The United Nations University
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P.O. Box 1390, Skulagata 4
120 Reykjavik, Iceland

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RENTS AND RENTS DRAIN IN THE LAKE VICTORIA NILE PERCH FISHERY

Simon Wahome Warui
Ministry of Livestock and Fisheries Development
Fisheries Department
P.O. Box 58187-00200
Nairobi
Kenya
samaki@samnet.com or simonwarui@yahoo.com

Supervisor
Professor Ragnar Arnason
Department of Economics
University of Iceland
ragnara@hi.is

ABSTRACT

A simple bio-economic model of a single industry exploiting a single resource stock was set. The model was applied empirically to determine the optimal economic rents of the Lake Victoria Nile perch fishery. The theoretical model is based on the Schaefer (1954) model on dynamics of population and the Fox (1970) exponential surplus model for optimisation. The main elements of this model are (i) a biomass growth function, (ii) a harvest function and (iii) a fisheries profit function. The current biomass, fishing effort, profits and economic rents were determined against those of an optimal sustainable fishery at an equilibrium level. The fishery inefficiency was determined and an optimal recovery path devised. An efficient management system was proposed to induce efficiency in the fishery and give incentives to fishers in the implementation of a fishery recovery strategy and for sustainable fishery management.

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AIDS	Acquired Immune Deficiency Syndrome
BMU	Beach Management Unit
CPUE	Catch per Unit Effort
EU	European Union
FAO	Food Agricultural Organisation of the United Nations
GEF	Global Environmental Facility
IFMP	Integrated Fisheries Management Programme
IQ/ITQ	Individual Quota/ Individual Transferable Quota
LVEMP	Lake Victoria Environmental Management project
LVFO	Lake Victoria Fisheries Organisation
LVFRP	Lake Victoria Fisheries Research Project
t	Metric ton (tonne)
MSY	Maximum Sustainable Yield
P.S.	Permanent Secretary
TAC	Total Allowable Catch
TURFS	Territorial User Rights
UNU-FTP	United Nations University-Fisheries Training Programme
US$	United State Dollar
KCBS	Kenya Central Bureau of Statistics

1 INTRODUCTION

Nile perch was introduced into Lake Victoria in the 1950s. By 1980 the Nile perch fishery had attained major commercial significance. Helped by successful international marketing campaigns, foreign and domestic investors installed fish processing plants specialising in Nile perch products. The demand for Nile perch landings increased tremendously inducing the entry of a greatly increased number of fishermen into the fishery. In 2006, the Nile perch fishery contributed over 24% of the volume of fish harvest and 66% of income generated through fisheries in the three East African countries of Kenya, Uganda and Tanzania (LVFO 2007 b).

The volume of fish harvested in Lake Victoria steadily increased between 2000 and 2006. In the year 2000, the harvest was 620,000 t. In 2005 it was 804.000 t and slightly over 1 million t in 2006. During the same period, the Nile perch fishery declined as a fraction of the total harvest from 42% in the year 2000 to 29% in 2005 and 24% in 2006.The fish production in 2005 had a beach value of US $340 million; and that of 2006 had a beach value US $371 million. In 2005, Nile Perch contributed 32% of the volume of all fish landed from Victoria and 71% of the landed value. These percentages had fallen to 24% and 66% respectively in 2006 (LVFO 2007a).

According to Lake Victoria Fisheries Frame Survey (2006) (LVFO 2007a), the fishing capacity also increased substantially between 2000 and 2006. The number of fishermen increased by 52% from 2000 to 2006. The number of fishing crafts increased by 63% over the same period. The number of fishing crafts using outboard engines increased by over 200% suggesting that the fishers now go much farther than before in search of fish. Over the same period, the total number of gillnets also increased by 88% and long-line hooks by 160%. Catch per unit effort (CPUE) dropped from 22,9 ton boat^{-1}year^{-1} in 1989 when the number of fishing boats was about 16.700 to 4,5 ton boat^{-1}year^{-1} in the year 2006 when the boats had increased to about 69.000 (Kyomuhendo 2002, LVFO 2008). This fall in CPUE is a strong indication of falling stocks.

On the basis of the income derived from the fisheries it is apparent that in terms of commercial value the Nile perch fishery dominates the Lake Victoria basin fisheries. In Kenya alone, which has a 6% share of the total Lake Victoria surface area, the income derived from the Nile perch fishery in 2006 was estimated to be US $134 million (landed value). Nile perch fish products processed by fish processing plants based in Kenya earned a further US $43,0 million in international trade. Thus, it may be estimated that the Nile perch fishery generated income of over US $177,0 million in Kenya alone.

The economic importance of the Nile perch fishery in the region as well as the perception of possible overfishing is further portrayed in the proceedings of the “First Lake Victoria Fisheries Organization and FAO Regional Technical Workshop on Fishing Effort and Capacity on Lake Victoria” conference held in Dar-es- Salaam (Tanzania) in December 2005 (FAO 2005) as quoted in Appendix 7. The conference concluded and resolved, among other things, the need to update the information on the current status of Nile perch.

The richness of the Nile perch fishery has not been adequately converted to improve social welfare for the lake communities. On the Kenya's side of the lake unemployment in the community runs at 46%, which is the highest in the country according to the "Kenya Integrated Household Budget Survey by the Kenya Central Bureau of Statistics (2006).

Various hypotheses have been advanced to explain why, despite being a resource of great significance in the market and by local standards generates high revenues; the fishery has a modest impact on fisher welfare. These include (i) the communities do not have a saving culture; (ii) they are victim of the AIDS scourge; (iii) they are too poor to be able to purchase effective fishing gears; (iv) there are exploitative middlemen in the fish marketing; (v) governments have failed in their duty to enable the communities to benefit from the fishery. It appears, however, that a much simpler and more standard explanation can be found in terms of the dissipation of the fishery rents through the common property problem and hence inefficient fishery exploitation (Gordon 1954).

Capture fisheries from common pool resources are subject to severe economic inefficiency all over the world. This appears as overexploited fish stocks, excessive fishing fleets and effort and generally poor profitability of the fisheries (Arnason 2007, Shotton 2000 and FAO 2005. Arnason 2007. identifies the common property arrangement of these fisheries as the fundamental source of the problem. He explains how the lack of private property rights in the harvesting of the fish and the underlying resources leads to all these detrimental outcomes. The Nile perch fishery and, indeed, the other fisheries of Lake Victoria are managed under a loosely regulated open access regime where anyone who can afford a fishing license is allowed to access the fishery without any significant constraints. Thus, an outcome as the one described above, is to be expected. While the cause of the Nile perch fishery's inefficiency is known, the extent of this inefficiency is not well known. What is the total amount of the economic loss due to Nile perch fishery inefficiency? How significant is it in the Lake Victoria basin region?

The main objective of this study is to present estimates of the economic inefficiency in the Lake Victoria Nile perch fishery. For this purpose, the long run rent maximising fishing effort will be calculated and compared to the biological and economic outcomes with the current situation. In addition, an efficient dynamic fishery recovery path from the current situation to the long run optimal one will be explored.

This study contributes in various ways: first, it provides estimates of the magnitude of current and maximal resource rents and thus the current rents loss. This is interesting in itself. Second, it provides a rationale for policy and management intervention to improve a fishery which is clearly in biological and economic trouble. Bearing in mind that the lake is shared by three East African countries, and they have adopted a common fisheries management plan, it is important that aggregate rents and rent drain be established to provide a measure of what is lost and what can be gained by rationalising this fishery. The information generated through this study will help the fisheries managers and policy makers in Kenya and the partner states through the Lake Victoria Fisheries Organization (LVFO) to fulfil one the resolutions of the Regional Plan of Action on Lake Victoria which is to maximise the benefits of fishing to the fisher communities on a high biomass and sustainable basis.

The rest of the thesis is organised as follows: Chapter 2 provides background information about the Lake Victoria and the Nile perch fishery. It also presents a brief review of the theory of economic rent and that of fisheries rent in particular. Chapter 3 specifies a simple aggregate bio-economic model of the Nile perch fishery to be used in rents estimation of this fishery. Chapter 4 deals with empirical estimation of model parameters covering data collection and methods. The unknown parameters of the model are estimated by fitting the model to a set of available observations on the Nile perch fishery. With the estimated Nile perch fishery model in place, it is possible, in Chapter 5, to calculate economic rents both in the current fishery and in the optimal fishery. The inexactness in the estimated Nile perch fishery model, i.e. the uncertainty about the real fishery, was partially accounted for by sensitivity analysis. Also, in Chapter 5, dynamic adjustment paths from the current situation to the optimal long run ones are investigated and their present values calculated. Finally, policy recommendations and conclusions drawn through this study are covered in Chapter 6 of this report.

2 BACKGROUND

This chapter will cover two issues; first it will deal with the fisheries related issues. It will attempt to describe the geography of the study area and its scope. The general fisheries of Lake Victoria will be described and thereafter the biology and the fishery of the Nile perch will be explored. Secondly, the concept of economic rents, in many ways the crux of the economic issues of the fishery, will be explained. This is to give a fore-knowledge of the relationship between the biological and economic aspects of the fishery, which is the focus of this study.

2.1 Study area description

Lake Victoria is the second largest lake in the world with a surface area of 68.800 km^2 and a shoreline of 3.450 km. Its mean depth is 40 m and maximum depth 84 m. The water retention time is about 140 years. The lake has a catchment area of 194.200 km^2 which extends to Rwanda and Burundi. The lake is shared by Kenya (6% by area), Uganda (43%) and Tanzania (51%). Lake Victoria basin has a population of over 30 million, a third of the combined population of the East African States, and the fastest growing with a population growth rate of 2,3% per year. There are 31 administrative districts around the lake distributed as follows: Tanzania 12, Uganda 11, and Kenya 8 (Figure 1). The basin is a major commercial centre. Apart from fisheries, other uses of the lake include tourism, transport, domestic water supply and hydro-power generation. Much of the population derives its livelihood directly or indirectly from the lake’s resources.

