MS Thesis

Environment and Natural Resources

Productive performance of the Lake Victoria fishing fleet in Uganda:

Technical efficiency and fishers' perspective

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Faculty of Economics

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HÁSKÓLI ÍSLANDS

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60 ECTS thesis submitted in partial fulfilment of a *Magister Scientiarum* degree in Environment and Natural Resources

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Abstract

Successful exploitation of biological resources, like fisheries, depends on monitoring and evaluation of stock size and active management to stop overexploitation. This can be difficult due to limited information available to resource managers to make management decisions, particularly in developing countries with weak institutions and limited resources. In this study, the performance of the fishing fleet of the Lake Victoria fisheries in Uganda is determined and used as an indicator of stock health and development. The analysis in the study is two-fold based on technical efficiency change of the fishing fleet and also fishers' perceptions of the production environment. The fishing fleet is categorized into six vessel groups distinguished as motorized or paddled using three gear categories; gill nets and long lines for the *Lates niloticus* (Nile perch) fishery, and small seine nets for the *Rastrineobola argentea* (dagaa/mukene/omena) fishery. In determining technical efficiency, the study employs the stochastic frontier approach for eight-year unbalanced panel data and assessment of fishers' responses during interviews analyzed in IBM-SPSS. Results indicated that maximum output in the fishery was obtained by motorized vessels, with the highest rate of technical progress (94%) for the motorized dagaa fishery. In terms of technical efficiency change, a general decrease in technical efficiency was observed for all vessel groups for the period 2005 to 2015. This was coupled with declining returns to scale as vessel inputs employed for the same time period resulted to declining catches. Declines were higher for the Nile perch long line and gillnet vessel groups than in the dagaa vessel groups. Labour hours in the dagaa fishery indicated congestion while more labour hours were required for maximising catches in the motorized Nile perch vessels. Fishers also perceived catches of Nile perch to be poorer than catches in the dagaa fishery thus more likely to affect the performance of the Nile perch vessel groups than the dagaa vessels.

Therefore, effort restricting policy measures for all fishery inputs should be integrated into the fishery management objectives, and the capacity for grassroots fisheries management developed.

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List of acronyms

BMU	Beach Management Unit
DEA	Data Envelopment Analysis
DFR	Directorate Fisheries Resources
EAC	East African Community
EAFRRO	East Africa Freshwater Fisheries Research Organization
FAO	Food and Agriculture Organisation
GN	Gillnet
IFMP	Implementation of Fisheries Management Plan
KLEMs	Capital, Labour, Energy and Materials
LL	Long line
LVEMP	Lake Victoria Environmental Management Plan
LVFO	Lake Victoria Fisheries Organisation
PPF	Production Possibility Frontier
RTP	Rate of Technical Progress
RTS	Returns to Scale
SFA	Stochastic Frontier Analysis
SMS	Motorised fishing Vessel
SP	Paddled fishing vessel
SS	Small seine net

1. Introduction

1.1 Background

As an economic activity, fishing plays a significant role to many in the developing countries around the world. In these countries, fishing practices are recognized as artisanal or small-scale with uses ranging from cultural/social bonding to economic use values. On a global scale, small-scale fisheries contribute about 50% of the global capture fisheries estimated at 93.7 million tonnes. Concurrently, fisheries support the livelihoods of about 8-12% of the global population from which 90% of the people are directly dependent on capture fisheries work with equal proportions between men and women (Jentoft & Chuenpagdee, 2015; FAO, 2016); therefore contributing to livelihoods, rural development, and poverty eradication.

In inland fisheries, generally characterized by small-scale/household-based activities, fish acts as an important source of animal proteins as two-thirds of the catches are destined for direct consumption (Welcomme et al., 2010; FAO, 2015). As a traditional and enduring livelihood in fishing communities, fisheries in developing countries have persevered through a combination of adaptation and resistance to changing environmental, social, political and economic conditions (Smith *et al*., 2017). However, given the challenges in an increasingly industrial and global world coupled with population growth, these fisheries have undergone efforts to improve their performance through technological improvement of the fishing fleet to cope with this trend. In Africa, technological improvements in the fisheries were introduced by the early colonial governments by replacing the then perceived inefficient and ancient traditional fishing methods with modern fishing equipment such as new gears like synthetic gill nets and trawls; and outboard engines to expand access to fishing grounds (Squires *et al.*, 2003; Kudhongania, and Chitamwebwa, 1995). In addition, technological development strategies in artisanal fisheries were initiated in the mid-1980s, with assistance programs directed towards improving the performance in a way of increased output from the harvesting sector (Squires *et al.*, 2003). Concurrently, the commercial importance of the fisheries grew with increased markets and infrastructure development resulting in expansion of fishing effort.

Initially, technological improvements in fisheries allow any given quantity of fish to be caught at lower unit costs thus improving performance (Cunningham *et al.* 1985). However, where there is no defined property rights (free entry and exit), this encourages the persuasive and excessive use of the given technology thus leading to overcapacity and overcapitalization. If these scenarios are not controlled, extraction rates, in the long run, exceed fish stock replenishment resulting in a decline in the catch per unit of effort and diminishing economic rents (Purcell & Pomeroy, 2015).

Studies determining the performance of fishing fleet technology have become of great importance in small-scale fisheries with the main aim of determining optimal levels of harvesting the fish resources while considering biological safe limits of fish stocks (Pinello *et a*l, 2016). The economic objectives of fisheries management include improving the economic benefits to the participants, appropriate allocation of resources between competing users and generation of economic benefits to the broader community (Morrison, 2010). However, achieving these objectives is difficult due to insufficient information on the performance of the fisheries resource and development under changing technological state of the fleet.

With reference to the Lake Victoria fisheries in Uganda, the study aims at determining the performance of the fisheries with reference to the existing technology used by the fishing fleet. Besides, fishers' insight of their production environment is also sought. In measuring productive performance, the input-output relationship of the fishing fleet is assessed through determining the technical efficiency changes and also users are assessed to determine the nature of their production environment and the possible effect on productivity.

1.2 Overview of Lake Victoria fisheries

1.2.1 Geography and socio-economy

Lake Victoria is Africa's largest freshwater lake with a surface area of 68,800 km^2 shared by three countries, Kenya (6%), Tanzania (51%) and Uganda (43%). The lake has a catchment area of 194,200 km^2 extending to countries Rwanda and Burundi with a rapidly growing population estimated at over 33 million people settled around the lake and up to 70 million around the lake's basin directly depending on the ecosystem services like water, hydro-power generation and food (Downing *et al*., 2014; Nyamweya, 2017). Fishing on the lake provides employment for about four million people involved both directly and indirectly (Taabu-Munyaho, 2014) making it important for the livelihoods of millions of East Africans.

In terms of the fisheries resources, historically, the lake was dominanted by cichlid fishes composed of over 500 species. However, the introduction of the predatory Nile perch in the 1960s led to ecosystem changes with the elimination of about 60% of the >500 haplochromine cichlid species (Witte *et al.*, 1992; Taabu, 2014). Consequently, the lake's fishery changed from the indigenous less valued species at the time and is currently dominated by three species composed of Nile perch, Nile tilapia, and the small pelagic Rastrineobola *argentae* (locally referred to as *mukene* in Uganda, *omena* in Kenya and *dagaa in Tanzania)*. Currently, fish catches are estimated to account for about 1% of the global landings and 8% of the inland capture fisheries landings (FAO, 2016; Nyamweya, 2017).

However, the species composition of the landed catches has varied over time. In the 1980s, the haplochromine species dominated (> 80%) followed by the Nile perch dominance (>70%) in 1980 to 1990s which later stabilised to about 250,000 tons in the mid-2000s; and the expansion of the small pelagic (dagaa/omena/mukene) in the early 1990s which has dominated the landed catch (> 65%) post the mid-2000s from less than 10% in the early 1970s. A resurgence of the haplochromine species has been observed in the last decade (Figure 1).

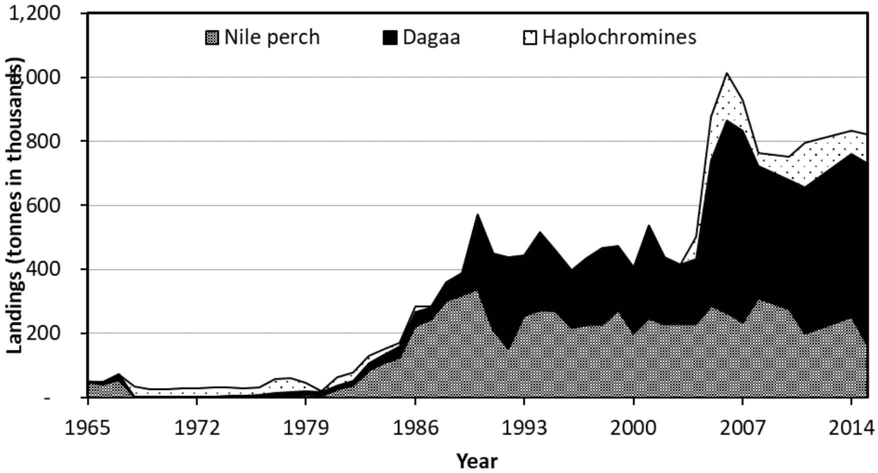

Figure 1. Fisheries production in Lake Victoria by species (*Source*; Kolding *et al*., 2013; LVFO, 2016).

1.2.2 Fishing effort and technology

It is also important to note that the growing fisheries production is coupled with increasing fishing effort and changes in fishing technology. The fishing technology involves the techniques and methods of catching fish (Kirkley & Squires, 1998). In Lake Victoria, these have undergone dynamic changes with the introduction of outboard engines and use of more efficient fishing gears such as gillnets long lines and seine nets compared to the traditional artisanal gears like basket traps and spears (Kudhongania and Chitamwebwa, 1995; Branch *et al*., 2002). Thus, the fishing technology in the lake is reflected by a combination of effort indicators which are quite complex, composed of a variety of fishing vessel types, gears and vessel propulsion (LVFO, 2014).

Statistics indicate that the number of fishers increased from about 40,000 fishers in the 1970s to over 200,000 fishers in 2014 indicating a labour intensive fishery; the number of fishing vessels also increased from over 40000 vessels to over 70,000 in the same time period (Kolding *et al*., 2014; LVFO, 2014). Similarly, statistics from fisheries frame surveys conducted from 2000 indicate an increase in the number of some of the major gear types. The number of gillnets increased from 650,000 in 2000 to over one million units in 2014, long line hooks from three million to over 14 million units and seine nets from 3000 units to over 18000 units over the same time period. Vessel propulsion, which specifies the nature of vessel navigation technology, is composed of three main methods; outboard engines, paddles and sails. There has been a four-fold increase in the number of fishing vessels using outboard engines from 4180 in 2000 to about 21,600 in 2014, paddled vessels which are the dominant fishing vessels increased by 30% and sailed vessels by 17% for the same time period (Table 1). This is indicative of the growing importance of vessel motorisation in the fishery with time.

Table 1: Key fishery effort variables in Lake Victoria (*Source;* regional frame survey reports 2000-2014)

Variable / Year	2000	2002	2004	2006	2008	2010	2012	2014	Change (%)
fishers	129,305	175,890	167,466	196,426	199,242	194,172	205,249	208,270	61
Vessels by the operation mode									
Outboard engines	4,108	6,552	9,609	12,765	13,721	16,188	20,217	21,578	425
Paddled	32,032	35,720	33,405	45,753	43,553	39,771	41,392	41,658	30
Sailed	6,304	9,620	8,672	10,310	9,811	8,424	7,871	7,346	17
Total Vessels	42,444	51,892	51,686	68,828	67,085	64,383	69,480	70,582	66
Major gear types									
GN	650,592	903,084	1,233,052	1,222,307	1,013,632	867,305	1,032,984	1,637,639	152
LL	3,496,247	8,098,023	6,096,338	9,044,550	11,267,606	11,472,068	13,257,248	14,217,648	307
SS	3,588	7,795	8,601	9,632	10,276	13,514	15,064	18,807	424

1.2.3 Fisheries management

Efforts to manage fisheries on the lake have been going on since the early 20th century when the fish protection ordinance was enacted (Geheb, 1997) and the first stock assessment was conducted in the late 1920s by Graham and in 1957 by Beverton (Kolding *et al*., 2014). These led to the first fishery regulation, the gillnet minimum mesh size regulation for the native Tilapia fishery. In 1947, the Lake Victoria Fisheries Services (LVFS) was formed to enforce fisheries regulations. This was later taken over by the East Africa Freshwater Fisheries Research Organization (EAFFRO) in 1960, which was disbanded with the dissolution of the East African Community in 1977. In 1994, the Convention on Lake Victoria Organisation was signed by the three East African Community Partner States namely Kenya, Tanzania, and Uganda leading to the current regional Lake Victoria Fisheries Organization with its headquarters in Jinja Uganda. The management approach with the earlier institutions (LVFS and EAFFRO) were based on top-down enforcement of fisheries management measures, with little consultation and participation of fishing communities (Nunan *et al*., 2015). Later, the co-management approach was introduced in 2000 based on the donor-driven need to involve the communities in small-scale fisheries management which was being promoted all over the world (Jentoft *et al*., 1998). On Lake Victoria, this was responding to the growing concern relating the prevalence of illegal fishing practices on the fisheries resource and the inadequate capacity within the central governments to effectively manage the lake fisheries (Nunan *et al*., 2015; Kolding, 2013). Consequently, management of the Lake Victoria fisheries is undertaken at different levels from the local, national and regional levels with fishery policies and regulations set at both the regional and national levels. Implementation of these policies and regulations is the core role of the local community management or Beach Management Units (BMUs) with the help of the national governments (Nunan *et al*., 2015).

In Uganda, fisheries management is guided using laws and policies specified in the Fish protection ordinance of 1950, Uganda's Fish Act 1970, the fisheries act cap 197 of 2000 and the National Fisheries policy 2007. From these, the most common regulations enforced by the department of fisheries through the BMUs include a mesh size regulation for gillnets, gear ban of gears like cast nets, beach seines and monofilament gill nets, licencing and vessel/fisher registration.

1.3 The objective of the study

The main objective of the study was to determine the performance of the Lake Victoria fishing fleet in Uganda. Specifically, the study also determined the;

- Technical efficiency changes of the fishing fleet over time; and
- Fishers' perceptions of the nature of their production environment.

1.4 The significance of the study

The fisheries resources in Uganda are important to the nation's socio-economic development, contributing about 2.5% to the national GDP and 12% to the agricultural GDP. Fisheries generate foreign exchange and provide livelihoods, income and food security to about 1.2 million people (UBOS, 2016). In Uganda, Lake Victoria contributes to almost half of the total fish production (DFR, 2012). Therefore any information towards the development of the fishery is vital to the fisheries managers.

According to Vision 2040, a development strategy, the Uganda government emphasizes the need for sustainable utilisation of the natural resources for socio-economic and environmental benefits (The Republic of Uganda, 2012). The results of the study are expected to contribute to the sustainable utilisation of the fishery resources in Uganda. The outcomes may support resource managers, policymakers, fishers and other relevant stakeholders in the fishery sector in making informed decisions to promote the sustainable management of fisheries resource in Uganda. Furthermore, the knowledge gained from this study could be applied to other Lake Victoria riparian countries such as Kenya and Tanzania in addition to other entities within the fisheries sector such as fish factories and aquaculture.

1.5 Research questions

In order to ascertain the performance of the fishing fleet, the technical performance of the existing fishing fleet and perception from the fleet users, the following research questions were considered;

i. What are the characteristics of the fishing fleet and how does the fleet differ from each other?
ii. What is the technical efficiency of the fishing fleet and how has it changed over time?
iii. What are the main factors affecting the fleet technical efficiency change and how have they varied over time?
iv. How has the fleet technology changed over time and what is the effect of technical efficiency change?
v. How do the current fisher perceptions relate to the technical efficiency changes of the fishing fleet?

1.6 Structure of the thesis.

The thesis comprises five main chapters summarised as follows.

In chapter one, the study gives an overview of technological changes of the fishing fleet in developing countries, the method used, objectives, research questions and significance of the study. In chapter two, a review of the concept of technical efficiency, its application in fisheries and possible methods; and a brief review of using the importance of fishers' related information in the study are given. In chapter three, a detailed account of the methodological aspects of the study, including the primary and secondary methods of data collection, the empirical model used to determine technical efficiency for the secondary data and organization of fisher perception data are discussed. In chapter four, the study results are given and are organized into two parts; the technical efficiency change of the fishing fleet and information from fishers about their production environment. The last chapter gives the discussion of the results, study limitations, recommendations and study conclusions are highlighted.

