.65	1482449	16858.7	<.0001
gn < 2.5	1	16591.79	16591.8	188.69	<.0001
gn_2.5	1	24079.31	24079.3	273.83	<.0001
gn_3.0	1	59675.98	59676	678.65	<.0001
gn_3.5	1	100810.59	100811	1146.44	<.0001
gn_4.0	1	39100.72	39100.7	444.66	<.0001
gn_4.5	1	39509.3	39509.3	449.31	<.0001
gn_5.0	1	49012.16	49012.2	557.38	<.0001
gn_5.5	1	7257.94	7257.94	82.54	<.0001
gn_6.0	1	484.23	484.23	5.51	0.019
gn_6.5	1	122.81	122.81	1.40	0.2373
gn_7.0	1	4737.35	4737.35	53.87	<.0001
gn_8.0	1	18251.56	18251.6	207.56	<.0001
gn_9.0	1	1060.80	1060.8	12.06	0.0005
gn_10	1	3267.33	3267.33	37.16	<.0001

Source	**DF**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
year	8	131441.82	16430.23	186.85	<.0001
gn < 2.5	1	11174.07	11174.07	127.07	<.0001
gn_2.5	1	15758.80	15758.80	179.21	<.0001
gn_3.0	1	15020.74	15020.74	170.82	<.0001
gn_3.5	1	11362.12	11362.12	129.21	<.0001
gn_4.0	1	3631.44	3631.44	41.3	<.0001
gn_4.5	1	1451.38	1451.38	16.51	<.0001
gn_5.0	1	140.62	140.62	1.60	0.2061
gn_5.5	1	2215.95	2215.95	25.20	<.0001
gn_6.0	1	10112.65	10112.65	115.00	<.0001
gn_6.5	1	6182.75	6182.75	70.31	<.0001
gn_7.0	1	14535.21	14535.21	165.30	<.0001
gn_8.0	1	20270.99	20270.99	230.53	<.0001
gn_9.0	1	1308.39	1308.39	14.88	0.0001
gn_10	1	3274.33	3274.33	37.24	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	8	131441.82	16430.23	186.85	<.0001
25less	1	11174.07	11174.07	127.07	<.0001
_2_5_inch	1	15758.81	15758.80	179.21	<.0001
_3_0_inch	1	15020.74	15020.74	170.82	<.0001
_3_5_inch	1	11362.12	11362.12	129.21	<.0001
_4_0_inch	1	3631.44	3631.44	41.30	<.0001
_4_5inch	1	1451.38	1451.38	16.51	<.0001
_5_0_inch	1	140.62	140.62	1.60	0.2061

_5_5_inch	1	2215.95	2215.95	25.20	<.0001
_6_0_inch	1	10112.65	10112.65	115.00	<.0001
_6_5_inch	1	6182.75	6182.75	70.31	<.0001
_7_0_inch	1	14535.21	14535.21	165.30	<.0001
_8_0_inch	1	20270.99	20270.99	230.53	<.0001
_9_0_inch	1	1308.39	1308.39	14.88	0.0001
_10_inch	1	3274.33	3274.33	37.24	<.0001
__10_inch	1	7.01	7.01	0.08	0.7777

Appendix 3: Regression model for Price-Length relationship.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	17	346013114234	20353712602	19331.2	<.0001
Error	32223	33927490954	1052896.7183		
Uncorrected Total	32240	379940605188			

R-Square	Coeff Var	Root MSE	Price Mean
0.72	36.35	1026.11	2823

Source	DF	Type III SS	Mean Square	F Value	Pr >F
Length	1	4403125869	4403125869	4181.92	<.0001
Length*Length	1	1770161019	1770161019	1681.23	<.0001
year*month	15	77334651327	5155643422	4896.63	<.0001

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Length	77.37	1.20	64.67	<.0001
Length*Length	-0.43	0.01	-41.00	<.0001
year*month 2005 August	-910.59	41.76	-21.81	<.0001
year*month 2005 July	-1024.93	41.26	-24.84	<.0001
year*month 2005 November	-812.73	39.59	-20.53	<.0001
year*month 2005 September	-753.72	40.04	-18.82	<.0001
year*month 2006 August	-592.92	38.92	-15.24	<.0001
year*month 2006 December	-903.56	39.09	-23.12	<.0001
year*month 2006 March	-455.27	41.69	-10.92	<.0001
year*month 2007 August	-646.93	38.64	-16.74	<.0001
year*month 2007 March	-628.92	38.77	-16.22	<.0001
year*month 2008 December	-458.22	40.66	-11.27	<.0001
year*month 2008 February	-267.10	39.01	-6.85	<.0001
year*month 2010 March	817.09	40.74	20.06	<.0001
year*month 2011 May	1892.20	38.92	48.62	<.0001
year*month 2014 May	2746.24	39.89	68.85	<.0001
year*month 2015 March	3960.57	38.48	102.93	<.0001