Figure 1: Lake Victoria Basin illustrating the position of Lake Victoria amongst the three countries’ administrative districts surrounding it (Sources: *East Africa Maps* and LVFO 2008)

2.2 General overview of Lake Victoria fisheries

The main fisheries in Lake Victoria of commercial significance are Nile perch, tilapine species and *Haplochromines* and *Rastreonobola argentia* ("dagaa"). Other fish species also harvested are Bagrus species, Clarias species, Syndontis species, Schilbe species, Protopterus species and Labeo species. However, they are neither significant in biomass nor market value. The fisheries are, for the most part, conducted by artisanal fishermen mainly using canoes propelled manually or with outboard engines (LVFO 2007a).

According to statistical data generated through the Lake Victoria Fisheries Research Programme (LVFRP) survey work done between 1997 and 2000 (LVFO 2007b) the average mean standing stock of all fish commercially exploited in the lake during this period was 2,17 million t. A subsequent survey conducted by the Integrated Fisheries Management Programme (IFMP) between year 2000 and 2006 indicated the standing stock to be 2,12 million t. The record further indicates that the highest ever recorded standing stock was 2,56 million t in February 2006, while the lowest ever recorded was 1,55 million t in August, 2005. The mean standing stock of Nile perch was estimated to be 1,29 million t in a 1999-2001 survey; about 59% of the total fish biomass in the lake at that time. A corresponding survey from 2005-2006 indicates that the Nile perch standing stock had fallen to 0.8 million t constituting about 39% of the total fish biomass in the lake. The standing stock of "dagaa", which is a prey of Nile perch, was estimated to be 0,48 million t in the first survey conducted between 1999 and 2001 and 0,83 million t in the second (Table 1) (LVFO 2007a).

Table 1: Fish biomass status in Lake Victoria (LVFRP and IFMP surveys (LVFO 2007a))

Period	Survey by:	Type of fish	Mean stock (t)	Highest stock (t)	Lowest stock (t)	Percentage to total (%)
1997-2000	LVFRP II	All commercial fish species	2,17	-	-	
2000-2006	IFMP		2,12	2,56 (February 2006)	1,55 (August, 2005)	
1999 - 2001	LVFRP II	Nile perch	1,29	-	-	59%
2000-2006	IFMP		0,82	-	-	39%
1999 - 2001	LVFRP II	*"Dagaa"*	0,48	-	-	22.4%
2000-2006	IFMP		0,83	-	-	38%
1999 - 2001	LVFRP II	Tilapia and Haplochromines	0,37			17.2%
2000-2006	IFMP		0,47			23%

Table 2: Catch of commercial fisheries of Lake Victoria and their contribution to landings by volume and value (LVFO 2007b)

Year	2005			2006	
Type of fish	Weight (t)	Landing value (million US$)		Weight (t)	Landing value (million US$)
Dagaa *(Rastreonobola argentia)*	352.000	40,8		573.000	74,2
Nile perch	256.000	241,4		255.000	244,86
Tilapia	80.000	37,4		74.000	38.213
Haplochromines	104.000	-		138.000	8.533
Other fish species	< 1%.	-		-	3,71
Total fish production (t)	**800.000**	**340**		**1.061.108**	**371**

Implied landing prices / 1000 t
Nile perch = 0,96 m US$ / 1000 t
Tilapia= 0,51 m US$ / 1000 t
"*Dagaa*" = 0,13 m US$ / 1000 t
Haplochromines = 0,06 m US$ / 1000 t

In the year 2005, total fish production in Lake Victoria had a landed value of US $340 million; and in 2006 the landed value had risen to US $371 million. In 2005, Nile perch contributed about 71% of the landing value. In 2006, this contribution had fallen to 66%. It is significant that *"dagaa",* which is the preferred prey for Nile perch, increased as a share of the total harvest from 44% in 2005 to 54% in 2006.

According to the LVFO (2007c) data, fishing capacity increased substantially between 2000 and 2006. The number of fishermen increased by 52%, from 129.305 to 196.426. The number of fishing crafts increased by 63% from 42.493 to 69.160. The number of fishing crafts using outboard engines increased from 4.108 to 12.700, a 211% increase. This suggests that the fishers go far in search of fish. Over the same period, the total number of gillnets employed increased by 88% and long-line hooks by 160 %.

Overall, the above evidence from the Lake Victoria fisheries exhibits clear signs of increased fishing effort and declining stocks of the more valuable species, especially Nile perch. In this respect, the Lake Victoria fisheries generally and the Nile perch fishery specifically follow the usual trends for open access, common pool fisheries (Gordon 1954, Harding 1968, Shotton 2000).

2.3 Current fisheries policy and management plan

The management system employed by the three East African countries for the Nile perch fishery, as well as for the other fisheries in the lake, is restricted to biological management measures. The objective of the system is to maximise biological yield by protecting spawning stocks, young fish and fragile habitats. Measures put in place include slot size regulation by use of selective fishing gears, closing breeding, juvenile and nursery areas, closed fishing seasons and restrictions on habitat degradation and pollution.

Although this type of management focuses on the bio-ecological component of sustainability, it has failed to achieve the desired outcomes. Nile perch seems to have declined substantially over time and fishing effort seems to have increased greatly. A great deal of administrative effort and funds are spent trying to control destructive fishing methods and gears. However, fishermen are always ahead in circumventing any new management approach. To enforce management regulations, new pieces of legislation have been put into place in quick succession trying to close off the loopholes the fishermen capitalise on. In some instances, a new subsidiary legislation put in place contradicts others already in existence in the same country or in neighbouring ones. There is an escalating complexity of rules and regulations and even the fisheries regulators acknowledge that they are confusing and make enforcement even more difficult.

To resolve these challenges the fisheries authorities in Kenya and also the other countries have engaged the fishers in participatory fisheries resource management through the formation of co-management organisations known as Beach Management Units (BMU). The fisheries management activities of the three countries have been harmonised through facilitation and moderation of the regional fisheries body known as the Lake Victoria Fisheries Organization (LVFO). A joint management plan was put in place in 2001 through a programme known as the Integrated Fisheries Management Programme (IFMP). An ecosystem approach to the management of the Lake Victoria resources was considered and adopted as the way forward. Effort was put in place under the coordination of LVFO (IFMP) to achieve the ecosystem approach objectives. While it should be acknowledged that the benefits of this approach may take time to accrue, the duration during which this approach is in progress has witnessed an escalation of fishing effort and a decline in catch per unit effort (CPUE) of Nile perch. It has been noted that some members of BMUs are the major culprits in violating the regulations they are supposed to enforce jointly with fisheries managers. Clearly, this behaviour undermines the purpose of the BMUs' formation.

It seems clear that the fisheries management to date, which is restricted to biological tools or an ecosystem approach, has neither been able to reverse the downward trend of Nile perch stock biomass nor make the fishery more profitable to the fishers. As regards these main purposes, it seems to have failed quite drastically.

2.4 Lake Victoria Nile perch fishery

2.4.1 Nile perch introduction

According to R.L. James (undated) and The American Museum of Natural History (1996), Nile perch was initially clandestinely introduced by the British Colonial Administration Fisheries Office in the Ugandan part of Lake Victoria in the 1950s in order to increase fish catches in the lake. The fish was sourced from Lake Albert in the Western part of Uganda. This was despite strong opposition by the biologists based on the lack of natural predators on Nile perch in the lake. Thereafter, subsequent reseeding was done intentionally in 1962 and 1963. By 1964, Nile perch was recorded in the Tanzanian part of the lake. By 1970 it was well established in the Kenyan part, and by the early 1980s it was abundant throughout the waters of the three countries sharing Lake Victoria. With no natural predator and abundance of food in the lake the fish flourished, often reaching up to 250 kg, it is a fierce predator and its predation decimated haplochromine populations into commercial extinction.

With the introduction of Nile perch into Lake Victoria, hundreds of endemic species were forced into commercial extinction. The loss of endemic fish species was devastating for the ecology of the lake, its genetic pool, and evolutionary biology; and, of course, the traditional fisheries. Before Nile perch, the Lake Victoria fisheries depended on catching catfishes, carps, and lung fishes that comprise the local diet. Today, these fish only amount to about 1% of the total fish harvest of the lake (LVFO 2007a). Loss of habitat and over-fishing have probably also contributed to the collapse of many of these fisheries. The ecosystem switch and the commercialisation of the Nile perch fishery have made many previous protein sources from the Lake unavailable for local consumption.

2.4.2 Biology of Lates nilotica (Nile perch)

Nile perch (*Lates niloticus*) is a species of freshwater fish in the family of Centropomidae of the order Perciformes. It is widely spread throughout much of the Afrotropic ecozone, being a native to Lake Chad, Congo, Nile, Senegal, Volta, Lake Turkana and other river basins. Its introduction into Lake Victoria was mainly from Lake Albert, but also from Lake Turkana. The present populations in Lake Victoria are apparently not pure *Lates niloticus*, but contain some genetic material from *Lates macrophthalmus* from Lake Albert. It is one of the largest fresh water fish, reaching a maximum length of nearly two meters, and weighing up to 250 kg. A five year old Nile perch fish can attain a weight of over 50 kg and over 100 cm in length (Figure 2).