2 Literature review

2.1 Technical efficiency

2.1.1 Definition and scope

Technical efficiency is defined by Kumbhakar & Lovell (2000) as the ability of a firm to obtain maximum output from a given set of inputs or to produce an output using the lowest possible amount of inputs. According to Koopmans (1951) "a producer is technically efficient if an increase in an output requires a reduction in at least one other output or at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output". Therefore, a technically inefficient producer could produce the same output with less of at least one input or could use the same inputs to produce more of at least one output. The concept of technical efficiency, its measurement, and the factors determining it are of crucial importance in production theory of firms in economics (Fried, Lovell, & Schmidt, 1993). Technical efficiency can be illustrated in form of a simple production process involving a single input and output (figure 2).

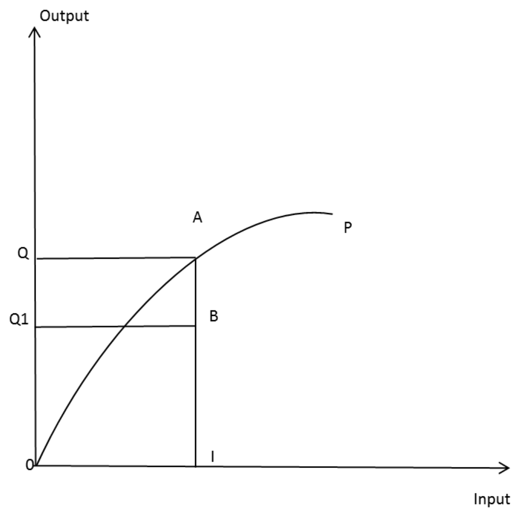

Figure 2: Technical efficiency of a single input-output production; technical efficiency score for an efficient firm is 1 and operates some point (AI) along the frontier OP whereas the technically inefficient firm has a score less than 1 and given as OQ1/OQ or BI/AI (Fried *et al.*, 1993).

Technical efficiency of a firm and the degree of use of variable inputs determines the output and capacity utilization of a firm's given technology. It is also worth noting that over time, for output maximising firms, the level of output a firm is capable of producing will increase due to technological changes that affect the ability of a firm to combine inputs

(Coelli *et al*., 2005). These technological changes cause the Production Possibility Frontier (PPF) to shift upwards as more output is obtainable from the same level of inputs. Therefore, determining the factors affecting it allows stakeholders to take measures to limit or improve it. Technical efficiency measurement has been applied to a variety of firms ranging from small to large firms and also in different economic sectors in business, national accounts and in resource management. In this study, the application is based on fisheries resources.

2.1.2 Technical efficiency in fisheries

The concept of efficiency in fisheries economics was earlier suggested by Schaefer (1954) and Scott (1955). These studies conveyed the idea of input usage in terms of effort variables used in fishing and the output variables as either the fish catch or revenue or sometimes both. In estimating efficiency, the primal production theory used for estimating firm efficiency is determined using four key determinants; capital, labour, energy and materials (KLEMs). However, in fisheries production literature, studies have applied composite effort variables to represent the production function depending on the researcher's objective (Morrison *et al*., 2010). The capital input for example in fisheries is heterogeneous involving vessel-specific measures such as engine size/power and gear stock, fishing strategies such as duration of hauls and one can consider representing all or a few of the capital inputs (Felthoven *et al.,* 2009; Morrison 2010). In doing so, heterogeneity of the capital input is accounted for, the different variables can also be distinguished and the constrained inputs can be substituted. Besides, distinguishing the inputs that are constrained like vessel characteristics can allow for substitutability between the constrained and unconstrained outputs. This helps determine the degree to which input controls (like boat size and engine power) in fisheries are likely to be effective and also their effect on the efficiency of fishery participants (Kompas *et al.*, 2004; Morrison 2010). Another important component is the ability to determine the effects of fishing technology embodied in the fishing fleet such as fish finders or fish aggregating devices (Natsir, 2016) whose input in a fishery affects efficiency; and fishery regulations such as gear limitations and management regimes like ITQ's (Morrison, 2010). Similarly, user/fisher variables such as skipper experience can also be used to determine fleet performance and can be obtained by using proxies such as education and fishing experience. These are considered as unobservable inputs in the production process which are not expressed in the original production function (Kirkley & Squires, 1998; Eggert, 2001; Squires *et al.,*2003; Lokina, 2009 and Morrison, 2010).

In the case of outputs, some fisheries are composed of single species, although majority have multiple species. Therefore, the production structure specification can also be used in measuring efficiency to incorporate multiple outputs/species (Madau, Idda, & Pulina, 2009; Squires,2003; Herero et al, 2006; Färe *et al.*, 2006). This, therefore, enables analysts to examine the degree of jointness or separability among the species impacting how the different species should be managed (Morrison, 2010).

Lastly, the production environment also affects fishing as an economic activity. This can be through random shocks such as movement of fish stocks, seasonal variations in stock availability or unavoidable weather factors that affect efficiency. Therefore, in the specification of efficiency models, researchers ought to consider this randomness (Morrison *et al*., 2010).

Efficiency studies in fisheries have been used widely in both small scale (see Pinello et al, 2016; Anene *et al.*, 2010 ; Jinadu, 2000; Squires *et al.,* 2003;Pham *et al.*, 2014) and commercial fisheries (Felthoven, 2000; Madau *et al*., 2009; Morrison, 2000) to tackle issues related to fishing capacity and capacity utilisation (Pham *et al.*, 2014; Felthoven, 2000; Madau *et al*., 2009; Morrison, 2000) and risk analysis (Herrero, 2004). Since economic inefficiency of fisheries might be a result of overcapacity, many researchers have focused on how to measure efficiency with regards to the fishing capacity (Morrison, 2011). Overcapitalisation in fisheries develops as a result of market imperfection, such as absence of clear property rights leading to problems including over-investment in fishing boats, gear and outboard engines, too many fishers/over manning, reduced profit, deterioration of livelihoods, increasing conflict in the fishery, and political strife in the management process (Pomeroy, 2012). Modelling and measuring of the fleet efficiency are aimed at enhancing fisheries' performance either by reducing fishing inputs due to overcapitalization or as a way to improve input variables through technological modifications of the fleet such as vessel size and engine fuel efficiency among others. Cases of these have largely been applied in developed industrial fisheries in Norway, Iceland, and Italy among others (Curtis & Squires, 2008).

Considering fisheries in developing countries, cases of overcapitalization have been reported in the coastal fisheries of South East Asia where over manning was reported (see Pomeroy, 2012) and also in Nigeria were artisanal inshore fisheries were more efficient than the overcapitalized offshore trawl fisheries (FAO/DANIDA, 1998). Most technological improvements in the fisheries of developing countries are based on subsidies, indicating the negative implication of subsidies on a fishery in improving the performance of the vessels (Kirkley & Squires, 1998).

2.1.3 Methods for determining technical efficiency

Various tools have been proposed or developed and applied to determine efficiency in fisheries and other sectors. These include the parametric Stochastic Frontier Analysis (SFA) method, the non-parametric Data Envelopment Analysis (DEA) and econometric transformation models (Fried, Lovell & Schmidt, 1993). In fisheries, most technical efficiency studies have focussed on SFA and DEA. Comparisons between these methods have been studied by Herrero (2005) and can be applied based on researchers objectives. The advantage of DEA over SFA is that it can be used for multi-species fisheries as it considers multiple inputs and outputs in the analysis whereas SFA is basically applicable to single species fisheries i.e. multiple input-single outputs. On the other hand, the SFA's functional structure can account for and specify vessels technical inefficiency caused by randomness, vessel characteristics or both. Since fishing is a stochastic activity susceptible to random shocks such as weather and seasonal stock variations, the study employed the SFA to assess the technical efficiency of the Lake Victoria fishing fleet.

Unlike the DEA, the SFA model specifications present a natural way of modelling technical efficiency change for multiple observations over a period of time (Schmidt *et al*., 1993). Since the study aims at determining technical efficiency change over time using panel data for the Lake Victoria fishing fleet, it is therefore more reasonable to use the SFA over the DEA.

2.1.4 Model specification-Stochastic Frontier Analysis

The Stochastic Frontier Analysis (SFA) was first proposed by Meeusen and Van den Broek (1977) and Aigner, Lovell, and Schmidt (1977). The authors applied the method to cross-sectional data, specifying one sided-error distribution for inefficiency. Later, the SFA method was further modified by Greene (1980a, 1980b) to include the distributional related ideas;

Stevenson 1980 who let the mode of inefficiency to be positive and Jondrow *et al.*, (1982) who discovered an estimator for the level of inefficiency. Based on Aigner, Lovell, & Schmidt (1977), the SFA follows a natural estimation method of maximum likelihood method (MLE) due to the parametric assumptions of the model. The parametric assumptions include the half-normal model, assuming that the inefficiency components $U_i s$ are identically and independently distributed (idd) half-normal random variables with variance $\sigma_u^2(u_i \sim idd\ N^+\ (0, \sigma_U^2))$ and statistical components $V_i s$ are normally distributed with zero means and variance $\sigma_v^2(v_i \sim idd\ N\ (0, \sigma_v^2))$. However, Schmidt and Sickles (1984) noted that stochastic frontier models that use cross sectional models have three major shortcomings. First, the consistency of the technical efficiency estimates of a given firm can vary from one period to another since the variance of distribution is conditional on the whole error term for each producer does not vanish as the size of the cross section increases. Secondly, the MLE based on the SFA and separation of the technical inefficiency from statistical noise, both require a strong distributional assumption that is to say, half-normal for the earlier and normal distribution for the latter. Finally, the assumption that the non-negative technical inefficiency error components are not related to the independent variables in the model could be biased since the firms technical inefficiencies could be correlated with their input choices. Technical efficiency using the Stochastic Frontier Production function on Lake Victoria was earlier conducted by Lokina (2009) to determine the technical efficiency of the fishing fleet for the Nile perch and mukene/dagaa/omena fishers using cross sectional data. In this study, the function was extended to panel data to determine technical efficiency changes in the fishing fleet for the same species.

Stochastic frontier production model for panel data

A panel data set has multiple entities, each of which has measurements at different time periods. Basically, a panel data occurs in the form;

$y_{it} = \alpha + f(x_{it}b) + \epsilon_{it}$ for X_{it} , $i = 1, \dots . . N\ t = 1, \dots \dots . T, \dots \dots \dots$.Equation 1

Where i is the vessel dimension and t is the time dimension.

y_{it} is the (log) output of vessel i at a given time t;

$f(x_{it}b)$ is a function that indicates functional form (e.g. Cobb-Douglas or translog) of the production function.

x_{it} is a $(k\ X\ 1)$ vector of vessels $i\'s$ input quantities at time t and b is a vector of unknown parameters.

The error term is specified as;

$\epsilon_{it} = v_{it} - u_{it}$ … … … … … ..Equation 2

Where, v_{it} is the statistical noise assumed to be identically and independently distributed (idd) $N(0, \sigma_v^2)$ and independent of the u_{it} are the non-negative random variables assumed to account for technical efficiency (see definition above). The v_{it} represent those effects that cannot be controlled by a vessel, considering in fisheries these can occur as weather conditions and measurement errors.

2.2 Fishers' perceptions

Aggregate production functions fail to consider policy invariant parameters/effects on fishers' choices and behaviour to maximize output based on existing policies and management institutions (Reimer *et al*., 2017). Therefore, besides using the production models to represent performance in fisheries, interviews with fishermen or contingent-behaviour experiments may provide researchers with valuable supplementary data to help select and explain models that are robust across the necessary range of institutional circumstances. Therefore, fishermen behaviour and perceptions towards the nature of their production environment was also sought with a series of questions involving their thoughts on the catches, challenges faced and effect of the existing management institutions.

3 Material and Methods

3.1 Study area

The study was based on the fisheries of Lake Victoria Uganda characterized by a heterogeneous fishing fleet with differences in gears used, vessel operation, and target species among others. For the sake of this study, six landing sites were selected; two in the district of Buikwe (Kiyindi and Kikondo), two in and Kalangala (Nakattiba and Kasenyi); and one in each of the districts Wakiso (Kasenyi) and Kampala (Gaba) (Figure 3.). The landing sites (apart from Kikondo) were selected using a two-stage stratified random sampling with the first stage composed of primary sampling units (PSUs) selected as a subsample of Catch Assessment Survey sites (NaFIRRI, 2014). At the second stage, secondary sampling units (SSUs) involved fisher/boat owners selected randomly at the specified PSU.

The stratification of the primary sampling units aimed at obtaining data based on major target species at the landing site as Kikondo and Kiyindi were selected for the Dagaa fishery, Nakattiba and Kasenyi-Wakiso specifically for the Nile perch fishery; and Kasenyi-Kalangala and Gaba with mixed fishery (Nile perch, Tilapia, and Dagaa). Other factors also included geographical representation (Figure 3) and also major vessel propulsion types as Kikondo was purposively selected to obtain data from Mukene/dagaa fishers using paddled vessels. Sail boats were excluded since they were seldom sampled encountered during the survey. Prior to the

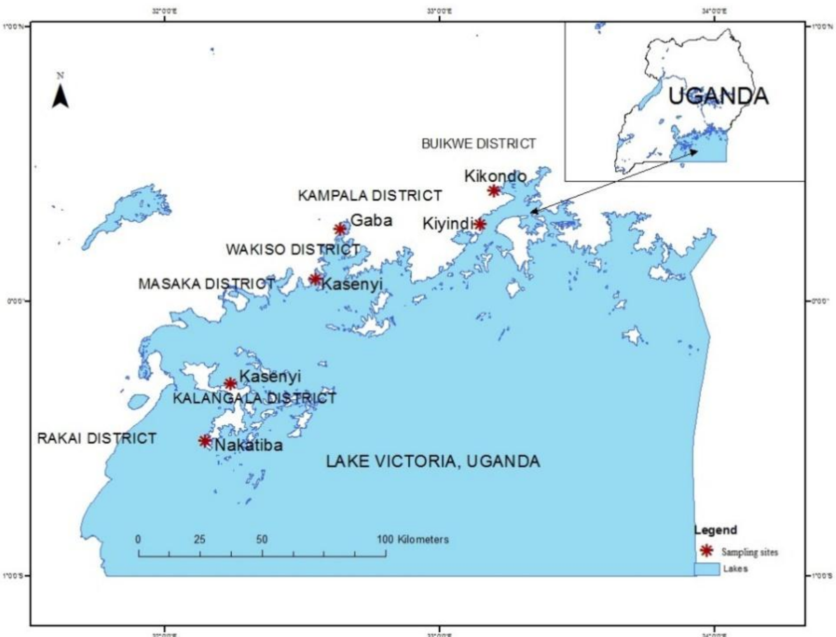

Figure 4. Study area and reference landing sites.

survey, selection of the landing sites was guided by frame survey data statistics (NaFIRRI, 2014).

3.2 Data

In order to answer the objectives of the study, data requirements were twofold and are described to represent technical efficiency data variables and fishers' perceptions.

3.2.1 Technical efficiency

In order to estimate the technical efficiency of the fishing fleet, eight-year panel data[1] (2005-2008; 2010-2011; 2014-2015) on the fishing vessels of five Lake Victoria riparian districts in Uganda was acquired from the stock assessment unit of National Fisheries Resources Research Institute (NaFIRRI). The panel structure of the data was organized as a series of independent cross-section surveys carried out in the given years. The organization was based on Deaton (1985) and Verbeek (2007) who suggested that individuals sharing common characteristics can be grouped into cohorts (e.g. vessel propulsion and gear type) and treated as observations in panel data. One major limitation of using repeated cross-section observations as panel data is that the same individuals are not always followed over time as it is with most panels. However, this type of panel data suffers less from problems of attrition and non-response from individuals and often has a substantially larger number of observations for both individuals and in time (Verbeek, 2007).

In the existing panel data, the study considered the variable catch as the output variable and gear numbers, and labour and fuel as the input variables for the SFA model. For the study, the choice of variables was based on physical capital measures (quantities) other than economic capital measures (prices) since the estimated function is a production possibilities frontier. According to Pascoe & Mardle (2003), both physical and economic variables can be used in the SFA model, however, the use of economic information is advantageous because it enables one to account for the whole capital stock which is not the case with physical measurements. It should, however, be noted that the selection of physical units in the present study is because the data on the physical measures such as gear numbers, number

[1] Series of catch assessment surveys conducted with support from the Implementation of Fisheries Management Plan (IFMP) project during 2005-2008; and Lake Victoria Environmental Management Program (LVEMP1) 2011 and 2014 & 2015 by LVEMP2.

of crew and hours fished were readily available in the panel than the economic data. It is also important to note that fuel (in litres) was not in the panel data however was considered in the cross sectional survey.