Figure 2: Adult Nile perch in Lake Victoria, about 110 cm and approximately 5 years old

Adult Nile perch occupy the habitats of the lake with sufficient oxygen concentrations, while juveniles are restricted to shallow and near shore environments. It is a fierce predator that dominates its surroundings. It feeds on fish (including its own species), the haplochromine cichlids, the zooplanktivorous cyprinid *Rastrineobola argentea*, and the prawn *Caridina nilotica*. The young stages feed on zooplankton and insects.

The fish spawns in shallow sheltered areas, all year round with peaks in the rainy season. The females spawn over 16 million eggs per breeding cycle.

In Lake Victoria, the size of males at first maturity is 50-55 cm total length (2 years of age) and that of females is 67.5 – 85 cm (2 – 4 years old). The maturity size has strongly decreased in recent years (Snoeks 2005, William and David undated, Tiljs, Frans and Jan 1993). This often indicates falling fish stock.

2.4.3 Abundance, distribution and fishing gear efficiency

A frame survey carried out in 2005 by the Integrated Fisheries Management Programme (IFMP) using the “swept area method” and correcting for the vertical distribution of Nile perch stock, estimated that the standing stock of Nile perch was 623.000 t with a mean density of 11 t km^{-2}; with 52% in Tanzanian waters, 40% in Ugandan and 8% in Kenyan. In 2005/2006 the Nile perch stock was estimated to be 571.000 t at a mean density of 6,8 t km^{-2} of which 53% was in Tanzanian waters, 31% in Uganda and 16% in Kenya (Inigo 2006). It is apparent from these surveys that over 50% of the Nile perch fishery is present in the Tanzanian part of the lake, followed by Uganda with between 30-40% and lastly Kenya with between 8-16%.

There is a great difference in fishing effectiveness in the harvest of the Nile perch using motorised boats and non-motorised boats. A boat that is manually paddled and using gill nets has an efficiency of catching an average of 5-7 kg $boat^{-1}$ day^{-1} in Kenya, 8-9 kg $boat^{-1}$ day^{-1} in Uganda and 14-15 kg $boat^{-1}$ day^{-1} in Tanzania. A motorised boat using a gill net has an efficiency of catching 16-20 kg $boat^{-1}$ day^{-1} in Kenya, 25-26 kg $boat^{-1}$ day^{-1} in Uganda and 31-35 kg $boat^{-1}$ day^{-1} in Tanzania. Thus generally, a motorised boat seems to be approximately three times more effective than a manually paddled boat using the same fishing method and gear (LVFO 2008). There is also apparently a significant difference in catch rates between different national parts of the lake. The catch rate was 11,000 t per month in Tanzanian waters, 5,000 in Uganda and 4,000 t in Kenya (LVFO 2007c). What causes this difference is unclear. It could be fish availability or differential catching efficiency.

2.4.4 Nile perch harvesting trend

The Nile perch took quite a long time after introduction in Lake Victoria to attain significant commercial status. It was not until 1976 that all the three East African countries sharing the lake started posting Nile perch harvest year after year. The fishery expanded fast from 1981 onward and by 1987, the Nile perch fishery had become a major commercial fishery (Figure 3). Foreign and national investors installed 35 fish processing plants mostly specialising in Nile perch products and the demand for Nile perch increased tremendously attracting an increased number of fishermen into the fishery.

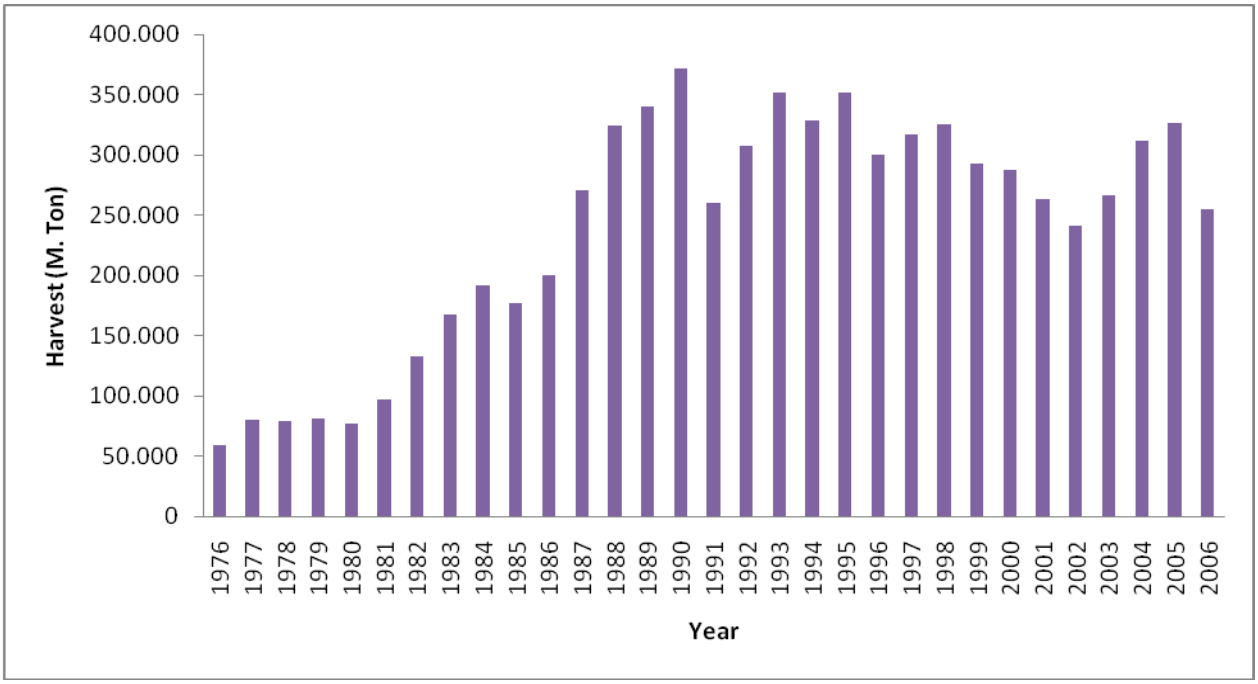


Figure 3: The Nile perch harvest trend for the last 30 years by the three East African countries (FAO 2008).

The peak in the Nile perch harvest of over 350 thousand t was attained in 1990. Catches of between 300 and 350, thousand t were sustained until about 1995. From then catches have exhibited a slowly declining trend with a minimum in 2002 of 240.000 t.

The falling catches from 1995 to the minimum level in 2002 were of considerable concern to the management institution of the three countries. They came up with a joint management plan with the aim of integrating the management of Nile perch through a programme called Integrated Fisheries Management Programme (IFMP).

To the fish processors, the decline in catches constitutes a threat to their business. The demand for Nile perch fish was high, prices good and profits high. The contracting catch constituted a threat to their investments and profits. To the fishermen, falling catches also meant less net income. They responded by increasing the fishing fleet which induced more fishermen to enter into the fishery. The period between 2000 and 2006 saw a great influx of fishermen whose numbers increased by 52% as already mentioned. There was also a 63% increase in the number of fishing crafts and the number of motorised boats increased by 211%.

The increase in fishing effort was accompanied by a gradual increase in harvest from 2003 to 2005 with a peak of 327.000 t. Thereafter, in 2006 the harvest declined to 255.000 t despite the sustained increased fishing effort. This evidence strongly suggests that Nile perch stocks have fallen substantially and are now probably well below their MSY levels. Also, provided catches are not greatly underestimated by the statistics, it suggests that Nile perch MSY is not much above 300 thousand t per annum.

It is worth noticing (Figure 4 below) that the three countries harvested maximally between year 1987 and 1998 with each attaining its harvesting apex during this period. Thereafter, the Tanzanian and Kenyan landings declined up to 2006. It is apparent that the increase in harvest observed between 2003 and 2005 was primarily due to Uganda. This could well be explained by the country’s effort to increase its fishing capacity through motorisation of fishing boats.