Fuel acts as a key input variable used by vessels especially in getting to their destined fishing grounds. Therefore, selection of the fuel variable was to characterise vessel technology by assessing the performance of the vessels using outboard engines dependent on fuel and those using paddles. Therefore, for purposes of including the fuel variable in the existing panel data to fit the theoretical model, an independent cross-sectional study was conducted from six landing sites as specified in the study area. The questionnaire used in the survey was a modified questionnaire of the Catch Assessment Survey[2] to include the fuel use by motorized vessels, a missing input variable in the panel data.

Based on the empirical estimation of the cross-sectional data, the fuel model was estimated using a forward stepwise selected model (James *et al*., 2014) and specified as;

$$9.01 + 0.02\,catch + 0.91\,Kasenyi_{Kalangala} + 3.4\,Kasenyi_{Wakiso} + 16.4\,Kiyindi + 6.3\,Nakatiba - 0.3\,Kikondo - 0.86\,vessel\_length + 0.12\,labour \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 3}$$

The fuel model was largely related to the fleet location, labour component, amount of catch and vessel length (Equation 3). The adjusted R square for the model was at 66% (cross-sectional data statistics in Appendix 1 and fuel model in Appendix 2) thus a reasonably good model for predicting fuel for the SMS and SP-SS vessel groups.

Summary statistics for the variables used in the stochastic frontier analyses are presented in Table 2 and in Appendix 3 for the time variation for the different variables.

From the data, six vessel-groups were identified and organized based on vessel propulsion mode and gear used; initials SMS are used for the motorized vessels and SP for paddled vessels fishing with either gillnets (GN), long lines (LL) or small seine nets (SS). It is also noteworthy that the SMS-SS group in the panel was available for only three years (2011, 2014 and 2015) opposed to eight years in the other vessel groups.

The mean values of trip-level data on the number of gears used, fuel quantity in litres and labour (product of crew number and hours fished) are presented as input variables and catch

[2] Catch Assessment surveys are surveys aimed at the fish harvest sector to generate information relating to both fish catches and fishing effort.

in kilograms as the output variable for the SFA model. Given the statistics, the mean fish catch and gear numbers in motorised vessels exceeded that from paddled vessels. The fuel variable was specific to SMS vessel groups and paddled seine nets (SP-SS), was highest for SMS-SS vessel group (26.51 ± 5.04 litres) and lowest for the SMS-LL vessels (8.43 ± 3.39 litres). The seine net fishing vessels, SMS and SP-SS target dagaa/omena/mukene which is a light-attracted species, thus fuel is required for lighting the fishing lamps and was considered for both propulsion and fishing.

The number of gears for long line and gillnet vessels is counted as individual units whereas the number of units in the seine net vessels (SMS-SS &SP-SS) was considered based on the number of panels. The latter gear is built such that, individual units (called panels in the data) are stacked to make one fishing gear and the number of units/panels stacked can be different between the two vessel groups as SMS-SS vessels (9.94 ± 1.74) had more units than SP-SS (7.12±1.85). Besides, long line vessels also use bait, therefore, an assumption is made to represent this input variable vis-à-vis the number of gears. Lastly, the labour input was highest for SMS-SS (30±10.4) and lowest for SP-GN (17 ±7.8).

Table 2: Summary statistics for the SFA model variables for the different vessel groups.

Variable	Measure	Statistics	SMS			SP			Total
			GN	LL	SS	GN	LL	SS	
Fish catch	kilograms	Mean	23.81	41.25	283.36	12.02	22.57	190.21	561.2
		Std Dev	23.63	48.19	247.85	15.18	24.28	181.24	540.4
		Min	0.00	0.00	0.00	0.00	0.00	0.00	0.0
		Max	302	540	1820	400	412	1600	5074.0
Gear	Number of units	Mean	60.39	776.96	9.94	28,2	369.12	7.12	1223.5
		Std Dev	16.76	647.35	1.74	24,13	341.42	1.85	1009.1
		Min	1.00	1.00	4.00	1.00	1.00	2.00	10.0
		Max	320	12000	14	600	9000	13	21947.0
Fuel	Litres	Mean	11.33	8.43	26.51	-	-	8.62	53.8
		Std Dev	3.05	3.39	5.04	-	-	3.83	13.1
		Min	4.23	2.2	18.42	-	-	4.7	29.6
		Max	22.23	27.81	55.01	-	-	36.9	127.3
Labour	Crew*hours fished	Mean	19.54	22.45	30.45	17.28	18.64	29.54	137.9
		Std Dev	5.49	9.84	10.37	7.75	8.17	13.39	47.30
		Min	2.00	3.00	8.00	1.00	1.00	4.00	18.00
		Max	72.00	108.00	60.00	80.00	80.00	80.00	480.00
Years observed			**8**	**8**	**3**	**8**	**8**	**8**	**8**
Sample (n)			**7149**	**2217**	**289**	**12064**	**3796**	**1102**	**26617**

3.2.2 Fisher perceptions

Data were obtained through face-to-face interviews with fishers and boat owners using a semi-structured questionnaire during the period June-August 2017. The questionnaire aimed at obtaining fishers perceptions on the fishery and was arranged to capture information on:

i) Respondent information such as fishing experience, age, gender, number of dependants and their involvement in fishing activities, occupation in fishing activity (Boat owner or crew), involvement (full-time/part-time), Vessel-gear combination used as well as the targeted species;

ii) fishery production related questions such as the choice of fishing site, status of catches and challenges faced in fishing as an economic activity (production environment)

iii) fisheries management related questions such as knowledge and perception of the existing regulations, the status of catches for the targeted species, existing management and regulations, their suggestions for effective management in the fishery.

Questions on fishery production and management were ordered questions following a categorised (yes/no) and Likert scale to obtain responses on how important or severe the aspect was to them.

3.3 Data analysis

3.3.1 Technical efficiency

Technical efficiency estimation requires an input-output relationship of a firm. For this study, the output variable was specified based on two main target species Nile perch and mukene/dagaa/omena since they were the dominant species during the survey albeit some vessels targeted other species too. In cases where a vessel was recorded with more than one target species, output was standardised to represent these two species. This was done using a formula specified;

$$Y_{Np} = \sum_{S=1}^{S=n} \frac{y_t p_t}{p_{Np}} \text{..........Equation 4}$$

Where, Y_{Np} is the total catch of a particular vessel represented in terms of species Np say Nile perch.

y_t represents catch of another species obtained in the same the vessel say tilapia and;

p_t is the price of a kilogram of tilapia and p_{Np} is the price per kilogram for Nile perch of the vessel.

3.3.2 Empirical model

Estimation of the SFA model requires a particular functional form of the production function. There is a range of functional forms available for the production frontier. The study focuses on the two commonly used specifications, the Cobb-Douglas (Equation 5) and the Translog production function (Equation 6). The Cobb-Douglas is a restricted model that includes parameters as first-order functional form whereas the translog is a less restrictive functional form that also includes second-order parameter interactions to provide the second order approximation (Coelli, 2005). The specifications are indicated as;

Cobb-Douglas functional form;

$$\ln Y_{it} = In\, \alpha + \beta_1 \ln N_{it} + \beta_2 \ln F_{it} + \beta_3 L_{it} + \beta_t t\, \epsilon_{it} \text{.......................Equation 5}$$

The translog functional form;

$$\ln Y_{it} = In\,\alpha + \beta_1 \ln N_{it} + \beta_2 \ln F_{it} + \beta_3 L_{it} + \beta_t t + \tfrac{1}{2}\beta_{NN} \ln N_{it}^2 + \tfrac{1}{2}\beta_{FF} \ln F_{it}^2 + \tfrac{1}{2}\beta_{LL} \ln L_{it}^2 + \beta_{NF} \ln N_{it} \ln F_{it} + \beta_{NL} \ln N_{it} \ln NL_{it} + \beta_{FL} \ln F_{it} \ln L_{it} + \epsilon_{it} \text{......................Equation 6}$$

where the subscripts i and t refer to the $i - th$ vessel observation at time period t.

α **,** is the production frontier intercept common to all producers in the period t

Y_{it} , represents the catch in kilograms for two main species that is Nile perch for the longline and gillnet vessels; and dagaa for the small seine vessels.

N_{it} , represents the total number of gears

F_{it} , represents the quantity of fuel used in litres

L_{it}, represents the labour used as a product of the number of crew per boat and the hours fished

t, represents a time trend used as a proxy for technical change for a given vessel group

Technical change, in this case, is used to describe the ability of a vessel to produce more (or less) with a given vector of inputs quantities in the period t in comparison to the levels feasible in period *s* (Coelli, 2005).

In equation 6, the study accounted for constant and non-neutral technical change.

However, it is also important to note that technical change is not always constant in production activities especially in stochastic activities such as fishing. Therefore, a production function that accounts for increasing or decreasing rates of technological change as well as biased (input specific) technological change by including a quadratic time trend and interaction terms between time and input quantities as indicated in Equation 7.

Therefore, the model in Equation 7 can further be specified as;

$$\ln Y_{it} = In\,\alpha + \beta_1 \ln N_{it} + \beta_2 \ln F_{it} + \beta_3 L_{it} + \beta_t t + \tfrac{1}{2}\beta_{NN} \ln N_{it}^2 + \tfrac{1}{2}\beta_{FF} \ln F_{it}^2 + \tfrac{1}{2}\beta_{LL} \ln L_{it}^2 + \beta_{NF} \ln N_{it} \ln F_{it} + \beta_{NL} \ln N_{it} \ln NL_{it} + \beta_{FL} \ln F_{it} \ln L_{it} + \tfrac{1}{2}\beta_{tt} t^2 + \beta_{Nt} t \ln N_{it} + \beta_{Ft} t \ln F_{it} + \beta_{Lt} t \ln L_{it} + \epsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{. Equation 7}$$

Production function given in equation 7 does not impose restrictions on the Returns To Scale (RTS) or the elasticity of scale function $f(x)$ and the Rate of Technical Change (RTC). In this regard, the RTS can be estimated from the sum of the marginal elasticity of output with regard to each input. The elasticity of scale can be estimated from the sum of the marginal elasticity of output with time regard to each input specified as;

$f(x) = \sum_{i=1}^{n} \frac{\partial lny}{\partial lnx_i} = \alpha_t + \sum_j \beta_{ij} lnx_j + \delta_i t$……………………..Equation 8

The function $\boldsymbol{f(x)}$ is not only vessel specific, it varies overtime unless the production function is homogenous of degree one. Therefore, Equation 8 defines elasticity of scale as a directional elasticity of the production function.

Besides, the Rate of Technical Change (RTC) this is derived as;

$RTC = \frac{\partial lny}{\partial t} = \gamma_t + \gamma_{tt} t + \sum_j \beta_j lnx_j$ … … … … … … … … … … … …..Equation 9

Technical progress is neutral if $\boldsymbol{\delta_j} = 0, j = 1, \dots \dots n$

Where lnx_j represents the vessel input quantities.

The model contains the term ϵ_{it} represented as the error term. This is further decomposed into two components specified as;

$\epsilon_{it} = v_{it} - u_{it}$ … … … … … … … ….Equation 10

v_{it} representing the random noise and u_{it} representing the technical inefficiency component. Since the aim of the study was to determine vessel technical efficiency for a given period of time, the study therefore applied a model specification of Battese & Coelli (1992) to determine the technical inefficiency u_{it} of a vessel i at a given time period t. This is further specified as;

$u_{it} = \{\exp[-\eta(t-T)]\}u_i$………………..Equation 11

Where, $t \in g(i); i = 1,2, \dots \dots \dots N$

Where η Is an unknown scalar parameter that captures the temporal variation of the firm's output-oriented technical efficiency. The parameter u_i are assumed to be independently and identically distributed as truncations at zero of the variance $N\ (0, \sigma_u^2)$ distribution. The level of technical efficiency of a vessel in period t is obtained as;

$TE_{it} = \exp(-u_{it})$ … … … … … … … … … … … … … … … …..Equation 12.

With the best predictor of the $\exp(-u_{it})$ obtained by using the conditional expectation of $\exp(-u_{it})$ given ϵ_{it}, $[(\exp(-u_{it})\ /\epsilon_{it}]$. In this specification, the exponential function is given as $\exp[-\eta(t-T)]$ has a value of one when t=T, the random variable u_i can be considered as the technical inefficient effect of the $i-th$ vessel in the last period of the panel. The nature of a firm's technical efficiency depends on the sign of the parameter η, If η is positive, then the model shows increasing technical efficiency) whereas a negative η sign is indicative of decreasing technical efficiency (Coelli et al., 1998).

The main disadvantage of this specification is that the ordering of the firms according to the magnitude of the technical inefficiency effects is the same at all periods (Coelli, 2005). However, in the study, vessels are organized based on an aggregate representation of the fleet characteristics (vessel propulsion and gear) rather than individual vessels.

The study also employs the parameterisation of Battese *et al.*, (1977) who replace σ_v^2 and σ_u^2 with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$. This helps in decomposing the error components with significant emphasis on the inefficiency term u. The parameter gamma (γ) must lie between zero and 1. If $\gamma = zero$, it indicates that the deviations from the frontier are due to entirely random noise (v) whereas if $\gamma = one$ indicates that the deviations from the frontier are entirely due to inefficiency effects (u) in the model.

Prior to the final model specification for the Lake Victoria fishing fleet, different hypothesis were tested and these included;

i. The structural form of the production function that is the Cobb-Douglas specification (Equation 5) or the translog specification (Equation 6).
ii. Presence of constant and neutral technical change $(\beta_t t)$.
iii. Presence of time-varying assumptions (η) of the inefficiency term (u_{it})

These were tested using a generalized likelihood ratio test specified;

$\lambda = -2\{\log[L(H_0)] - \log[L(H_1)\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.$ Equation 13.

Where $\log[L(H_0)]$ and $\log[L(H_1)]$ are obtained from the maximized values of the log-likelihood function under the null hypothesis (H_0) and the alternative hypothesis (H_1). Additionally the L,-R statistic has a chi-square distribution with degrees of freedom equal to the number of restrictions involved in a given test. Prior to the estimation of the models, the data were normalized such that the mean value of each logged variable was zero following Coelli *et al.*, (2005). Estimation of the SFA model and prediction of technical efficiencies for the fishing fleet was then performed using R 3.2.2 software (R Core Team, 2017). In the R, packages frontier developed by Coelli & Henningsen (2013) and plm, special package for panel data developed by Croissant & Milo (2008) were used for the analysis.

3.3.3 Fisher perceptions

Fisher perceptions determined from the quantitative survey data obtained were analyzed using non-parametric tests in SPSS (IBM SPSS, 2013). Responses followed a categorical yes/no and Likert scale type format measuring the level of agreement or disagreement with the question. Descriptive statistics of the respondent's profile and vessel characteristics were obtained based on frequencies. To test for significance between variables, Chi-square tests for independence were conducted to test for dependent relationships between variables with the level of significance (α) determined at α = 0.05. For the case Likert scale questions, the five-point Likert type scale questions (from strongly agree, agree, neutral, disagree and strongly disagree) were collapsed to three (agree, neutral, disagree) for simplicity in analysis and interpretation. Responses were grouped to represent the main target species that is dagaa, Nile perch, and tilapia.

4 Results

4.1 Respondents profiles and fishery characteristics

A total of 273 respondents from six landing sites of Gaba (25), Kasenyi-Wakiso (36), Kikondo (47), Kiyindi (82), Nakattiba (45) and Kasenyi-Kalangala (38) were obtained (Table 3). Of the 273 respondents, 49% engaged in the Nile perch fishery, 48% engaged in the dagaa fishery while the remaining few engaged in the tilapia fishery. Respondents were predominantly male (99%), with the few women participants specializing in the dagaa fishery. Majority engaged in fishing as crew (86%) while others were vessel owners (13%) and managers (1%) specifically in the Nile perch fishery. Fishing experience in the study was divided into three groups; involving new entrants with five years' experience or less (45%), experienced fishers with six to fifteen years of experience (33%), and very experienced fishers with more than 15 years of experience (22%). Overall, fishers experience increased with age (Figure 4). Engagement in fishing activities was considered a full-time activity by the majority (88%) of the respondents and those who were part-time fishers engaged in other activities such as farming, fish trade, and small-scale businesses. Half of the respondents engaged some of their household members in fishing activities, from which 90% engaged them as fishing crew while 10% engaged them in other related activities such as net preparation and fish trade. In terms of leadership positions, only 7% of the respondents interviewed held positions with the local beach management.