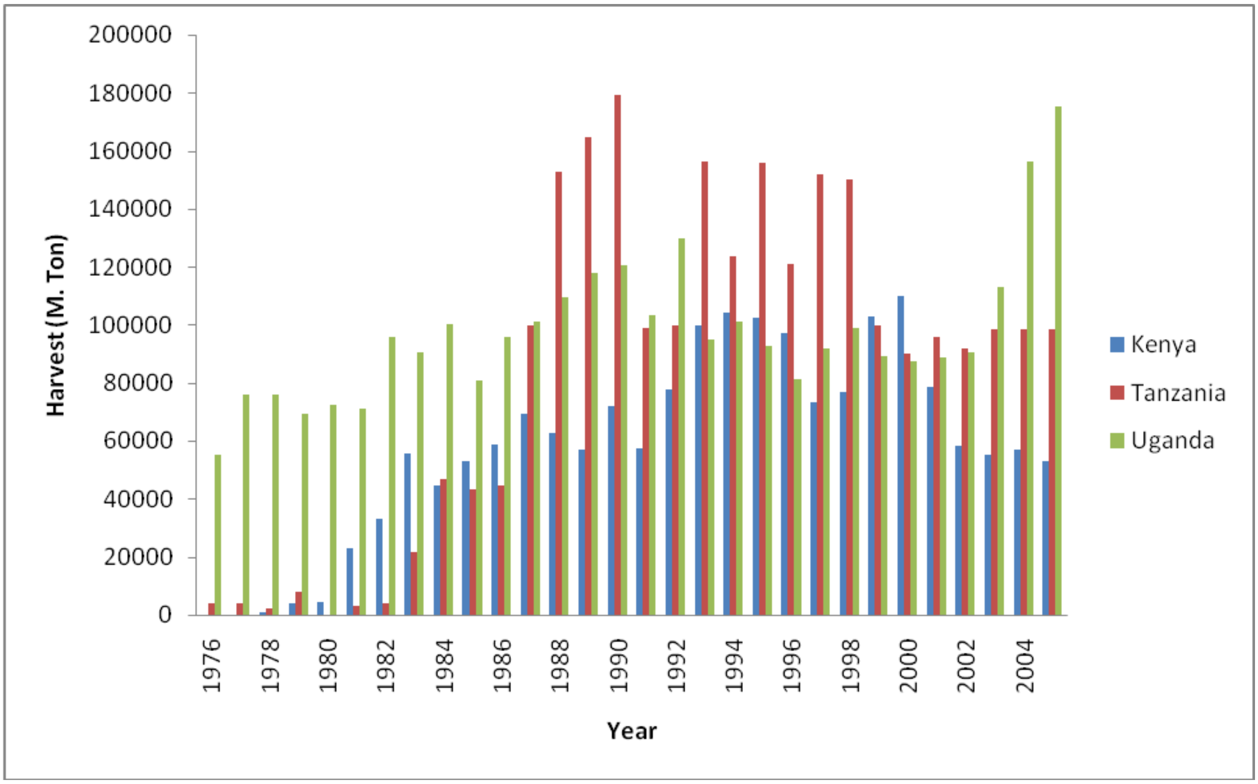


Figure 4: The trends in Nile perch harvesting in Kenya, Uganda and Tanzania for the last 30 years (FAO 2008).

2.4.5 Fishing effort trend

There has been a general trend of increasing fishing capacity by the three countries (Figure 5). The number of boats increased from 43.000 in 2000 to 69.000 (actual boats) in 2006 while the number of fishermen rose from 129.000 to 196.000 during the same period. This "effort escalation" has not been matched by an equivalent harvest increase. On the contrary, the Nile perch harvest has shown a decline in 2006 when the fishing effort was at its highest level.

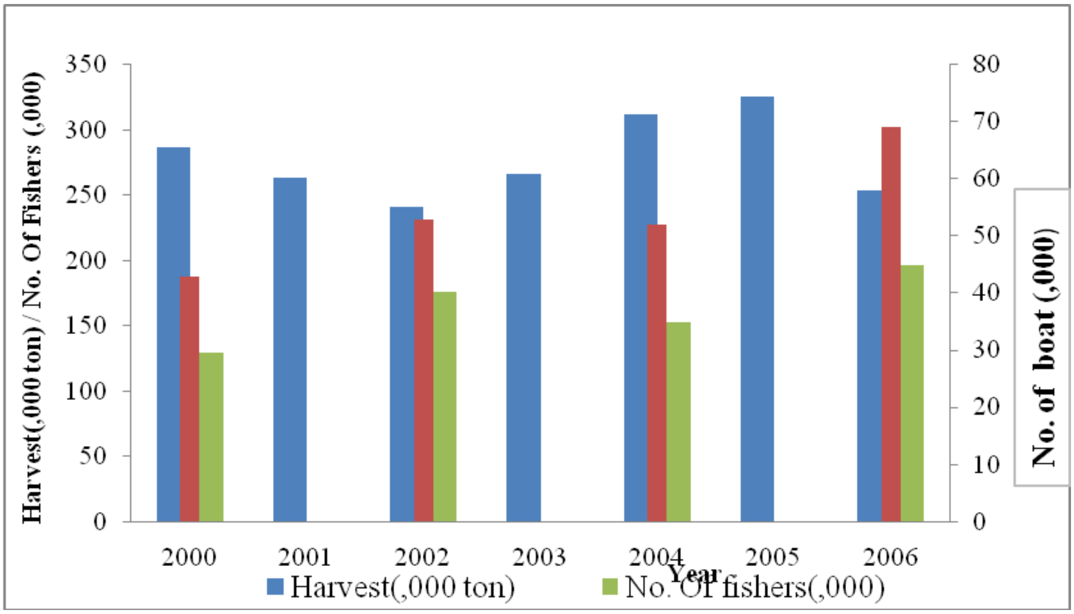
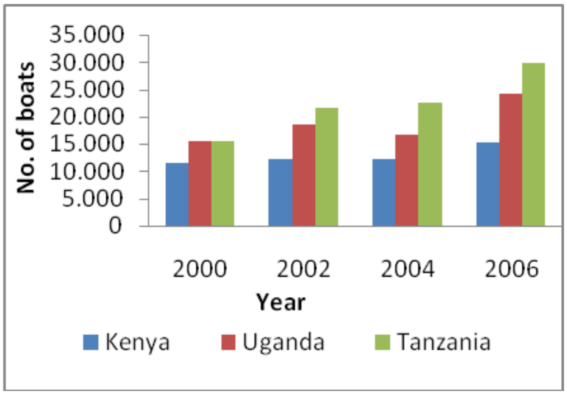
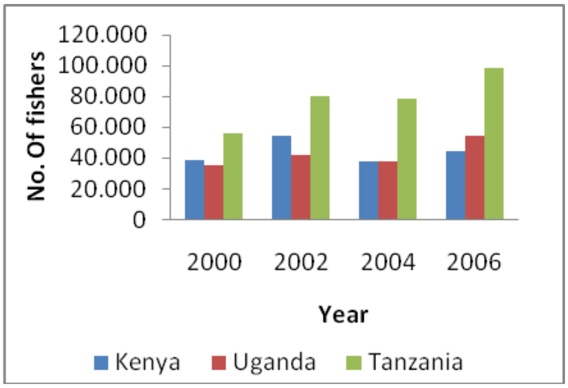


Figure 5: The general trend in the deployment of the total number of fishing boats and fishermen with time and their impact on fish harvest in Lake Victoria's Nile perch fishery from 2000 to 2006.

Tanzania has the greatest number of fishing boats followed by Uganda with Kenya having the least number of boats during the period since 2000. There was a general increase in the number of boats in each country with Tanzania and Uganda showing the sharpest increase of 93% and 55% respectively and Kenya with an increase of only 32%, (Figure 6 (a)).

A similar trend is observed in the number of fishermen across the three countries with Tanzania showing the highest increase of 75%, Uganda 55% and Kenya15% during the same period. The number of fishermen increased from 56,0 thousand to 98,0 thousand in Tanzania; from 34,9 thousand to 54,0 thousand in Uganda; and from 38,4 thousand to 44,3 thousand in Kenya (Figure 6 (b)).



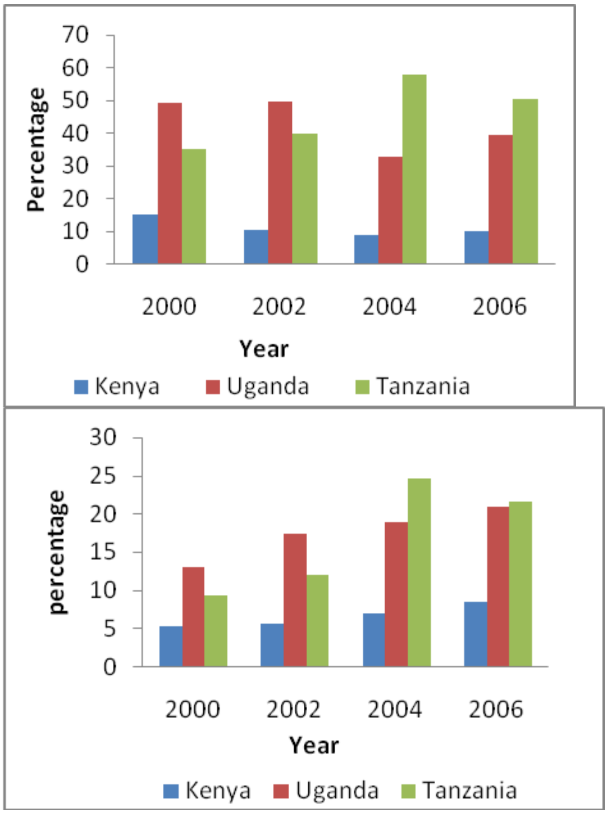


(a) (b)

Figure 6(a) and (b): The changes in the number boats and fishermen and their deployment amongst the three East African countries between 2000 and 2006

The disparity in the number of boats and fishermen could be explained by the disproportionate allocation of Lake Victoria’s surface area among the three countries: with Tanzania having the greatest portion (51%) followed by Uganda (43%) and Kenya having the least share of (6%) thus giving differential spatial opportunities for more fish biomass. However, the percentage rate of increase during the same time indicates the presence of stiff competition amongst fishermen to catch most the fish for the demanding market through increasing their fishing capacity.

The rate of motorisation provides evidence of the competition amongst fishermen, and maybe also between the three countries, for catch. In the period 2000 to 2002, the highest proportion of motorised boats was in Uganda with about 50% of all motorised boats. However, according to the Fisheries Frame Surveys (2004 and 2006), Tanzania overtook Uganda in motorisation, commanding between 50% and 58 % of all motorised boats on the lake. This race to increase fishing capacity is also evidence of each country’s proportional increase in motorisation. About 22% of all Tanzanian boats were motorised by 2006 compared to only 9% in 2000. In Uganda about 20% were motorised by 2006 as compared to only 13% in 2000 and 9% in Kenya in 2006 as compared with 5% in 2000.



(a) (b)

Figure 7: The distribution of motorised boats amongst the three countries (a) and the percentage proportion of motorised boats in each country (b)

Possibly because of improved boats and fishing techniques rather than an increase in the Nile perch stock, catch per unit effort (CPUE) increased to a high of 22,9 t boat^{-1}year^{-1} in 1988 when the number of fishing boats was about 16,7 thousand. Since then there has been a steady decline of CPUE with the lowest value of 4,7 t boat^{-1}year^{-1} in 2006, the most recent year (Figure 8). This trend provides strong evidence of a reduced stock of Nile perch.

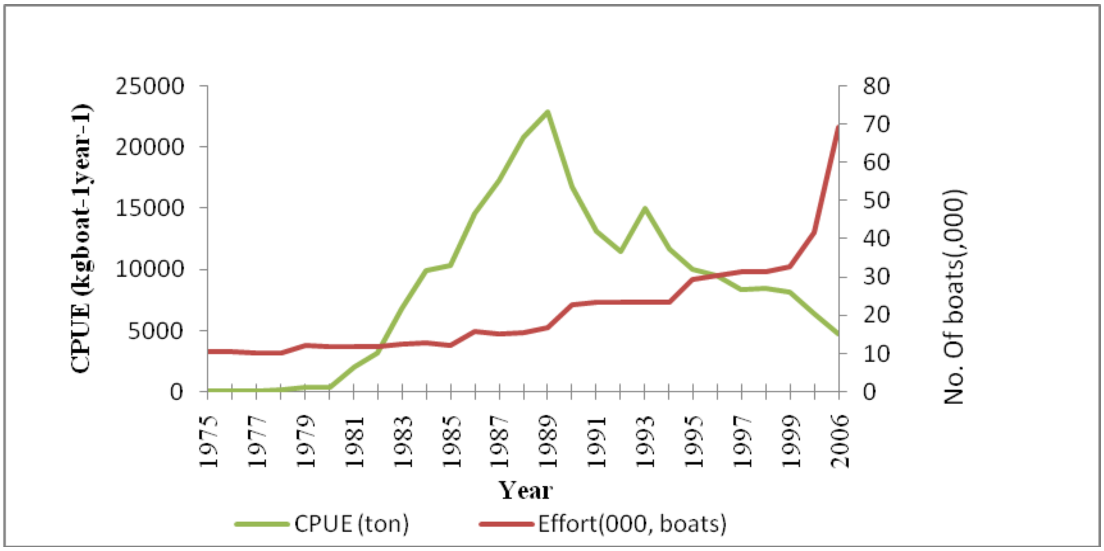


Figure 8: The Nile perch catch per unit effort (CPUE) trend with the increasing number of fishing boats (Kyomuhendo 2005, LVFO 2007c).

2.4.6 Socio-economic aspects of the Nile perch fishery

The Nile perch "boom" is threatening to displace fishers in two ways: first by the loss of other fish which traditionally constituted the catch of the original fishers. Second, by concentrating production in the hands of wealthier entrepreneurs - the ones who can best afford the heavier investments in gear needed for successful exploitation of Nile perch. Most wealthy merchants from urban affluent communities have invested heavily in fishing gears which they lease to local fishermen. These include outboard engines, good boats relative to those of other fishermen, fishing nets and hook and lines. In return, the fishermen are committed to selling their harvest only to those merchants. Increased motorisation of fishing effort to meet the fish processors' fish demands has severely marginalised artisanal fishers, in addition to rapidly depleting fish stocks (FAO 1988).

The expansion of capital-intensive, industrial-level processing of Nile perch and its successful marketing have resulted in massive transfers of fish protein supplies away from food-deficit areas to serve the lucrative urban and export markets. This has led to heightened displacement of small-scale fish distributors, mostly women, who depended on the trade as an important source of income.

2.5 Basic concepts of economic rents

In economic rent concept there is a demand curve and a supply curve for economic goods. The supply of goods is independent of the price and thus fixed as shown in the diagram in Figure 9. The price, *p*, is the market clearing price for goods *q* supplied. The goods *q* would still be supplied regardless of whether the price is zero as the

supply is fixed. Thus the whole price *p* is regarded as surplus per unit of quantity. The total economic rent attributable to the resource is measured by rectangle *p.q*.
The economic rents depicted in Figure 9 also represent rental profits to the owner of the good. This is what the owner would gain from renting a resource of quantity *q* to the demander.

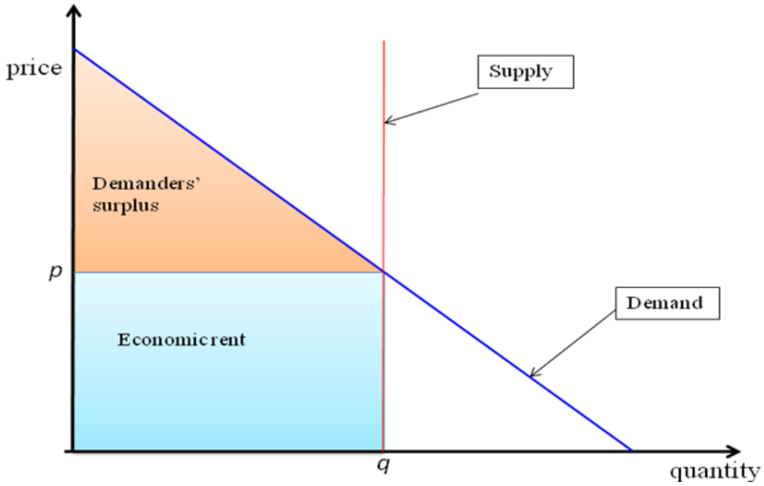


Figure 9: The concept of economic rents illustrating the relationship between supply and demand and their effect on price (Arnason 2007).

However, economic rents do not represent the total economic benefits of the supply *q*. Total benefits are measured by the sum of economic rents and the demanders' surplus represented by the upper triangle in the diagram. If the demanders are the producers buying or renting *q* from the owner at price *p*, their profits would be the demanders 'surplus (Arnason 2007). Thus, total profits would be greater than the economic rents.

Figure 9 represents fisheries rents where the resource supply is not fixed by nature. At each point in time, it is possible to alter the extraction level. In one extreme it can be determined by free access to the resource and in case there are no economic rents or constraints by the fisheries management to maximise economic benefits from the fishery. In between are various fisheries management regimes which restrict the quantity of harvest at different levels.

However, in all these cases of resource extraction there is a supply curve which is normally not vertical as shown in Figure 9. This supply represents the degree of present value profit maximisation that is undertaken by the resource owner or the fisheries manager and not the cost in monetary outlay. The actual supply in this case is where the supply curve intersects the demand curve- and at which point there will be economic rents. For an optimally managed fishery, this supply curve and the corresponding fisheries rents are as illustrated in Figure 10. Less than perfectly managed fisheries will give rise to harvest supply curves below the one illustrated in Figure 10 and actual supply between *q* and q^o. In an open access or totally unmanaged fishery, this supply curve will coincide with the horizontal axis. The supply will be q^o and the fisheries rents are identically zero.

According to Figure 10, the actual supply is q and the resource rents are defined by the multiple $\lambda\lambda$ .q. There is no cost associated with the supplying q-the supply price, λ, is an imputed price. It represents the opportunity cost of reducing the size of the resource, sometimes referred to as a user cost (Gordon 1954) missing. This user is the result of the maximisation of the present value of the profits and is generated by the concern that “oversupply” now might hurt future profits.

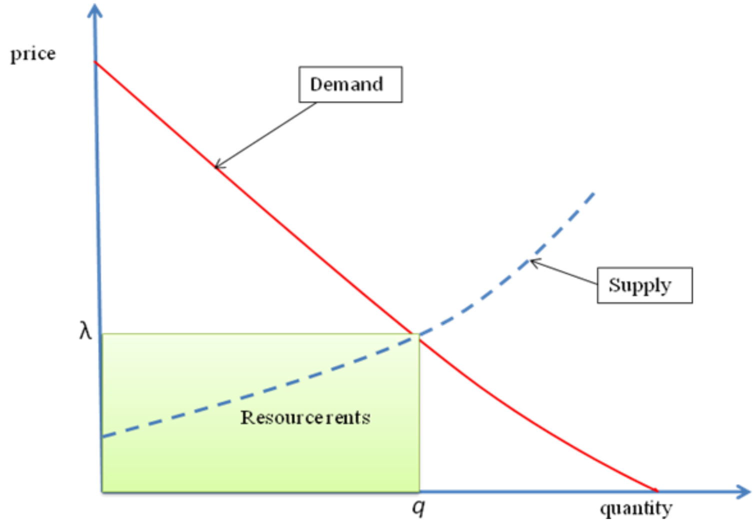


Figure 10: Resource rents of a resource extraction industry where the demand and supply curve converge giving the optimal price, λ, for the supply of goods of quantity *q* (Arnason 2007)

From Figure 10, it is clear that λ is equivalent to the demand price for the quantity q. This demand price is the marginal profits (additional profits of having one more unit) of q. This marginal cost is hereby denoted by the symbol Π_q which may be recognised as the first derivative of Π in respect to q, where Π, denotes the profits. Thus, we get the relationship:

$$Rents = \lambda . q = \Pi_{q.}\, q$$

On the basis of this relationship, it is possible to calculate fisheries rents if the profit function the variables on which it depends at λ and the quantity q are known. This relationship is the basis on which the estimation of rents and rent loss in this study will be made.

3 A BIOECONOMIC MODEL OF THE NILE PERCH FISHERY

To explain the Nile perch fishery and investigate improvements in its utilisation, we construct a simple bio-economic model of the fishery. The main elements of this model are (i) a biomass growth function, (ii) a harvest function and (iii) a fisheries profit function. The first function represents the biology of the model. The second function constitutes the link between the biological and economic part of the model and the third function represents the economic part.