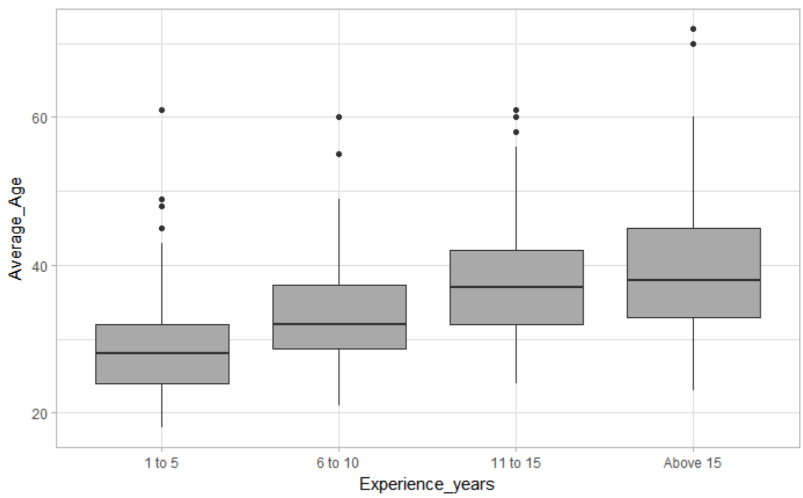

Figure 5: The relationship between fishers experience and age.

A relatively high number of respondents (74%) operated in motorized vessels than paddled ones in all fisheries, however, paddled vessels were more common with the dagaa fishery (n=44) than the Nile perch (n=23). The type of gears used was related to the target species that is; Nile perch fishers largely used gill nets and long lines whereas dagaa fishers predominantly used seine nets. Ownership of vessels varied between the two fisheries as the average number of vessels owned in the Nile perch fishery had a wide variation albeit relatively higher (6.45 ± 8.8) than for the dgaa fishery (1.41 ± 0.7). In case of other target species, Nile perch fishers were likely to also target tilapia, lung and catfish; whereas the dagaa fishers were also likely to target haplochromine species.

Table3: Respondent and fleet characteristics based on the type of fishery- Nile perch, dagaa and tilapia.

		Type of fishery.			
Variable	**Description**	**Nile perch**	**Dagaa**	**Tilapia**	**Grand Total**
Status of respondent	Boat manager	2			2
	Boat owner	9	28	2	39
	Crew member	123	104	5	232
Gender	Men	134	129	7	270
	Women		3		3
Education level	No education	32	15	-	47
	Primary level	79	83	4	166
	Secondary level	19	29	2	50
	Tertiary level	4	5	1	10
Age	Average	32.7	34.4	34.3	33.6
	St Dev	8.8	10.2	12	9.6
Involvement in fishing	Fulltime	119	116	6	241
	Part-time	15	16	1	32
Experience in fishing	1 to 5 years	53	64	3	120
	6 to 15 years	51	39	2	92
	Above 15 years	30	29	2	61
Number of dependants	Average	3.7	4	1.6	3.8
	St Dev	4.8	4.7	2.1	4.7
Household help in fishing	Yes	65	73		138
	No	69	59	7	135
Household activities	Fishing crew	62	58		120
	Post-fishing	3	11		14
Involvement in management	Yes	12	7	1	20
	No	122	125	6	253
Vessel operation	Motor Engine	111	88	3	202
	Paddle	23	44	4	71
Vessels owned per boat owner	Average	6.45	1.4	3	2.9
	StDev	8.8	0.7	2.8	5.1

		Type of fishery.			
Variable	**Description**	**Nile perch**	**Dagaa**	**Tilapia**	**Grand Total**
	Min	1	1	1	1
	Max	32	3	5	32
Gear used	GN	110	-	7	117
	LL	19	-		19
	SS	4	129		133
	Others	1	3		4
Other target species	Haplochromines	-	6	-	-
	Lung and catfish	8	-	-	-
	Dagaa	4	-	-	-
	Tilapia	27	-	-	-
	Synodontis	-	-	1	-
Landing site	**Gaba**	**20**	**3**	**2**	**25**
	K-Wakiso	**35**	**1**		**36**
	Kikondo	**4**	**43**		**47**
	Kiyindi	**7**	**75**		**82**
	Nakattiba	**36**	**9**		**45**
	K-Kalangala	**32**	**1**	**5**	**38**
Sample	**N**	**134**	**132**	**7**	**273**

4.2 Technical efficiency

4.2.1 Hypothesis testing

Considering Equation 14, different hypotheses were tested. For a good structural form of the model, different hypotheses were tested and results indicated in Table 4. In the first step, the hypothesis was tested to determine a representative structure of the production function based on the two functions given as the Cobb-Douglas (Equation 5) and translog production function (Equation 6). For all the vessel groups, the Cobb-Douglas specification was rejected in favour of the translog specification (Table 4). In general, the translog production function places no functional constraints on the returns to scale, the elasticity of substitution and homotheticity thus the input and substitution elasticity is not under constant returns but rather variable returns to scale (Lundvall and Battese, 2000) for all vessel groups. Secondly, the hypothesis for technical change was tested for all vessel groups and two equations were run where H_0 represents constant and neutral technical change (Equation 6) and the H_1 (Equation 7) represents non-constant and non-neutral technical change. The H_0 in this case was also rejected in favour of the alternative hypothesis for all vessel groups. Finally, the H_0 of time-invariant technical inefficiency was tested, similar to the above mentioned tests, the two models were also considered with H_0 as in Equation 6 to represent time-invariant technical inefficiency and the H_1 formulated as Equation 7 with an extra parameter Eta (η) representing the technical inefficiency temporal variation specified in Equation 11 to represent a model with time variant technical efficiency. The null hypothesis involving time invariant technical inefficiency was rejected for all vessel groups indicating that the technical inefficiency component u_{it} of the vessel groups varied over the specified time period. For all hypothesis tested, the log-likelihood values indicated in Table 4 for the H_1 were significantly maximised (lower negative likelihood) compared to the null hypothesis (H_0) and accepted at 5 percent level of significance or less.

Table 4: Statistics for the hypothesis tests of the stochastic frontier production model.

Vessel group	Hypothesis	Log-Likelihood		Chi-square	p-value	Decision
		$\log[L(H_0)]$	$\log[L(H_1)]$			
		Cobb-Douglas Vs Translog function				
SMS-GN	$H_0: \beta_{NF} = \beta_{NL} = \beta_{LF} = 0$	-10860	-10817	84.85	3.5e-16 ***	Reject H_0
SP-GN	$H_0: \beta_{NF} = \beta_{NL} = \beta_{LF} = 0$	-19910	-19694	430.96	2.2e-16 ***	Reject H_0
SMS -SS	$H_0: \beta_{NF} = \beta_{NL} = \beta_{LF} = 0$	-299.01	-218.62	161.12	2.2e-16 ***	Reject H_0
SP-SS	$H_0: \beta_{NF} = \beta_{NL} = \beta_{LF} = 0$	-1084.1	-980.5	207.3	2.2e-16 ***	Reject H_0
SMS-LL	$H_0: \beta_{NF} = \beta_{NL} = \beta_{LF} = 0$	-3236	-3196	80.12	3.4e-16 ***	Reject H_0
SP-LL	$H_0: \beta_{NF} = \beta_{NL} = \beta_{LF} = 0$	-6403.7	-6370.4	66.48	2.4e-14 ***	Reject H_0
		Neutral Vs Non- neutral technical change				
SMS-GN	$H_0: \beta_T = \beta_{TT} = \beta_{NT} = \beta_{FT} = \beta_{LT} = 0$	-10817	-10716	201.76	2.2e-16 ***	Reject H_0
SP-GN	$H_0: \beta_T = \beta_{TT} = \beta_{NT} = \beta_{FT} = \beta_{LT} = 0$	-19687.	-19694	14.43	5.8e-16 ***	Reject H_0
SMS-SS	$H_0: \beta_T = \beta_{TT} = \beta_{NT} = \beta_{FT} = \beta_{LT} = 0$	-218.45	-214.62	7.66	0.018*	Reject H_0
SP-SS	$H_0: \beta_T = \beta_{TT} = \beta_{NT} = \beta_{FT} = \beta_{LT} = 0$	-980.5	-924.7	111.52	2.2e-16 ***	Reject H_0
SMS-LL	$H_0: \beta_T = \beta_{TT} = \beta_{NT} = \beta_{FT} = \beta_{LT} = 0$	-3196.0	-3178.5	35.01	1.49e-16 ***	Reject H_0
SP-LL	$H_0: \beta_T = \beta_{TT} = \beta_{NT} = \beta_{FT} = \beta_{LT} = 0$	-6370.4	-6309.0	122.79	2.2e-16 ***	Reject H_0
		Time-variant Vs. time invariant technical efficiency				
SMS-GN	$H_0: = \eta = 0$	-10817	-10697	240	2.2e-16 ***	Reject H_0
SP-GN	$H_0: = \eta = 0$	-19694	-19648	92.63	2.2e-16 ***	Reject H_0
SMS-SS	$H_0: = \eta = 0$	-218.45	-174.33	88.25	2.2e-16 ***	Reject H_0
SP-SS	$H_0: = \eta = 0$	-980.5	921.6	117.8	2.2e-16 ***	Reject H_0
SMS-LL	$H_0: = \eta = 0$	-3196.0	-3139.71	112.5	2.2e-16 ***	Reject H_0
SP-LL	$H_0: = \eta = 0$	-6370.4	-6274.5	191.87	2.2e-16 ***	Reject H_0

4.2.2 Output elasticity

Table 5 demonstrates the estimates obtained from the SFA model described by the translog production function specified in Equation 7. From this, we observe the output elasticity of vessel input variables, the nature of technical change and technical efficiency given parameters σ_u and η.

The first aspect of the SFA model deals with the output elasticity for the different vessel groups. In production economics, determination of elasticity is necessary for the estimation of responsiveness of yield (in this case fish catch) based on the given inputs (Coelli et al., 2005). Output elasticity from the translog SFA model can be represented by the first order coefficients given that input variables are mean-scaled (Henningsen, 2014; Pascoe & Mardle, 2003). Subsequently, based on the SFA model (Table 4), output elasticity for the number of gear and fuel[3] inputs were statistically significant with the expected signs (positive) for all vessel groups; however, the output elasticity for the labour input was negative for the SMS & SP-SS vessel groups and not different from zero for other vessel groups. On that note, the estimated first-order coefficients of the inputs (Table 4) may not be particularly meaningful in explaining vessel inputs (gear numbers, fuel and labour) responsiveness to the fish catch. Therefore, the study considered estimating output elasticity derived from Equation 8. Results are presented in Table 6, and Figure 5 which depicts a graphical representation of the different output elasticity for the different input variables for the given time period. The output elasticity for each vessel input varied among the different vessel groups although labour indicated the most outstanding variation. The responsiveness of labour to fish catch increased by seven-fold for the SMS-LL and by 1.3 times for the SMS-GN between 2005 and 2015 while indicating a decline for the other vessel groups with the most drastic decline for the SMS-SS by 2.3 times from 2011 to 2015 and by 1.9 times for the SP-GN vessel group.

The elasticity of the number of gear units increased for the SMS-LL from 22% in 2005 to 2015. Other vessel groups such as the SP-GN and SP-LL experienced a gradual increase from 2005 to 2011 followed by a gradual decline from 2011 to 2015; and gradual decline by the SP-SS vessel group (Figure 5). Lastly, the fuel variable common to the SMS and SP-SS

[3] For vessels using fuel to fish

vessel groups indicated the highest responsiveness to output relative to other variables. The elasticity of the fuel variable, however, indicated a declining trend for the vessel groups apart from the SP-SS whose elasticity was relatively constant over the study period. Slow declining fuel elasticity was recorded for the SMS-GN, drastic decline for the SMS-LL and SMS-SS vessel groups from 2011 to 2015 preceding a period of constant returns from 2005 to 2008 for the SMS-LL.

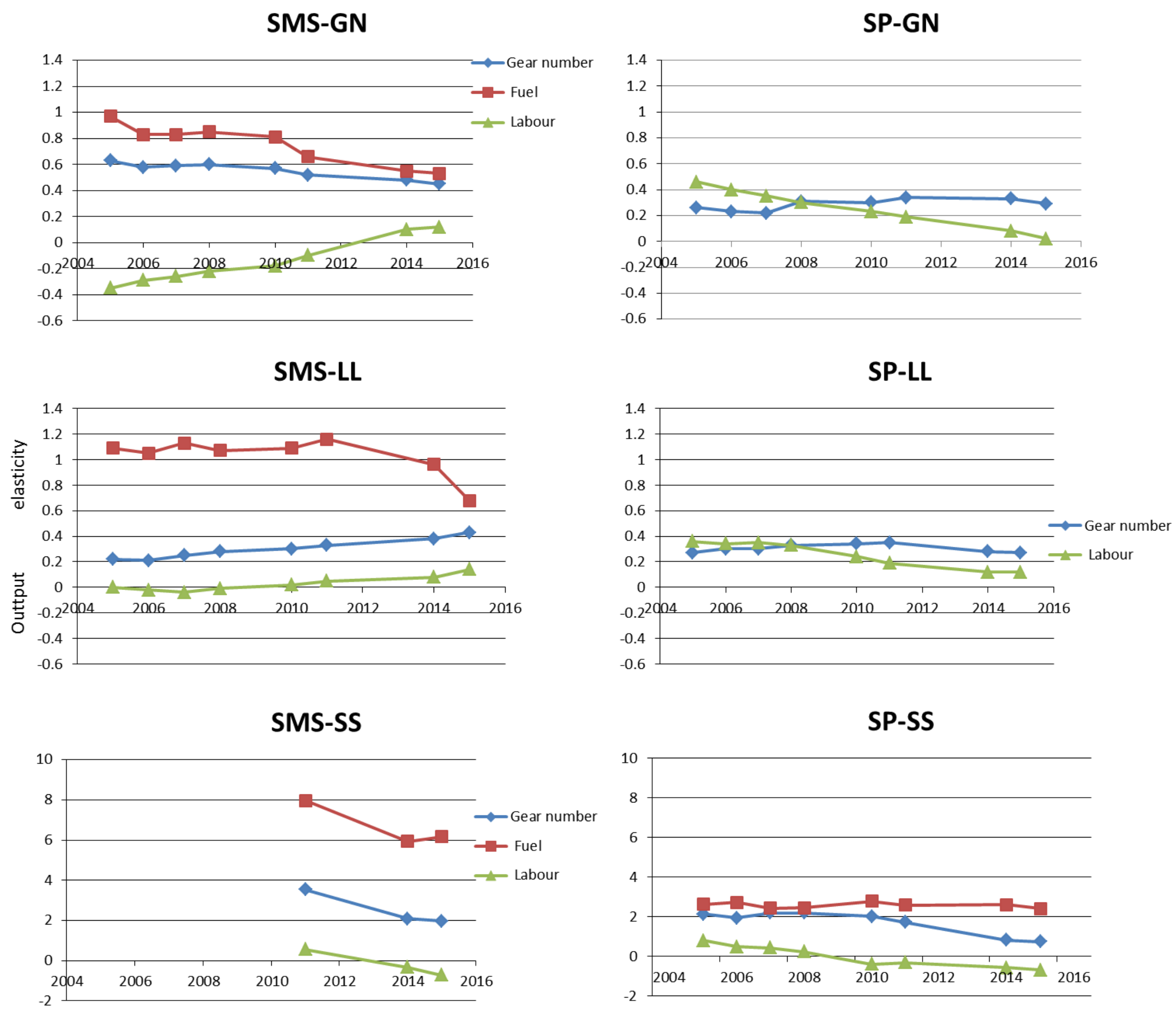

Figure 6: Change in output elasticity of the input variables for the different vessel groups over time; SMS-Motorised and SP-Paddled vessels using LL-long lines, GN-gillnets and SS-small seines; vertical scale based on target species as LL & GN target Nile perch while SS target Dagaa/Omena/Mukene.

Table 5: Maximum likelihood estimates for parameters of the stochastic frontier production function.