More precisely, the model is as follows:

$$x = G(x) - y \qquad \text{(Biomass growth function)} \qquad (1)$$

Where *x* represents biomass, *G*(*x*) is biomass growth and *y* the level of harvest. The function *G*(*x*) is natural biomass growth. This function is assumed to follow the basic biological specifications.

The volume of harvest is taken to depend positively on fishing effort as well as the size of the biomass to which the fishing is applied. This harvesting function can be written as follows:

$$y = Y(e, x) \qquad \text{(Harvesting function)} \qquad (2)$$

The profit function depends on the fish price, the sustainable fish yield and the fishing operation costs. The fishing costs depend on the use of economic inputs, which is the fishing effort we can represent the profit function equation as follows:

$$\pi = p \cdot Y(e, x) - C(e) \qquad \text{(Profit function)} \qquad (3)$$

Where *p* represents the price of fish landings and *C*(*e*) is the cost function of fishing effort.

The five variables of this model, i.e. *x*, *y*, *π*, *e* and *p* represent biomass, harvest, profits, landings price and fishing effort, respectively. The first three, .*x*, y and π are endogenous - determined within the model. The fourth, the landings price of fish, is exogenous - determined by market conditions outside the fishery. The fifth, fishing effort, is a natural control variable for the fishery, which the fisheries authorities can influence.

The above model comprises three elementary functions; the natural growth function, *G*(*x*), the harvesting function *Y*(*e*, *x*), and the cost function, *C*(*e*). We adopt widely-used specific forms for these functions.

3.1 The biomass growth function

Populations of organisms cannot grow infinitely. Growth of organisms is constrained by environmental conditions and food availability. It has been shown that populations of organisms strive to stabilise at the highest possible population size for a given set of conditions (Schaefer 1954). Marginal growth of a population increases when the size of the population decreases, and marginal growth decreases when the size of the population increases, this may be called density dependent growth. Biological growth of such a population may be expressed as:

$$G(x) = rx - sx^2 \qquad (4)$$

Where x is population size, r is the growth rate of the population and s is the mortality rate which is negative. This is the parabolic equation also referred to as Verhults' equation or the logistic growth equation (Schaefer 1954).

When the population reaches the environmental carrying capacity, K, growth is reduced and mortality increases. Growth and mortality of the population becomes equal, and rate of change of population size with respect to time (*dx/dt*) becomes zero.

The mortality rate can now be expressed in terms of r and K as

$$s = \frac{-\mathbf{r}}{K} \qquad (5)$$

Substituting s in equation (4) by (5) we get the most commonly used expression of logistic growth equation.

$$G(x) = rx\left(1 - \frac{x}{K}\right) \qquad (6)$$

In 1970 W.W. Fox outlined an alternative surplus –yield model, assume Gompertz growth function, resulting in an exponential relationship between fishing effort and population size and asymmetrical harvest curve (Fox 1970). Generalised form of the Fox curve can be represented as (Winsor 1932):

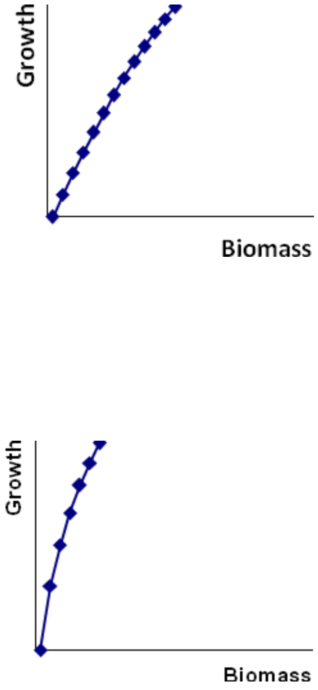
$$G(x) = \mu x(\ln K - \ln x), \qquad (7)$$

In this formulation the carrying capacity of the biomass is K, as in the logistic formulation. However, unlike the logistic, the Fox growth function is not symmetric and the intrinsic growth

rate, $\lim\limits_{x \mapsto 0} \frac{G(x)}{x}$, is infinite compared to r for the logistic.

The major difference between the logistic model and the Fox model is that at lower population sizes the Fox model predicts a higher growth rate than the logistic model.

At higher population sizes, the logistic model predicts a higher growth rate than prediction by the Fox model. In the logistic model maximum growth occurs at half of the maximum population level. In the Fox model maximum growth occurs at a population level less than the half of the maximum population, or around 37% of the maximum population. In other words, the population growth curve of the Fox model is skewed to the left while the population growth curve of the logistic model is symmetrical (Figure 11 (a) and (b)).



(a) Logistic biomass growth **(b) Fox biomass growth**

Figure 11(a) and (b): Logistic and Fox biomass growth curves respectively illustrating the biomass growth rate with increases in biomass for a population that follows the logistic and Fox growth functions respectively.

3.2 The harvesting function

Assuming that each unit of effort harvests equal amounts from the targeted stock, harvest may be described by (Schaefer 1954):

$$y\ (e, x) = qex \qquad (10)$$

Where q is the catchability coefficient. Equation (10) implies that harvest (h) is proportional to the stock size (x) at a given fishing effort e. Assuming an equilibrium situation where catch equals natural growth, the equilibrium stock size *(x)* may be expressed in terms of K q, e and for the harvesting model in accordance to the generalised Schaefer (1954) version:

$$Y(e,x) = q \cdot e \cdot x^{b}, \qquad (11)$$

where coefficient b indicates the degree of schooling behaviour by the fish (Normally $b \in [0,1]$).

3.3 The cost function

Fishing effort has an index of economic input in the form of labour, investment, fuel, maintenance and supplies, fixed costs and overhead that is devoted to the fishery on an annual basis. The annual cost of fishing C(e) is proportional to effort e. It was assumed in this study that the fishing vessels are homogeneous.

For the cost function we choose:

$$C(e) = c \cdot e + fk, \qquad (12)$$

Where fk represents fixed costs

3.4 The complete model

The complete model under those functional specifications becomes:

$$\dot{x} = \alpha \cdot x - \beta \cdot x^{2} - y,$$

$$\text{or} \qquad \text{(Biomass growth function)} \qquad (13)$$

$$\dot{x} = \alpha \cdot x - \beta \cdot ln(x) \cdot x - y$$

$$y = q \cdot e \cdot x^{b} \qquad \text{(Harvesting function)} \qquad (14)$$

$$\pi = p \cdot y - c \cdot e - fk \qquad \text{(Profit function)} \qquad (15)$$

The last two equations can be combined to yield a simpler version of the model:

$$\pi = p \cdot y - \left(\frac{c}{q}\right) \cdot y \cdot x^{-b} - fk \qquad \text{(Profit function)} \qquad (16)$$

The ratio (c/q) viewed as a single parameter known as the normalised marginal costs. It shows that the marginal costs and catchability, c and q do not play an independent role in this model. What counts in the model is the ratio of the two.

3.5 Sustainable yield

Annual rate of renewal of fish stock depends on three major factors: biological environment, physical environment, and magnitude of the remaining population. Biological and physical environment may be considered to be constant in the long run (Schaefer 1957). Population size is reduced by natural and fishing mortality. Harvesting increases the total mortality. As the fish population strives to balance the total mortality with growth, the population reaches a new equilibrium at a point where the growth rate equals total mortality, which occurs at a lower population size than the environmental carrying capacity level *K*. When the fish stock reaches equilibrium with a given effort level, all biological growth of the population is harvested and there is no net change in the population size. Then

$$y\,(e, x) = G\,(\mathrm{x}) \tag{17}$$

$$G(x) = rx\left(1 - \frac{x}{K}\right) = qxe \tag{18}$$

(Note: Work based on simplified sustainable Schaefer function. The study was not able to get the sustainable function for the generalised Schaefer function.

and when $X \neq 0$

$$x = K\left(1 - \frac{qe}{r}\right) \tag{19}$$

By substituting *x* in equation (18) with equation (19), we get the long term catch equation:

$$\mathbf{y} = qKe - \frac{q^2Ke^2}{r} \tag{20}$$

This implies that although harvest is a function of effort and stock size for a short term, in the long run stock size becomes only a function of effort (given that environmental conditions are constant) and the sustainable yield too becomes a function of effort only.

Equation (8) takes the form of a parabolic equation, which allows us to use a linear regression in order to estimate the parameters of the function of sustainable harvest (y). Dividing both sides of equation (8) by effort (*E*) we get the linear equation of catch per unit effort (CPUE).

$$CPUE = qK - \frac{q^2K\mathbf{e}}{r} \tag{21}$$

Assuming that the biological growth of the subjected population follows the model suggested by Gompertz, and also assuming the fleet is homogenous and all vessels have the same fishing power:

$$G(x) = \mu x \ln\left(\frac{K}{x}\right) = qex \underset{\square}{\Rightarrow} x = Ke^{-\frac{qe}{\mu}} \tag{22}$$

By substituting *x* in equation (6) with (22) we get

$$y = qeKexp.^{\frac{-qe}{\mu}} \tag{23}$$

Dividing both sides of equation (23) by fishing effort (*e*) yields:

$$CPUE = \frac{y}{e} = qK\ exp.^{\frac{-qe}{\mu}} \tag{24}$$

A log-linear expression is found by:

$$\ln(CPUE) = \ln(qK) - \left(\frac{q}{\mu}\right).e \tag{25}$$

4 EMPIRICAL ESTIMATION

4.1 Necessary data

The fisheries model specified above contains six unknown parameters: $\alpha, \beta, \left(\frac{c}{q}\right), b, p, fk$. In addition to calculate profits (and rents) information on the harvest, *y*, and the biomass, *x* was needed. So, all in all eight pieces of information are needed to calculate fisheries rents.