Variable	Motorised						Paddled					
	Gillnets		Long lines		Small-seine		Gillnets		Long lines		Small-seine	
	Estimate	z-value	Estimate	z-value	Estimate	z-value	Estimate	z-value	Estimate	z-value	Estimate	z-value
Constant	-0.18*	-2.25	0.32**	3.14	-10.1***	-19.86	-0.05	-0.55	-0.13	-1.15	0.99***	8.53
Log (Gear_no)	0.53***	5.64	0.39***	6.12	6.23***	7.04	0.44***	13.27	0.32***	7.17	0.48**	2.81
Log (Fuel)	0.82***	6.3	1.06***	7.09	17.24***	16.87	-	-	-	-	1.66***	9.86
Log (Labour)	0.11	0.88	0.08	0.54	-1.72***	-4.46	0.02	0.27	0.12	1.01	-0.21.	-1.82
0.5 log (Gear_no^2)	0.34***	6.32	0.100***	3.81	-1.67	-1.72	0.30***	20	0.09***	6.33	1.50***	5.92
0.5 log (Fuel^2)	1.53***	4.81	1.68***	5.63	-12.01***	-10.29					-0.91***	-10.26
0.5 log (Labour^2)	-0.62***	-4.25	-0.38.	0.83	0.001	0.004	0.23***	4.4	-0.26**	-2.08	-1.46***	-6.43
Log(Gear_no)*Log (labour)	-0.09	-0.94	-0.16***	-2.75	0.33	0.71	-0.06**	-3.18	0.09**	2.98	0.91***	5.12
Log (Gear no) * log (Fuel)	0.31*	2.55	0.06	0.8	-4.71***	-4.44	-	-	-	-	-2.02***	-11.08
Log (Labour) * Log (Fuel)	-0.15	-0.85	0.16	0.79	1.12*	2.52	-	-	-	-	1.22***	9.59
Time	0.09**	3.26	0.28***	9.14	0.94***	6.61	0.15***	6.51	0.10**	2.74	0.09***	2.75
0.5 Time^2	0.02**	3.81	0.044***	8.36	0.24***	5.02	0.02***	6.34	0.02**	2.87	0.009.	1.90
Time*Gear_no	-0.01	-0.63	0.01.	1.66	-0.33***	-3.3	0.003	0.89	-0.01	-1.07	-0.12***	-6.43
Time*Fuel	-0.01	-0.66	-0.02	-1.01	-0.29**	-2.611	-	-	-	-	-0.06**	-3.05
Time*labour	0.05*	3.02	0.02	1.05	0.14**	2.93	-0.04***	-5.57	-0.02.	-1.95	0.07***	4.76
σ^2	2.06***	10.64	3.24***	9.77	0.79***	6.55	2.06***	12.49	4.65***	8.46	0.55***	4.99
γ	0.45***	8.64	0.71***	21.66	0.84***	29.48	0.27***	5.28	0.64***	15.04	0.46***	4.21
σ_u^2	0.92***	11.31	2.29***	6.78	0.66***	5.48	0.56***	3.36	2.94***	5.32	0.27*	2.30
σ_v^2	1.14***	118.48	0.94***	35.55	0.12***	10.23	1.50***	74.78	1.67***	43.83	0.30***	22.90
σ_u	0.96***	11.32	1.52***	13.55	0.82***	10.96	0.75***	6.74	1.71***	10.65	0.51***	4.60
σ_v	1.07***	118.49	0.97***	71.10	0.35***	20.45	1.23***	149.57	1.29***	87.67	0.54***	45.81
η	-0.48***	-5.56	-1.07***	-5.04	-3.01***	-2.39	-0.37***	-5.28	-1.1***	-7.00	-0.38***	-3.37
Log Likelihood	-10697.04		-3139		-174.32		-19647.92		-6274.49		-921.61	

Significance denoted: 0 ‘***’; 0.001 ‘**’; 0.01 ‘*’; 0.05 ‘.’; 0.1 ‘’; 1

4.2.3 Returns to scale

The returns to scale values were obtained from the aggregate value of the output elasticity of the vessel inputs derived from Equation 8. Results for the returns to scale for the study vessel groups are and shown graphically in Figure 6. In general, the seine net vessel groups (SMS & SP-SS) accrued the highest returns compared to other vessel groups (values in Appendix 5). Based on the comparison between vessel propulsion with respect to the gears used, it is observed that the motorised (SMS) vessel groups accrued higher returns to scale values than their paddled (SP) counterparts. Increasing returns (>1) were specific to the SMS and SP-SS vessel groups while decreasing returns were indicated by the SP-GN and SP-SS vessel groups throughout the study period. However, it is also observed that the returns to scale for all vessel groups declined over time irrespective of their vessel operation and gear used.

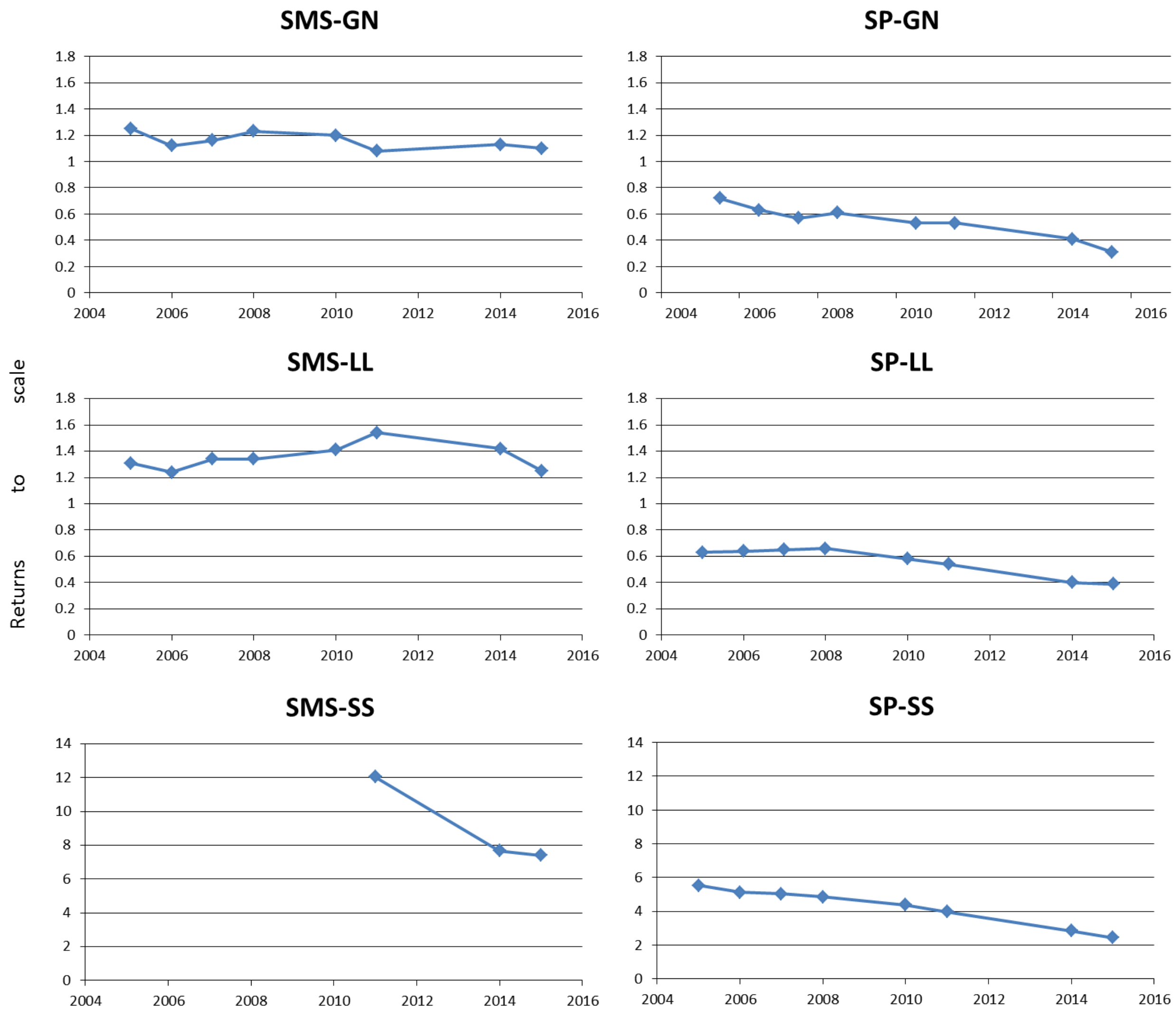

Figure 7: Returns to scale for the different vessel groups over time; SMS-Motorised and SP-Paddled vessels using LL-long lines, GN-gillnets and SS-small seines; vertical scale based on target species as LL & GN target Nile perch while SS target Dagaa/Omena/Mukene.

4.2.4 Technological change

Initially, the technical change from the SFA model indicated technical improvement given that the parameter *time* was positive and statistically significant at 5% level or less for all vessel groups (Table 6). Besides, the coefficient *0.5*time^2* was also positive and significant implying that the technical change improved at an increasing rate (non-constant technical change). The rate of technical change (RTC) was further derived using Equation 9 and results indicate technical regress at the beginning of the study period (2005-2008) for the GN and LL vessel groups followed by gradual increase in 2010-2011 and relatively high increase in the period 2014-2015. It is observed that SP-SS vessel group followed a slow gradual increase in RTC while the SMS-SS vessel group which is also the most recent vessel group in the study observed the highest rate of technical change (progress) in the study (Table 6). The SMS-SS vessel group indicated technical regress at the beginning of vessel operation in 2011 (-0.31) followed by a two-fold increase in technical improvement in 2014 and further improvement in 2015. Additionally, slow rates of change occurred for the SMS-GN and SP-LL vessel groups with only 10% in 2015.

Table 6: The rate of technical progress for all vessel groups

Vessel group	RTP							
	2005	2006	2007	2008	2010	2011	2014	2015
SMS-GN	-0.09	-0.07	-0.05	-0.03	0.01	0.02	0.08	0.10
SMS-LL	-0.17	-0.12	-0.08	-0.03	0.06	0.10	0.24	0.28
SMS-SS						-0.32	0.37	0.61
SP-GN	-0.07	-0.04	-0.02	0.00	0.05	0.07	0.13	0.16
SP-LL	-0.06	-0.05	-0.03	-0.02	0.01	0.03	0.09	0.10
SP-SS	0.02	0.03	0.03	0.05	0.09	0.09	0.14	0.14

4.2.5 Technical efficiency

Similar to the technical change, technical efficiency (TE) results were estimated using the residuals of the first step estimation of the SFA model with parameters σ_u *and* σ_v associated with the distribution of TE; and parameter η for the temporal variation of technical efficiency (Table 4). Parameters u and v are the decomposed error terms of the SFA model indicated as σ_u and σ_v representing the technical inefficiency of the fishing vessels and random noise respectively. From Table 4, it is observed that the error due to vessel specific technical inefficiency σ_u was greater than random noise component σ_v for the SMS-LL, SMS-SS and SP-SS. On the other hand, σ_v was greater than σ_u the for the SMS-GN, SP-GN and SP-SS vessel groups. Nevertheless, the technical inefficiency term σ_U for all vessel groups was significant values and also the parameter η. Thus, the time variant technical efficiency values were further derived using Equation 11 for all vessel groups (see Appendix 5 and Figure 8). Comparison between vessel propulsion (SMS & SP) with respect to gear types showed minimal variation in the technical efficiency estimates (Figure 7). At the beginning of the study period, each vessel group[4] irrespective of propulsion and gear type operated at efficient points along the production frontier (recall Figure 1) with TE

[4] Recall SMS-SS is observed from 2011

estimates ranging from 0.97 and 0.96 for the SP-GN and SMS-GN vessel groups to 1 for the other vessel groups. Both GN and SP-SS vessel groups indicated a gradual decline in vessel technical efficiency throughout the study period whereas the vessels in the SMS-LL and SP-LL vessel groups indicated relatively stable efficiency estimates for the period 2005-2008, followed by a gradual decline in 2010-2011 and a more drastic decline in the years 2014-2015. This was also similar with vessels in the SMS-SS vessel group that operated with relatively stable technical efficiency in 2011 and 2014, followed by a drastic decline in 2015. Decline in vessel group technical efficiency over time is associated with the negative value of η in the SFA model (Table 4) indicating a shift towards technically inefficient points of the production frontier.

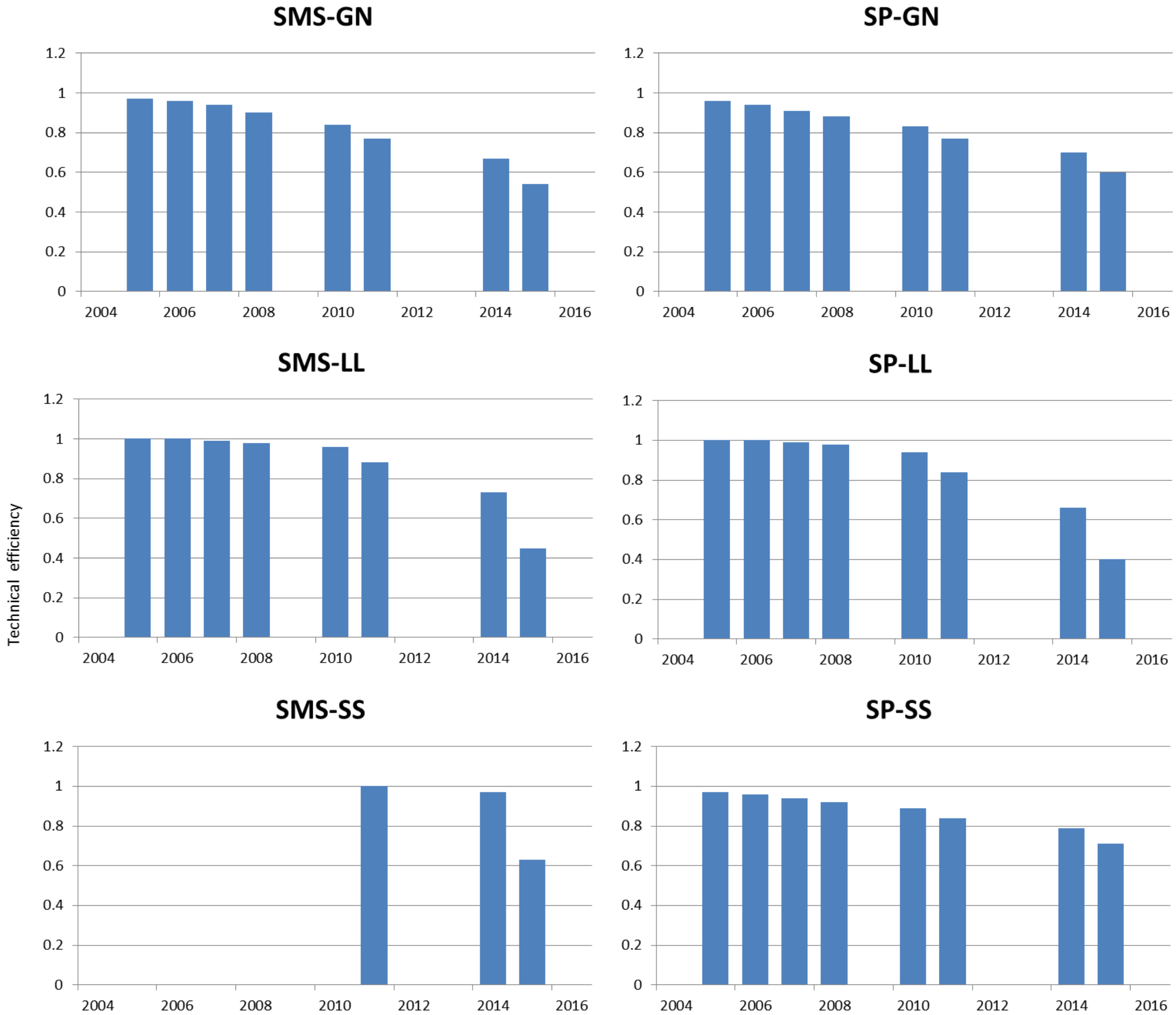

Figure 8: Technical efficiency change of the vessel fleet over time; SMS-Motorised and SP-paddled vessels using GN-gillnets, LL-long lines and SS-small-seine

Figure 8, further indicates the annual technical efficiency distribution for long line vessels groups. To recall, the technical inefficient component σ_u in these vessel groups is greater than the random noise component σ_v. Thus, for both the SMS-LL (Figure 8a) and SP-LL (Figure 8b) vessel groups, it is evident that most vessels operated at >0.95 technical efficiently in the years 2005-2008 with low variation in TE estimates for both vessel groups, followed by a slight decline in technically efficient vessels in 2010-2011 and a drastic decline in the technically efficient of vessels with great variability in the TE estimates ranging from 0 - 0.80 in 2015 for the SMS-LL and 0 - 0.70 for the SP-LL.

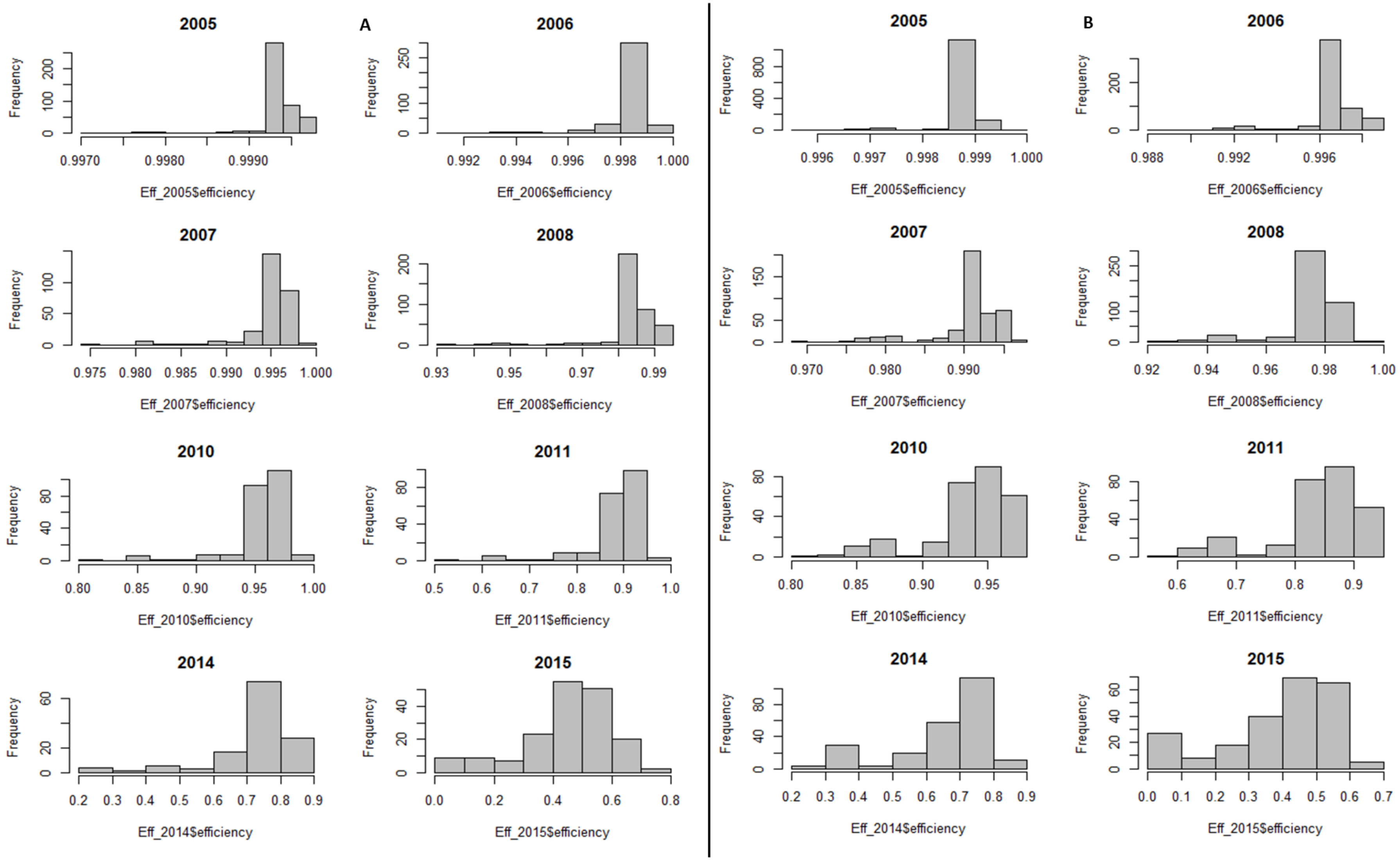

Figure 9: Changes in technical efficiency for the period 2005-2008; 2010-2011; 2014-2015 for vessel group A-SMS-LL and B-SP-LL

4.3 Fishers’ perceptions

4.3.1 Perception of fish catches

Respondents rated the catches of Nile perch as the worst with a mean response of 2.83 ± 0.5, followed by tilapia 2.35 ± 0.7. The dagaa catches, on the other hand, were rated as rather stable following a mean response rate of 2.01 ± 0.8 (Table 7). Rating of the dagaa catches was significantly related to vessel propulsion (χ^2 (2) = 18.16, $p< 0.05$) as paddled vessels fishers were more likely to rate the catches as better off (49%) than their motorised counterparts (25%) (Figure 9). Respondents’ perception on the catches was however not significantly related to other fisher/vessel characteristics.

Table 7: Respondent’s perceptions of the status of fish catches

	Target species			
Rating	Nile perch	Dagaa	Tilapia	Other species
Better off	8	51	8	3
Constant	8	43	19	2
Worse off	125	53	27	5
Mean	2.83	2.01	2.35	2.2
StDev	0.5	0.8	0.7	0.9
Min	1	1	1	1
Max	3	3	3	3
Sample size	141	147	57	10

Rating based on a scale; 1- Better off, 2- Constant off, 3- Worse off.

Some respondents answered for multiple species based their perceived knowledge in fishing thus the total sample size is greater than 273.

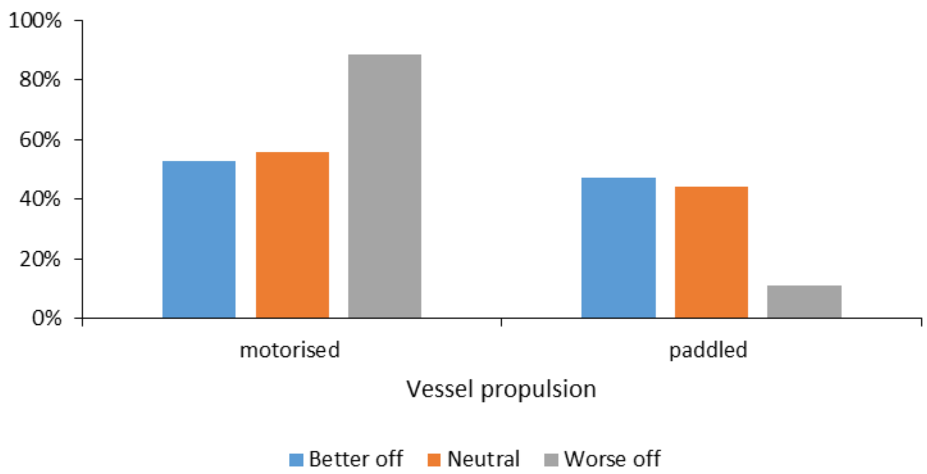

Figure 10: Perception of dagaa catches between respondents using motorised and paddled vessels.

4.3.2 Factors influencing the choice of a fishing site

When asked about the factors considered in the selection of a particular fishing site, respondents (68%) considered the weather condition as a major factor in selecting a fishing site (Table 8). This was followed by species abundance specifically for the Nile perch fishers (χ^2 (2) = 9.5, p =0.009) with over 59% respondents agreeing to this aspect. Fishing experience was another relatively vital factor considered by respondents targeting the different species including 47% by dagaa, 46% Nile perch and 43% tilapia fishers. Distance to the fishing ground, restricted access and other reasons like crew availability did not matter to the majority of fishers.

Table 8: Respondents motive for the choice of fishing site

Choice of fishing site	**Target species**							
	Nile perch		dagaa		Tilapia		**Total**	
	Yes	No	Yes	No	Yes	No	Yes	No
Weather	91	43	89	43	5	2	185	88
Fishing experience	61	73	62	70	3	4	126	147
Restricted access	23	111	7	125	0	7	30	243
Abundance of species	79	55	53	79	3	4	135	138
Search for target species	60	74	43	89	0	7	103	170
Distance to landing	36	98	30	102	0	7	66	207
Other reasons	9	125	30	102	1	6	40	233
Sample size (n)	134		132		7		273	

There was a significant relationship ($\chi^2$2 (2) = 10.3, p =0.006) between respondents' experience in years and choice of the fishing site due to weather. Respondents that had fishing experience of more than 15 years (75%) and 6 to 10 years (76%) were more likely to consider the weather in the selection of a fishing site than fishers who had fished for five years and less (56%) (Figure 10).

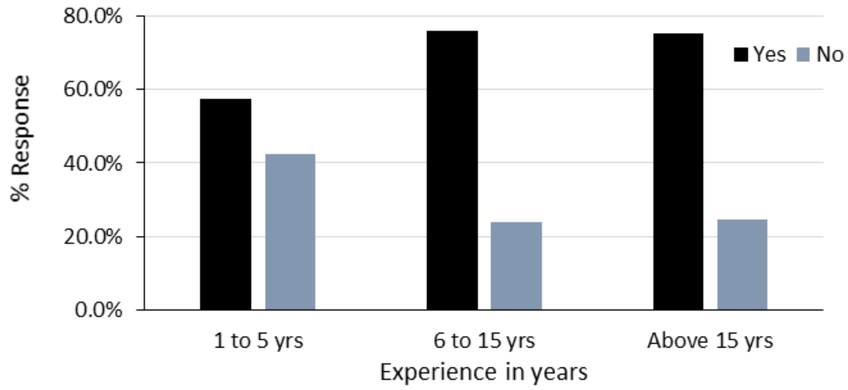

Figure 11: Respondents' choice of the fishing site based on weather Vis a Vis their fishing experience

4.3.3 Challenges faced in fishing.

In general, all challenges were considered severe, however, some varied among respondents based on their target species, gear, and demographic characteristics. Severity was also expressed in terms of mean values (Table 9) rated from 1 as severe and 3 as less severe, therefore the closer to 1 the more severe the challenge in relation to others. Reduced fish catches were rated as the most severe challenge by all respondents followed by high input costs, theft, reduced fish sizes, long fishing hours, conflicts, unregulated entry of people into the fishery, use of illegal gears and weather. Nile perch fishers (71%) were more likely to rate long hours fishing as severe (χ^2 (4) = 31.10, $p < 0.05$) than the dagaa (27%) and tilapia fishers (2%).

It was also interesting married respondents (83%) were more likely to rate high input costs as severe than those who were single (16%) or separated (2%). (Figure 11)

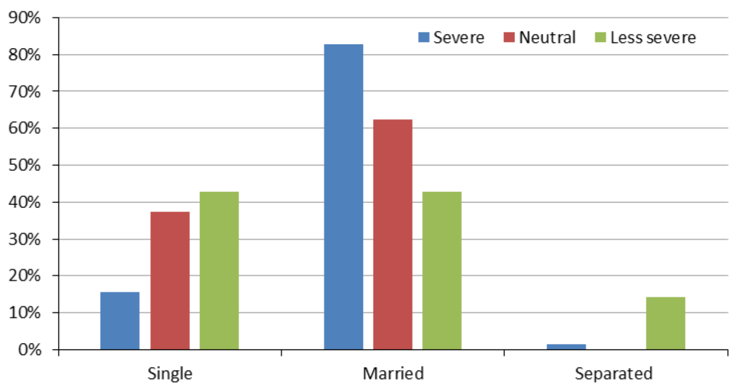

Figure 12: Perceived severity of high input costs based on respondents marital status.

Table 9: Challenges as perceived by the fishers based on 273 questionnaires, albeit not all questions were answered (n= number of respondents).

Target species	Rate	Conflicts	Unregulated entry	Reducing catch	High costs	Illegal gears	Reducing sizes	Long fishing hours	Bad weather	Theft
Nile perch	Severe	107	69	107	95	68	84	88	39	35
	Neutral	5	25	4	7	23	17	6	23	4
	Less severe	12	18	4	4	16	7	5	22	2
Dagaa	Severe	82	67	88	87	47	61	34	47	32
	Neutral	6	32	10	8	25	13	23	17	1
	Less severe	22	10	2	3	14	4	4	6	4
Tilapia	Severe	4	2	5	3	4	6	2	2	3
	Neutral	1	2	0	1	1	0	0	1	0
	Less severe	2	2	0	0	1	0	1	1	1
	Mean	1.35	1.52	1.12	1.14	1.56	1.27	1.3	1.63	1.23
	StDev	0.73	0.72	0.4	0.44	0.75	0.56	0.56	0.78	0.59
	Min	1	1	1	1	1	1	1	1	1
	Max	3	3	3	3	3	3	3	3	3
	n	241	227	220	208	199	192	163	158	82

Rating based on a scale; 1- Severe, 2- Neutral, 3- Less severe

4.3.4 Knowledge about fishery regulations

More respondents were familiar with regulations concerning mesh size (mean 1.1±0.42), illegal gear (1.13±0.5) and boat registration/licensing (1.23±0.61) than closed fishing seasons (2.25±0.76) and closed fishing areas (2.29 ± 0.89) (Table 10). Responses on mesh size regulation, illegal gear ban and boat registration were comparable among respondents of different target species. However, responses varied for closed fishing seasons and areas as respondents who targeted Nile perch (n=11) and tilapia (n = 1) were less likely ($p<0.04$) to know about closed fishing seasons than those targeting dagaa (n =25).

Table10: Respondents' knowledge about regulations

		Knowledge of regulations				
Species	response	Mesh size	Illegal gear	Closed seasons	Closed areas	Boat registration
Nile perch	Yes	121	122	11	27	94
	Not sure	1	2	19	18	6
	No	6	5	85	69	13
Dagaa	Yes	104	96	25	35	85
	Not sure	1	0	16	9	2
	No	5	10	63	52	5
Tilapia	Yes	7	7	1	1	3
	Not sure	0	0	0	0	0
	No	0	0	5	5	2
Overall	Yes	232	225	37	63	182
	Not sure	2	2	35	27	8
	No	11	15	153	126	20
	N	245	242	225	216	210
	Mean	1.1	1.13	2.52	2.29	1.23
	StDev	0.42	0.5	0.76	0.89	0.61
	Min	1	1	1	1	1
	Max	3	3	3	3	3
	Better off- 1; Neutral-2; Worse off-3					

Knowledge of a particular regulation was likely to influence respondent's perception of the effectiveness of that particular regulation. There were significant relationships between knowledge of mesh size regulation (χ^2 (4) = 14.6, p =0.006), boat registration (χ^2 (4) = 22.5, p < 0.000) and closed seasons (χ^2 (4) = 20.7, p <0.000) with respondent perception on effectiveness of the respective regulation. With the exception of closed fishing seasons, all the stated regulations were perceived to ensure effectiveness that is, mesh size (1.04 ± 0.25), illegal gear (1.04 ± 0.25), boat registration and closed areas (1.6 ± 0.84). Most respondents (n = 147) irrespective of target species did not agree with closed fishing seasons as an effective regulation (2.38 ± 0.88) in ensuring fisheries management (Table 11).

Table11: Respondents' perception of the existing fisheries regulations

		Perception of the effectiveness of regulation				
Species	response	Mesh size regulation	Illegal gear ban	Closed fishing seasons	Closed fishing areas	Boat registration.
Nile perch	Agree	128	114	27	71	97
	Neutral	1	8	11	14	4

		Perception of the effectiveness of regulation				
Species	response	Mesh size regulation	Illegal gear ban	Closed fishing seasons	Closed fishing areas	Boat registration.
	Disagree	0	3	75	32	11
Dagaa	Agree	103	92	32	71	91
	Neutral	3	12	9	16	1
	Disagree	3	6	68	19	4
Tilapia	Agree	7	7	1	3	4
	Neutral	0	0	1	1	2
	Disagree	1	0	4	2	0
Overall	Agree	238	213	60	145	192
	Neutral	4	20	21	31	7
	Disagree	3	9	147	53	15
	N	245	242	228	229	214
	Mean	1.04	1.16	2.38	1.6	1.17
	StDev	0.25	0.46	0.88	0.84	0.53
	Min	1	1	1	1	1
	Max	3	3	3	3	3

Based on Likert scale Agree =1, Neutral=2 Disagree=3.

4.3.5 Suggested management institutions

Based on the 250 respondents who stated their suggested management, 42% recommended fishers, 38% local beach management (BMU), 30% central government and only 8% suggested local government (Table 12). Respondents' suggestions on fishers and local beach management varied depending on their target species. Dagaa fishers were more likely to suggest the local beach management (n= 56), whereas the tilapia (n= 4) and Nile perch (n= 62) respondents suggested fishers as their preferred management institution. The response towards central government and local government was quite comparable among the respondents as these were the least preferred management institutions. Management suggestions also varied based on the type of gear used (χ^2 (3) = 16.6, p = 0.001) as respondents using long lines (61%) were more likely to prefer local beach management than gillnet fishers (52%) who were more likely to suggest fishers. Seine net fishers were divided between the two institutions.

Table12: Suggested management institutions

Suggested management.

Species	Response	Fishers	BMU	Local Gov.	Central Gov.
Nile perch	Yes	62	37	12	40
	No	62	87	112	84
Silver fish	Yes	39	56	8	33
	No	80	63	111	86
Tilapia	Yes	4	1	0	3
	No	3	6	7	4
Overall	Yes	105	94	20	76
	No	145	156	230	174
Sample	n	250	250	250	250

There were also variations based on landing site as local beach management institutions were preferred for 58% of respondents in Kikondo and almost half the respondents at Kasenyi-Wakiso whereas fisher-based institution was preferred by 64% respondents at Gaba and Nakattiba (Figure 12).