It may be noted that in optimal equilibrium, *y* and *x* will be determined by the optimality conditions. So, in that position only the six unknown parameters need to be known in order to calculate rents. It is even simpler in a zero profit position. For in that position rents in this model (linear in *y*) will be simply the parameter *fk*. More generally, however, we neither have equilibrium nor pre-determined profits. In those cases the eight pieces of information to calculate rents must be known or calculated.

There are many ways to estimate the unknowns in the fisheries model defined by (13) and (16). The following describes one way based on commonly available data for a fishery. The data are of two types:

(i) biological data which are often available or can be guessed with a fair degree of accuracy, and
(ii) fisheries data for a specific (recent) year, which are very often available or can be guessed with a fair degree of accuracy.

Based on the known values from the available data it is straight-forward to verify the unknowns of equations (13) and (16) based on the equations in Table 3 below.

Table 3: The formulas used to determine the model’s unknown parameters using the data available

Formulae to calculate model parameters	
Unknowns	Formulae
Logistic function	
$\hat{\alpha}$	$\hat{\alpha} = 4 \cdot \frac{MSY}{X_{max}}$
$\hat{\beta}$	$\hat{\beta} = 4 \cdot \frac{MSY}{X_{max}^{2}}$
Biomass in base year, $\hat{x}(t^*)$	$\hat{x}(t^*) = \frac{\hat{\alpha}}{2\hat{\beta}} \cdot \left(1 \pm \left(1 - \frac{4 \cdot \hat{\beta} \cdot (y(t^*) + \dot{x}(t^*))}{\hat{\alpha}^2} \right)^{0.5} \right)$
Fox function	
$\hat{\alpha}$	$\hat{\alpha} = MSY \cdot ln(X_{max}) \cdot \frac{exp}{X_{max}}$
$\hat{\beta}$	$\hat{\beta} = MSY \cdot \frac{exp}{X_{max}}$
Biomass in base year, $\hat{x}(t^*)$	$\hat{\alpha} - \hat{\beta} \cdot \ln(\hat{x}(t^*) \ \ \cdot \hat{x}(t^*) = \dot{x}(t^*) + y(t^*)$
Normalised marginal costs, $\left(\overset{\wedge}{\frac{c}{q}} \right)$	$\left(\overset{\wedge}{\frac{c}{q}} \right) = \frac{(p(t^*) \cdot y(t^*) - \Pi(t^*)) \cdot (1 - \varepsilon)}{y(t^*) \cdot \hat{x}^{-b}(t^*)}$
Fixed costs, $\hat{fk}$	$\hat{fk} = (P(t^*) \cdot y(t^*) - \Pi(t^*)) \cdot \varepsilon(t^*)$
The schooling parameter, $\hat{b}$	b
Landings in year t^*, $\hat{y}(t^*)$	$y(t^*)$
Price of landings in year t^*, $\hat{p}(t^*)$	$p(t^*)$

To be able to use the equations in Table 3 to derive the value of the unknown parameter, some known biological and fisheries data must be estimated first. It is upon those estimates that the unknown parameters will be calculated from. The data suggested are as tabulated in Table 4 below.

Table 4: Biological and fisheries data necessary for estimating a model's unknown values

(i) Biological data	
Maximum sustainable yield	*MSY*
Virgin stock equilibrium	X_{max}
The schooling parameter	b
(ii) Fisheries data in a base year	
Biomass growth in year t^*	$\dot{x}(t^*)$
Landings in year t^*	$y(t^*)$
Price of landings in year t^*	$p(t^*)$
Fishing effort t*	$e(t^*)$
Profits in year t^*	$\Pi(t^*)$
Fixed cost ratio in year t^* ($fk/TC(t^*)$)	$\varepsilon(t^*)$

These are eight pieces of variables on Nile perch biology and fisheries that must be provided first. However, it is worth noting that there are many other ways to obtain the estimates of the model unknowns based on different sets of data.

4.2 Data sources and collection

Data was also sourced from research publication on Lake Victoria. Biological data included fish stock status in the base year; virgin stock (Xmax); maximum sustainable yield (MSY); fish abundance, density and distribution and harvest; Nile perch schooling parameter (*b*). Fishing effort data included: number of boats, types of boats and distribution, number and distribution of fishermen and fishing gear efficiency. The data was collected from the following organisations, institutions and technical working groups:

i. Lake Victoria Fisheries Organization (LVFO)
ii. Food Agriculture Organization of the United Nations (FAO)
iii. Regional Technical Committee on Frame Surveys on Lake Victoria
iv. Fisheries Department

To get the needed information a literature review was done and secondary data extracted from reports and journals. Enquiry was done in the three East Africa countries through fisheries department's to get data that was not available in publications and reports, though readily available in each country.

4.3 Estimation of model parameters

4.3.1 Maximum sustainable yield (MSY)

It was very difficult to get adequate fishing effort data for the three countries to estimate the MSY of the Nile perch fishery. Data available started from the mid 1990s and was grossly scanty. However, adequate Nile perch harvest data sourced from the FAO database for the last 30 years was used to make assumptions of the MSY. On the strength that for the last 30 years, the highest ever landed biomass of Nile perch was 351.000 t, in 1993 and 1995, with all other catch levels oscillating between 250.000 and 325.000 t, it was assumed that the MSY of this fishery is about 300.000 t. This assumption is subject to error and should be subjected to sensitivity analysis to determine how its change would affect the policy objectives of this study.

4.3.2 Virgin stock equilibrium (Xmax)

The 2005 and 2006 surveys were conducted using a hydro-acoustic method by IFMP to generate information on biomass, composition, and distribution and population structure of the two major commercial species, Nile perch (>10 cm TL) and “dagaa”. The main observation was that the standing stock of Nile perch was 0,82 million t from August 2005 to August 2006 and it contributed 39% of the total. A different method used at the same time known as “swept area method” and correcting for the vertical distribution of the Nile perch stock, Nile perch stock in the whole lake was estimated to be 623.000 t with a mean density of 11 t km-2; with 52% in Tanzanian waters, 40% in Uganda and 8% in Kenya. In 2005/2006 the Nile perch stock was estimated to be 571.000 t at a mean density of 6,8 t km-2 of which 53% was in Tanzanian waters, 31% in Uganda and 16% in Kenya. The conclusions drawn from the analysis on the data derived using the swept area sampling method suggested that Nile perch stock is probably at about 40% of the unexploited level (LVFO 2007a).

This was the basis of this study in estimating the virgin stock of the Nile perch. The standing stock level of the year 2005/2006 which was 571,000 t (which was 40%) of the virgin stock was multiplied by 2.5 to get 1,427,500 t as the estimate of the virgin stock.

4.3.3 Schooling parameter (b)

Nile perch does not school. They are dispersed all over the whole water body. Species that do not aggregate together have a high schooling parameter ≤ 1.0. On the basis of this argument, the schooling parameter of Nile perch could be between 0,80 and 1,0. For the purpose of this study, the value was assumed to be 0,85. As this was an assumed figure it needs to be subjected to sensitivity analysis to evaluate its effect on the economic benefits of the fishery.

4.3.4 Alpha parameter (α)

This parameter was calculated in accordance with the appropriate model in Table 3 above giving a value of 0.84.

4.3.5 Beta parameter (β)

The value of β was calculated using the equation in Table 3. Its value is 0,00059.

4.3.6 Biomass growth in year 2006

As recorded above in the section on virgin stock equilibrium (X_{max}) estimation, several studies have been conducted in the lake. The 2005/06 study using the hydro-acoustic method estimated the Nile perch standing stock to be 0,82 million t in August 2005 to August 2006. Another study using the "swept area method" estimated standing stock to be 623.000 t. However, the 2005/2006 Nile perch stock declined and was estimated to be to be 571.000 t using the same "swept area method". For the purpose of this study the data generated through the "swept area method" was adopted. The net difference between the two years was -52.000 t well within the errors of stock estimate. Therefore, in this study, I adopt a zero figure for the biomass growth of year t*

4.3.7 Landings in year t*(y(t*))

In 2006, a total of 1.061.108 t of fish was harvested from the lake (LVFO 2007c). Nile perch harvest contributed 24% by weight and 66% of the total landing price. The 24% of the total landed fish was calculated to be 254.666 t. This was the figure adopted in this study as the base year landing.

4.3.8 Price of landings in year t* (p(t*))

The price of fish landings in the year (t* (p(t*)) was given in local currencies and later converted into US$ equivalent. The landing fish prices are harmonised across the three countries through co-management organisation. One kilogram of Nile perch fish had a landing price of US$ 1,5/kg. Though the three countries use different currencies the value of fish price was the same when based on an international currency like what was done in this study using the US$.

For the purpose of this study this figure was converted into million US$/1000 t. Thus it was used as:

1.5 million US$/1000 t

4.3.9 Fixed cost ratio in base year eps (t)*

To calculate this value, first the fixed cost was calculated at the rate of 5% of the total revenue. This is on the theoretical basis that fixed cost should be as close to zero as possible for long time resource management. Then the fixed cost ratio in base year was calculated as a ratio of the total fishing cost. The detailed procedure of deriving the total fishing cost is detailed in Appendix 4:

Fixed cost= 5%* price of landings
=5%*381.999.000
=US $19.099.950

Calculation of the fixed cost ratio was done as follows:

Fixed cost/total fishing cost
=19.099.950/329.115.822
=0,058 or 5,8%

4.3.10 Fishing effort

The boats were to determine the fishing effort in the base year. This is due to the fact that the boat is the determinant of the human workforce and gears deployed in the water. The boats were also used to differentiate who is a fisherman and who is a labourer. Those with boats also happen to be the owners of the fishing nets and fishing lines. Rarely do those who own boats also do the fishing.