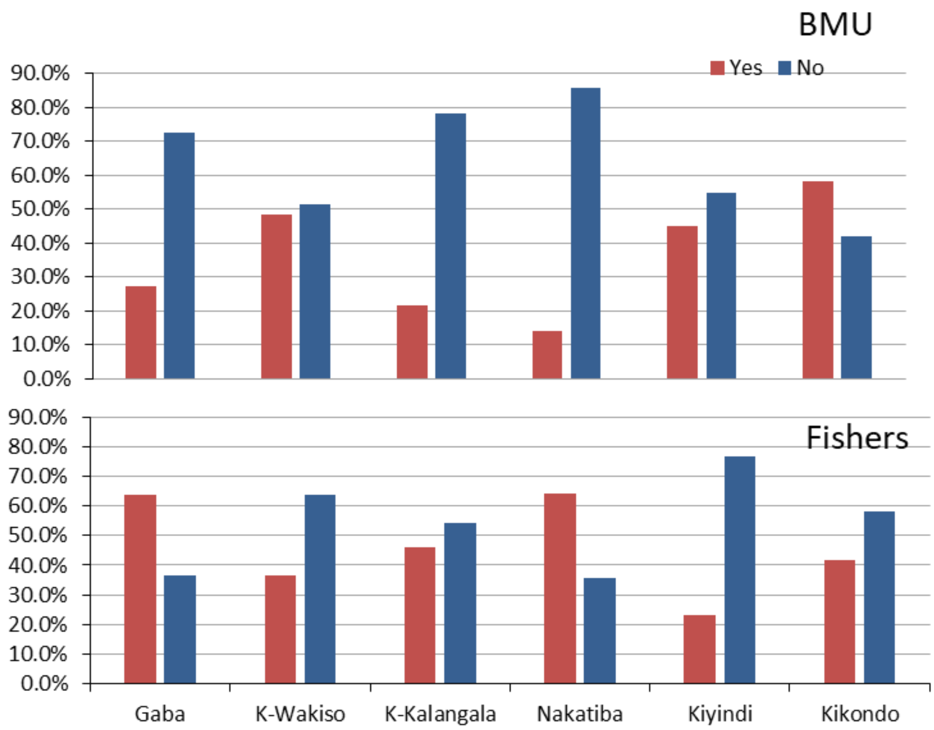

Figure 13: Respondents support for BMU and fishers as their suggested management institution according to landing site.

5 Discussion

The study aimed at determining the performance of the fisheries on Lake Victoria in Uganda based on the technical efficiency of the fishing fleet and fishers perception of their production environment. Fishing fleet and fishers were categorized on the basis of the dominant fisheries, Nile perch and dagaa, and vessels grouped by mode of propulsion into paddled (SP) and motorized (SMS). The dominant gear types were gillnets and longlines for Nile perch; and seine nets for the dagaa fleet.

5.1 Technical efficiency

To obtain the fleet technical efficiency, a non-restricted translog SFA model (Equation 7) was specified as sufficient for the Lake Victoria fishing fleet. The derived technical inefficiency measure, u_{it}, varied significantly ($p< 0.05$) over time for all vessel groups and was non-neutral because of the time variation with vessel inputs (Table 5). Results of the model were thus decomposed to reflect the changes in output elasticity, returns to scale, technical progress and technical inefficiency over time. The derived output elasticity for vessel inputs indicated that fuel was the most important input variable for the vessels throughout the study period (Figure 5). The variable was specific to motorised vessel groups (SMS) and the SP-SS vessel group with the highest output elasticity values over time compared to other vessel inputs. As a result, these vessel groups indicated increasing returns to scale (RTS > 1) opposed to the declining returns indicated for the SP-GN and SP-LL vessel groups (Figure 5). Increasing returns to scale in production imply that fishing vessels are able to obtain a more than proportionate catch for a given combination of vessel inputs while decreasing returns to scale indicate less than proportionate increase for a given combination of inputs. For motorised vessels studies, such as Muhoozi (2002) and Pascoe & Mardle (2003), indicate that these vessels are attributed to higher fish catches due to their ability to access relatively remote and potentially productive fishing grounds inaccessible to their paddled counterparts. It is also worth noting that the fuel use for the SP-SS vessels is used for lighting of fishing lamps but not propulsion, which is also a significant input for the SMS-SS (dagaa) fishing vessels. However, contribution of the fuel variable in the study period indicated a declining importance (Figure 7) from 2010-2011 for the SMS-GN and 2014-

2015 for both SMS-LL and SMS-GN vessel groups indicating that over time, the amount of fuel used accrued lesser catches than before.

Labour output elasticity among the vessel groups was interesting and varied in several ways. Declining labour elasticity was observed for the paddled (SP) and the motorised dagaa (SMS-SS) vessel groups, with negative labour elasticity for the seine net (SS) vessel groups (Figure 5). With reference to the production function, the negative output elasticity observed for the dagaa vessel groups (SMS and SP-SS) are indicative of heavy input usage or input congestion (Coelli *et al*., 2005). The implication of input congestion occurs as an opportunity cost in either lost output or loss in other input dimensions to maintain the existing output (Briec et al., 2016). Therefore, the decline in the labour elasticity over time indicates that more crew hours than required were used in the dagaa fishery. On the contrary, the labour elasticity of the SMS-GN and SMS-LL vessel groups indicated a gradual increase from the negative and null elasticity at the beginning of the study period to positive elasticity at the end of the study period (Figure 7). This implies that over time, employing more of crew hours (labour) is becoming vital in maximising fish catches for the two vessel groups SMS-LL and SMS-GN. Similarly, employing more gear units (long line hooks) also accrued catches for the SMS-LL vessel group over the study time. Based on the labour input, the results also indicate the likely labour developments in the two fisheries in Lake Victoria. The Nile perch (SMS-GN & SMS-LL) and dagaa fisheries (SMS & SP-SS) could indicate fisher adjustment strategies given the changing composition of fish stocks in Lake Victoria (Figure 1). Fishers either participate in the motorised GN and LL and fish for longer hours for the large size fish or target smaller sized Nile perch using the SP-GN and SP-LL vessel groups (Mpomwenda, 2016). Furthermore, it is highly likely that they have joined the thriving dagaa fisheries for maximum output thus better wages leading to labour congestion. Considering the high level of unemployment in Uganda (UBOS, 2016), it is also possible that the marginal cost of labour on the lake is very low making it is easy for vessel captains to hire an additional crew or even employ household members, especially for the dagaa while elevating their social status. Labour input congestion in the dagaa fishery was also indicated by Lokina (2009) in Lake Victoria Tanzania based on a cross-sectional study.

The rate of technical change (RTC) observed for all vessel groups indicatesg an upward shift in the production frontier OP (Figure 2). To recall, technical progress is concerned with the ability of a vessel to produce more with the given vector of input quantities for the specified time period (Coelli *et al*., 2005). The annual RTC growth through the study period was highest for the motorised dagaa fishing vessels (SMS-SS) and lowest for the SMS-GN fishers. In the study, the two vessel groups depict the commercial fishing fleet for the two species, merging this to the fisheries production developments in the lake, the observed changes in the proportions of species (Figure 1) for which the slow growth of the Nile perch fishery could be due to the decline in harvestable stocks by the motorised Nile perch fishing fleet and increased RTP for the now abundant dagaa stocks (Taabu, 2014). Although the study period is limited to the mid-2000s, it is likely that earlier development of the Nile perch species was linked to a higher RTC prior to its decline. Squires & Vestergaard (2013) indicate that for common property resources like fisheries, technical progress results in an enigma, where vessels interested in private efficiency induce process innovations that eventually surpass resource stock leading to a decline in the catches. This can also be explained as “fishing down the food chain” (Pauly et al., 2000), whereby some fishers are transferring their effort (motorised vessel) to fishing smaller sized fishes for the Nile perch and also the dagaa fishery (using the SMS & SP-SS vessels). Therefore, it is likely that fishing effort is gradually shifting from the large predatory Nile perch fishery to the small pelagic dagaa species due to overexploitation. In an earlier study by Davis *et al* (1987), technical progress was attributed to the decline of whales. Technical progress is perceived as one of the greatest pressure on global fisheries given that capital stocks of fishing fleets have built up to an over capitalised state but policy advice remains focused solely on reducing capital stocks, fishing effort or subsidies ignoring technical progress (Squires & Vestergaard, 2013).

On the other hand, technical efficiency results indicated a declining trend for all vessel groups. Based on the 2015 technical efficiency estimates, the dagaa fishing fleet (SMS & SP-SS) indicated more efficient vessels that is, 0.71 for SP-SS and 0.63 for SMS-SS than the Nile perch fishery with less than 0.6 efficiency for GN and LL vessel groups. Therefore, based on species, it is evident that dagaa fishery attained a better performance in terms of maximising catches than the Nile perch fishing fleet. However, the technical efficiency estimates in this study are contrary to the results from a cross-sectional study by Lokina (2009), where the technical efficiency level for the Nile perch vessels was relatively higher (0.75) than the Dagaa vessels (0.70). The general decline in fleet technical efficiency in the study matched the declining returns to scale (RTS) for all the vessel groups, albeit all SMS and SP-SS vessel groups operated at RTS>1. Scholars in fisheries efficiency note that while vessels operate with increasing returns, they are likely to experience short-run productivity gains as they increase fishing effort. Consequently, this leads to reduced efficiency in the long run as catch is reduced for their given effort level thus declining catch per unit effort (Pauly and Zeller, 2005; Kirkley & Squires, 1999). This is not surprising especially for the SMS-GN vessel group as declining CPUE was observed using the same data (Mpomwenda, 2016). Thus reduction in efficiency of the fishing fleet would indicate declining catches resulting from overharvesting.

It is worth noting that this study is the first to explore technical efficiency changes for the Lake Victoria fishing fleet using the available catch assessment survey panel data. Unfortunately, determining of the fleet technical efficiency in the study did not include the vessel specific effects such as skipper experience, education, vessel and gear age, and environmental variables (such as seasonality) as suggested by Pascoe and Mardle (2003). Thus the TE estimates in the study could possibly be overestimated or even biased. However, the use of such information was outside the scope for the study as such information in the fisheries is not always available for fisheries in developing countries especially on a long term basis.

Nevertheless, a further study could be done to compare the TE changes for similar vessel groups in the Lake Victoria riparian countries of Kenya and Tanzania.

5.2 Fishers' perceptions

Fishers were asked for information on five main issues pertaining to their production environment. These included; factors that affected their choice of fishing area, perception of fish catches, challenges faced in the fishery, perception on the fishery regulations and management institutions. Seeking fishers' perception in the study aimed to provide the researcher with valuable supplementary information in making comparison of the performance of the different vessel groups (fishing fleet) on Lake Victoria as indicated in the previous section on TE. It should however be noted that fishers responses in the survey were primarily influenced by target species rather than vessel group as most sampled respondents operated in motorised fishing vessels (Table 3). Vessel group representativeness in both fisheries was minor as most fishers sampled (74%) operated in motorised fishing vessels than paddled ones. Therefore, fisher perceptions were based on target species (Nile perch and dagaa fishery) rather than the study's specified vessel groups.

Based on the result, some of the noticeable socio-economic features between these fisheries were based on the status of the respondents and vessel ownership. Boat owners and fishing crew were common to both fisheries, however, in the Nile perch fishery, boat managers were encountered for boat owners having several vessels and fishing crew. This description was earlier reported for the Nile perch fishery given that its earlier development (Figure 1) accrued profits to fishers leading to heavy investment in motorised vessels and employment of fishing crew (Benkenstein, 2011). Therefore, fewer owners with relatively large number of vessels were sampled in the Nile perch fishery than the dagaa fishery whose development (in terms of vessel motorisation) is recent as indicated in the existing panel data. It was also interesting to note that in both fisheries, respondents sampled engaged household labour in fishing thus signifying the importance of the social ties and structures in the Lake Victoria fisheries (Nunan et al., 2018) and labour-using component specified earlier for the vessel groups.

Another important aspect was on the nature of the production environment, as the weather condition on the lake mattered most to fishers thus reflecting the degree of stochasticity in their production environment.

On rating performance based on the fish catches, it was common that the catches of the Nile perch fishery were rated worse whereas those of the dagaa fishery were rated as relatively stable. Thus from this it is likely that paddled dagaa fishing vessels performed better relative to other vessel groups similar to the TE results. Furthermore, comparison within the vessel propulsion in the dagaa fishery (SS vessel groups) indicated that respondents from motorised dagaa vessels were also more likely to indicate that the state of their catches had declined than their paddled counterparts. This was not surprising as most fishers indicated that reducing fish catches was one of the major challenges faced in the Lake. Similar results on fishers perception on the status of catches were reported by Cepić & Nunan (2017) supporting that majority of fishers sampled at selected landing sites of the three riparian Lake Victoria countries expressed the belief that catches had declined in the fishery.

In assessing the nature of fishery regulations, fishers frequently supported regulations they were aware of such as mesh size regulation, illegal gear ban and vessel registration. Other two specified regulations that is, closed areas and closed fishing seasons were seldom known with limited support for the closed fishing seasons. All the regulations examined in the study are stipulated in the fisheries laws of Uganda (Fish protection ordinance 1950, the Uganda's Fish Act, cap 197 of 2000 and the National Fisheries policy 2007), therefore it is likely that fishers are better informed about the mesh size, gear ban and boat registration than closed fishing seasons and areas.

It is also important to note that fisheries management is based on co-management that was established with the core objective of eliminating illegal fishing methods (Onyango, 2015) thus less emphasis on closed fishing seasons. Closed fishing seasons would also be seen as a potential threat to fisher's livelihoods as majority of respondents were fulltime fishers with limited alternative activities. Similar findings on negative perception on closed fishing seasons has been reported in other fisheries such as in the Brazilian small-scale shrimp fishery (Musiello-Fernandes *et al*., 2017) and also on Mafia Island in Tanzania (Kincaid, *et al*., 2014).

In assessing the preferred management, respondents were more likely, to support fisher-based management institution than other alternatives. The least preferred alternative was management by the local government. However, local government officials are seen to have inadequate capacity and personnel to effectively manage fisheries (Nunan et al., 2015; Kolding, 2013). Based on empirical evidence, fishers and BMU members are much closer to the resource and knowledgeable about fisheries operations than local government officials. Local government officials and sometimes government officials were seen as being more interested in collecting taxes and license fees rather than in enforcing other important regulations. Therefore, fishers would regard them as ineffective in ensuring management on the lake.

5.3 Conclusion and recommendations

Determining the performance of fishing fleet in data deficient fisheries is quite complex. In this study, the performance of the Lake Victoria fishing fleet was determined based on the technical efficiency and fisher's perception of their production environment. The study applies a panel data SFA model to determine the technical efficiency of the fishing fleet based on the dagaa and Nile perch fishery. To attain the fleet technical efficiency, the study illustrated a cost-effective way to measure resource situation and development by using an existing panel data and an independent cross-section study to manipulate missing data variables. In the study, six dominant vessel groups were identified based on vessel propulsion (motorised or paddled) and gear type (LL and GN for Nile perch fishery and SS for the dagaa fishery). It is suggested that the potential of maximising output from the Lake Victoria fishery resource is obtained by operating motorised fishing vessels rather than paddled vessels. Comparison between species indicated that the dagaa fishing vessels (SMS-SS and SP-SS) performed better than the Nile perch fishing vessels (GN and LL) indicated by higher returns to scale, relatively higher technical efficiency estimates (as of 2015) and also fishermen's perceptions on the status of the species catches.

It is also interesting to note that in the fishery, two major fleet developments have emerged in relation to the Nile perch; in the motorised gillnet and long line vessels, fishing labour (crew*hours) is increasingly becoming important in maximising output whereas in other vessel groups there is a tendency of over manning. This indicates fishers engaged in the motorised Nile perch fishery going longr distances to catch big fish while their paddled counterparts go shorter distances to catch smaller fish indicating clear signs of overexploitation thus a need for management measures. The decline in technical efficiency indicates that too many vessels chasing too few fish indicated by the increased rate of technical change for all vessel groups. These would therefore require relegating vessels in the fishery to only those that give maximum returns to the fisher as suggested above. From the study, therefore, it is recommended that;

Motorised vessels in the fishery should be maintained as they accrue increasing returns from the fishery thus are suitable for maximising output to fishers than the paddled counterparts.

For maximum returns to scale, vessel input combinations for vessel groups SMS-GN be maintained at 2005 levels, SMS-LL and SMS-SS at 2011 levels.

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In addition, there is need for the government to create networks for alternative livelihood opportunities to fishers and fisher communities. These would include developing infrastructure for other fishing activities especially in post-harvest fishing activities such as community fish handling and processing infrastructure, marketing among others. As a result, this will also curb over manning observed in the dagaa/omena/mukene fishery as alternative livelihoods will create alternative sources of income other than fishing.

In general, effort restricting policy measures for all fishery inputs should be integrated into the fishery management objectives, and also building the capacity in grassroots fisheries management to incorporate and implement measures such as closed fishing seasons and areas for better stock health management.

The results of the present study indicate that it is essential to periodically monitor and assess the performance of the fishing fleet and its effect on the fishery stock health. This is because other factors such as seasonality and other vessel specific characteristics were out of the scope of the study due to limited data for those variables, however, these should be explored in future research opportunities.

Finally, there is also need to assess the changes in technical efficiency of the fishing fleet on other Lake Victoria riparian countries (Kenya and Tanzania) for a better comparison of the study results. This will help identify the inter-country differences and similarities, create a more proficient conclusion and policy recommendation for the trans-boundary fisheries resource.

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8 Appendix

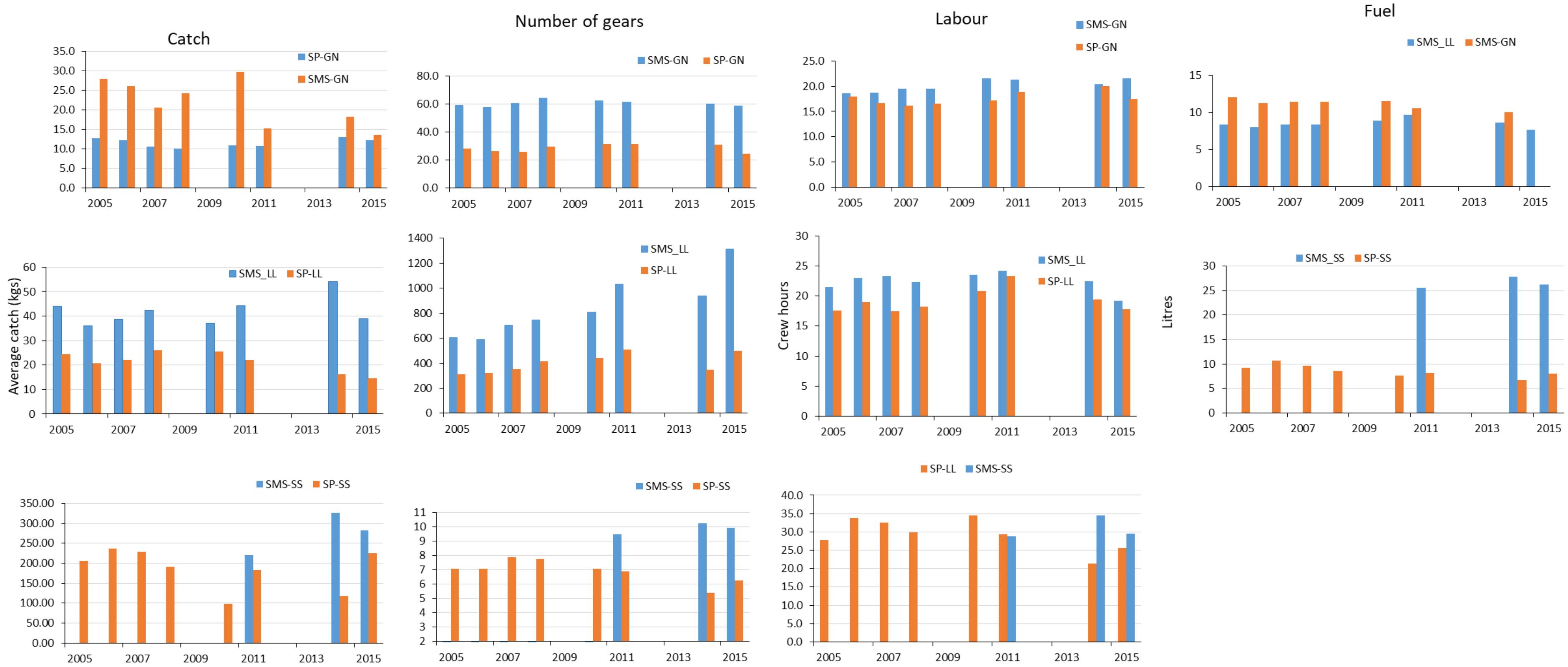
Appendix 1; summary results of vessel input variables for the different vessel groups based on the cross-sectional data

Variable	Description		SMS-GN	SMS-LL	SMS-SS	SP-GN	SP-LL	SP-SS
Units	Number of gears	mean	65.1	352.5	8.3	62.7	280.0	7.0
		StdDev	14.3	277.7	1.1	18	207.8	0.1
		Max	120	1000	10	100	400	7.0
		Min	11	10	5	20	40	6.0
Labour	Crew*hours fished	mean	24.57	22.74	34.91	29.75	16.67	36.88
		StdDev	5.95	6.01	8.59	4.15	5.03	6.14
		Max	40	34	48	36	22	52
		Min	12	10	9	22	12	27
Fuel	Litres	mean	6.98	9.02	21.71	0	0	7.45
		StdDev	3.87	4.4	8.53	0	0	1.1
		Max	25	25	47.5	0	0	9
		Min	3	1.5	8	0	0	2.5
Catch	Kilograms	mean	5.73	5.13	158.56	8.57	8.5	81.49
		StdDev	5.13	6.42	99.76	9.52	4.82	45.27
		Max	25	47	560	50	12	230
		Min	0	0	5	0	3	0
Sample	Vessels sampled	**n**	95	65	91	35	3	74

Appendix 2; Fuel input model from the cross-sectional data

Fuel Model				
variable	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	9.01	3.33	2.71	7.12e-03 **
Catch	0.02	0.00	4.21	3.35e-05 ***
Kasenyi-Kalangala	0.91	1.72	0.53	0.60
Kasenyi-Wakiso	3.44	1.50	2.29	0.02 *
Kikondo	-0.37	1.73	-0.21	0.83
Kiyindi	16.35	2.11	7.73	1.38e-13 ***
Nakattiba	6.31	1.85	3.41	7.3e-04 ***
Vessel_Length	-0.87	0.42	-2.05	0.04 *
Labour	0.11	0.04	2.57	0.01 *
Significance Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Residual standard error: 4.844 on 319 degrees of freedom				
(35 observations deleted due to missingness)				
Multiple R-squared: 0.6708, Adjusted R-squared: 0.6625				
F-statistic: 81.24 on 8 and 319 DF, p-value: < 2.2e-16				

Appendix 3; Changes in the SFA model variables-Catch, number of gears, labour and fuel for the specified time period



Appendix 4; estimated change in output elasticity for the vessel input variables for the different vessel groups

		Output elasticity							
Vessel group	Input variables	**2005**	**2006**	**2007**	**2008**	**2010**	**2011**	**2014**	**2015**
SMS-GN	Gear number	0.63	0.58	0.59	0.60	0.57	0.52	0.48	0.45
	Fuel	0.97	0.83	0.83	0.85	0.81	0.66	0.55	0.53
	Labour	-0.35	-0.29	-0.26	-0.22	-0.18	-0.10	0.10	0.12
SMS-LL	Gear number	0.22	0.21	0.25	0.28	0.30	0.33	0.38	0.43
	Fuel	1.09	1.05	1.13	1.07	1.09	1.16	0.96	0.68
	Labour	0.00	-0.02	-0.04	-0.01	0.02	0.05	0.08	0.14
SMS-SS	Gear number						3.54	2.08	1.96
	Fuel						7.97	5.93	6.16
	Labour						0.55	-0.33	-0.72
SP-SS	Gear number	2.13	1.93	2.18	2.18	2.01	1.71	0.81	0.74
	Fuel	2.62	2.72	2.43	2.45	2.78	2.58	2.61	2.40
	Labour	0.79	0.48	0.43	0.22	-0.40	-0.32	-0.57	-0.70
SP-GN	Gear number	0.26	0.23	0.22	0.31	0.30	0.34	0.33	0.29
	Labour	0.46	0.40	0.35	0.30	0.23	0.19	0.08	0.02
SP-LL	Gear number	0.27	0.30	0.30	0.33	0.34	0.35	0.28	0.27
	Labour	0.36	0.34	0.35	0.33	0.24	0.19	0.12	0.12

Appendix 5 ; Change in the average technical efficiency of the Lake Victoria fishing fleet.

Vessel type		summary	Year								% TE change
			2005	2006	2007	2008	2010	2011	2014	2015	
SMS	GN	Mean	0.97	0.96	0.94	0.90	0.84	0.77	0.67	0.54	-0.43
		StDev	0.01	0.01	0.02	0.03	0.06	0.09	0.11	0.13	
	SS	Mean						1.00	0.97	0.63	-0.37
		StDev						0.00	0.02	0.14	
	LL	Mean	1.00	1.00	0.99	0.98	0.96	0.88	0.73	0.45	-0.55
		StDev	0.00	0.00	0.00	0.01	0.03	0.07	0.12	0.16	
SP	GN	Mean	0.96	0.94	0.91	0.88	0.83	0.77	0.70	0.60	-0.37
		StDev	0.01	0.01	0.02	0.03	0.05	0.07	0.08	0.10	
	SS	Mean	0.97	0.96	0.94	0.92	0.89	0.84	0.79	0.71	-0.27
		StDev	0.01	0.02	0.02	0.03	0.05	0.06	0.09	0.11	
	LL	Mean	1.00	1.00	0.99	0.98	0.94	0.84	0.66	0.40	-0.60
		StDev	0.00	0.00	0.00	0.01	0.03	0.07	0.14	0.16	

Appendix 6; Questionnaire one

Questionnaire 1

The purpose of this survey is to assess the productive performance of fishing vessels on Lake Victoria through collecting data on vessel level inputs and their costs and the outputs in terms of prices and landed catch.

Date			

Vessel serial number		Country	
District		Sub-county	
Landing site		Enumerators' name	
Name of respondent		Phone	

1. Status of respondent

Boat owner		Fisher		Other (Specify)	

2. Fishing experience of respondent (years)

1-5		6-10		11-15		Above 15	

VESSEL INPUT FIXED COSTS

3. Vessel ownership

Own		Rent		Other specify…………………	

4. If you rent a boat, how much do you pay per day? _____________ (Shs per day).
5. If you own a boat, give relevant information in table below

Type of boat	Number	Length	Unit cost	Repair costs *(Shs/half yearly)*	Lifespan (*Years)*
Ssesse Flat					
Ssesse pointed					
Parachute					
Other (specify)……….					

6. Vessel operation mode.

Propulsion mode		Number	Unit cost	Repair/maintenance costs	Life span
Motor engine (-------- HP)					
Paddles	Large				
	Small				

7. Gear information; Types, numbers, and cost of gear(s) used.

Gear Types	Number	Size (Meshes /hook size)	Unit cost *(Shs/unit)*	Repair costs *(Shs/month)*	Life span (*Months*)
Gillnets – multifilament					

Gillnets - monofilament					
Long lines					
Small/ Mukene seines					
Beach/ Boat seines					
Cast nets					
Others 1(specify) ______					
Others 2 (Specify)					

8. How much did you pay for the boat license last year? ____________________ Shs
9. How much did you pay for boat registration last year? ___________________ Shs
10. Parking fees ___________________ Shs
11. Management taxes___________________ Shs

mukene/dagaa/omena fishers only.

12. Give information on the expenses used in Mukene fisheries.

Item	**Number/quantity**	**Unit cost**	**Repair costs *(Shs per week)***	Lifespan
Lanterns				
Generator				
Bulbs				
Basins				
Drying Nets				
Others (specify)				

13. **VESSEL VARIABLE COSTS.**

Expenses (per fishing trip)		Number/Quantity	Unit cost
Labor	Fishing		
	Net preparation		
	Other specify		
Food			
Kerosene for Lanterns (Mukene fishers)			
Petrol and Oil for Generator (Mukene fishers)			
Fuel and engine oil (for motorized vessels)			
Ice			
Bait			
Other (specify) ________________________			

VESSEL OUTPUT

14. Catch and price.

Species	No. of fish (large fish)/Number of basins/buckets (Mukene)	Catch (kg) large species	Price per kg/ Price per basin

15. Is the catch shared? Yes…………………… No……………………
16. If yes please explain the share system/proportion on your boat…………………………

OTHER INFORMATION

17. Days fished in a week…………………………..
18. Hours fished ………………………………..
19. Additional comments………

………………………………………………… THANK YOU.

Appendix 7;Questionnaire two

9 Questionnaire_2

Perception of fishers with the existing fisheries regulations and management.

The purpose of this survey is to assess your perspective on the existing regulation and management structures.

Date			

Vessel serial number		Country	
District		Sub-county	
Landing site		Enumerators' name	
Name of respondent		Phone	

FISHING EXPERIENCE

1. Fisher's status: Full time ( ) Part time ( )
2. If part time, specify other occupation: ………………………………………….
3. Could you please indicate your experience in fishing?
   1-5 ( ) 6-10 ( ) 11-15 ( ) 15 and above ( )
4. What fish species do you mainly target?
   Tilapia ( ) Nile Perch ( ) Mukene ( ) Other ( )

   Others (Specify) ______________________
5. What is the vessel-gear combination used for fishing (Tick wherever applicable).

	Gear			
Vessel type	GN	SN	LL	Other (Specify…………….)
Parachute				
Ssesse (Motorised/sail)				
Ssesse (paddled)				

Other (Specify………)				

6. Please rate how the following factors affect the choice of your fishing site.

Aspect	Please tick where applicable.
Weather	
Fishing experience	
Crew availability	
Restricted access to other fishing grounds	
Abundance of fish	
Looking for particular species.	
Distance to the landing site	
Theft	

PERCEPTION ON CATCHES

7. How would you rate the general catches over the last 10 years for the main target species [represent; 1= Better off, 2= Worse off, 3= Constant]?

Species	Better off	Constant	Worse off
Nile perch			
Nile Tilapia			
Silver fish/ Mukene			
Haplochromines			
Others, specify……….			

8. Based on your experience in the fishery, please rate the nature following problems in affecting fishing as an economic activity? (What are the major problems faced in fishing).

Aspect	Very severe	Severe	Neutral	less severe	Not sure.
Unregulated entry of people into the fishery.					
Conflicts over fishing grounds					
Reducing fish catches					
Increasing use of illegal gears					
Increasing fishing input costs					
Looking for particular species.					
Decreasing fish sizes					
Changing weather variations					
Other specify…………					

MANAGEMENT ASPECTS

9. Are you a member of the local beach management/landing site committee? Yes ( ) No ( )

10. If yes, how are you involved? 1. Member ( ) 2. None ( ) 3. Top management (Specify)…………………………

11. Which of the following fishing regulation are you familiar with?

Regulation	Yes	No	Not sure
The gillnet mesh size regulation			
Illegal fish gear ban			
Closed fishing seasons			
Closed areas (breeding and nursery grounds)			
Boat registration and licensing			

12. Do you think that all fishers at this beach are aware of these regulations? Yes ( ) No ( )

13. If no, why do you think so...?

14. In your own opinion can you please rate the following regulations in ensuring effective fisheries management at this landing site? Mark with X your preference.

Regulation	Strongly agree	Agree	Neither	Disagree	Strongly disagree
Gillnet minimum mesh size regulation.					
Fish gear Ban (Beach seines, cast nets, etc.)					
Closed fishing seasons					
Closed areas/restrictions on Breeding and Nursery grounds					
Boat registration and licensing with BMU/landing site.					

15. What roles does the current management execute?
……
……
………………………………………………………………………………

16. In your own opinion which one of the following Institutions would effectively handle cases when regulations are broken? (Please mark priority with X and choose one)
Fishers ( )
BMU office ( )
Local government fisheries office ( )
State government ( )
All the above ( )
None ( )

17. In your own opinion what suggestions would be appropriate in improving the fisheries? (Mark where appropriate)
1. ………
………
………………………………………………………………………………

Socio-demographic characteristics of respondents

18. Gender: Male ( ) Female ( ) Age: ………………………………………

19. Marital status: Single ( ) Married ( ) Widow ( ) others (specify): ………………

20. Number of households: ……………………………………

21. Are any of them involved in fishing activities? Yes ( ) No ( )
22. If yes, what role do they play? ……………………………
23. Education level: No education ( ) Primary Education ( ) Secondary education ( ) Tertiary/Vocational Studies ( ) Senior School Certificate ( ) Tertiary education ( ) Name of fishing village/Landing site: ………………………
24. Ethnic group: ……………………………………

THANK YOU FOR YOUR PARTICIPATION.