In the base year, there were 56.395 non-motorised and 12.765 motorised boats. To standardise them so that all the boats would be homogenous and for ease of calculation this study investigated the effectiveness of motorised boats against the non-motorised but using the same fishing gear in the three countries, Kenya, Uganda and Tanzania. A motorised boat using a gill net is about three times more effective than the non-motorised in Kenya and Uganda and slightly less than three times efficiency in Tanzania (LVFO 2007a). Thus a factor of 3 was used to standardise the motorised boats to the non-motorised. The number of motorised boats was multiplied by three to get 38.295 boats. The figure was summed up with the original non-motorised to come up with the figure 94.690 non-motorised boats. This was the value adopted in this study as the fishing effort. However, it is worth noting that this method has a weakness in that the motorised fishing vessels were using outboard engines of different horse powers and thus could have been different in their fishing effectiveness in fishing over the non- motorised boats.

4.3.11 Profits in base year 2006

The profit of the base year was derived by subtracting the total fishing cost from the total revenue. The total revenue and total fishing cost was calculated as follows:

Profit= Revenue *(R)* – Total cost *(TC)*

<u>Revenue</u>

Landing in base year* price of landings in year
Total revenue= 244,86*1,5
= 381.999 million US$

<u>Total cost</u>

The total cost was a summation of different costs namely labour, fuel, fixed costs, depreciation costs and other costs. They were calculated as shown in Appendix 4 and reported in the summary in Table 5 as follows.

Table 5: Summary of costs of fishery economic inputs

	Cost (US$)
Labour	191.000.000
Fuel	83.610.750
Fixed	19.100.500
Depreciation	14.137.872
Other costs (overhead)	21.266.700
Total cost (US$)	329.115.822

Profit = 381.999 -329.115.822
= US $52.883.178

4.4 Empirical assumptions and estimates

The following table summarises the biological and fisheries estimates that will be used jointly with the equations in Table 3 to calculate the model's unknown parameters.

Table 6: Nile perch biological and fisheries estimated parameters to be used in the model's unknown parameters estimation.

(i) Biological data		Assumed value
Maximum sustainable yield *(thousand t)*	*MSY*	300
Virgin stock equilibrium *(thousand t)*	X_{max}	1.427,50
The schooling parameter	*b*	0,85
(ii) Fisheries data in a base year		
Biomass growth in year *t*(thousand t)*	$\dot{x}(t^*)$	0
Landings in year *t* (thousand t)*	$y(t^*)$	254,67
Price of landings in year *t* (million US$/1000 t)*	$p(t^*)$	1,50
Fishing effort t* *(thousand boats)*	$e(t^*)$	94,69
Profits in year *t** (US$) *(million US$)*	$\Pi(t^*)$	52,8
Fixed cost ratio in year *t** ($fk/TC(t^*)$)	$\varepsilon(t^*)$	0,058

4.4.1 Estimated values (calculated)

On the basis of the formula given in Table 3 above the study obtained the following estimates of the model parameters as recorded in Table 7 below.

Table 7: Model parameters calculated using equations in Table 3 and the biological and fisheries estimates in Table 6 above.

Unknowns	Estimate
Logistic function	
$\hat{\alpha}$	0,84
$\hat{\beta}$	0,00059
Biomass in base year, $\hat{x}(t^*)$	436,30
Normalised marginal cost, $\widehat{\left(\frac{c}{q}\right)}$	213,39
Fox function	
$\hat{\alpha}$	4,15
$\hat{\beta}$	0,57
Biomass in base year, $\hat{x}(t^*)$	264,3
Normalised marginal cost, $\widehat{\left(\frac{c}{q}\right)}$	139,38
Fixed costs, $\hat{fk}$	19,09
The schooling parameter, $\hat{b}$	0,85
Landings in year t^*, $\hat{y}(t^*)$	254,7
Price of landings in year t^*, $\hat{p}(t^*)$	1,50

5 MODEL SIMULATION AND RESULTS

5.1 Sustainable fisheries

5.1.1 Landing biomass space (iso-(or equi-) profit curves)

The parabolic graph (Figures 12 and 13) represents the biomass growth function. The biomass function covers biomass from zero to the carrying capacity of about 1,427 thousand t and has a maximum sustainable yield of about 300 thousand t. The iso-profit curves are in harvest units (multiples of MSY). For the purpose of this fishery the harvest units are in thousand t. The equation for an iso-profit curve is:

$$y = \frac{gam * XMSY * P(x) + fk}{P(x) - \left(\frac{c}{q}\right) \cdot x^{-b}}$$

where gam = 0.0, when Iso-profits = 0
gam = 0,25, when Iso-profits = 0,25*MSY
gam = 0,50, when Iso-profits = 0,50*MSY

To convert this into monetary units the harvest units should be multiplied by the landings price as follows:

Profit = *p.y*

Where *p* is the landing price and *y* is the yield/harvest

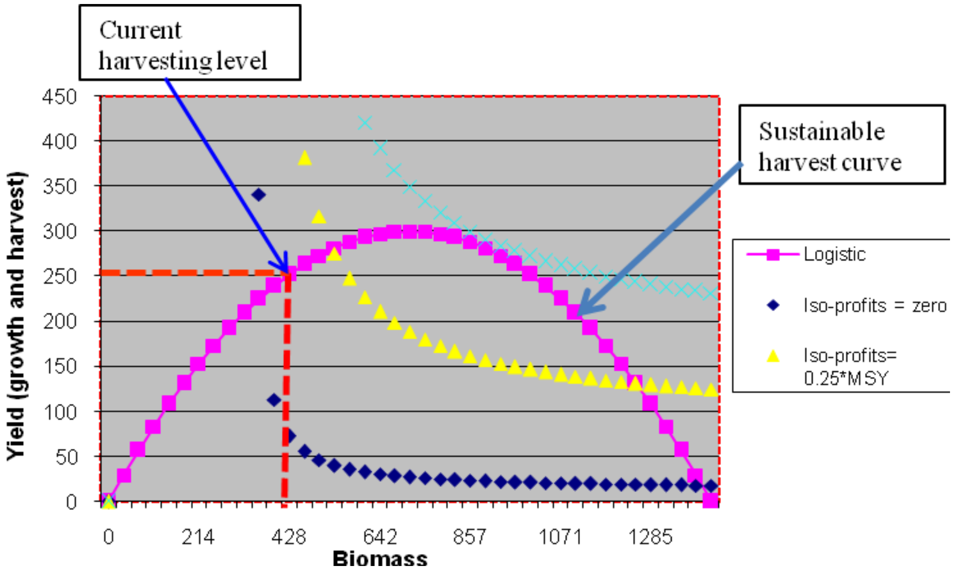


Figure 12: Logistic iso-(or equi-) profit curves

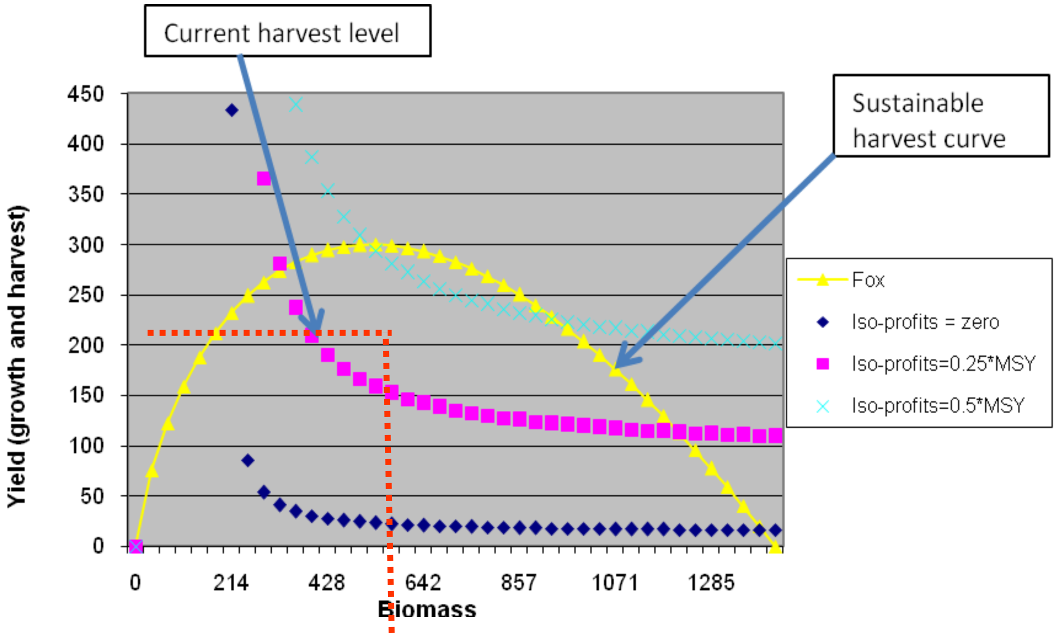


Figure 13: Fox iso-(or equi-) profit curves

Figures 12 and 13 above represent the summary description of the Nile perch fishery. The figure is drawn in the space of fishable biomass and landings (harvest) and applies at each point of time and, therefore, also in equilibrium

If, for any biomass level, landings lie on this curve, a biological equilibrium prevails. The other curves in this diagram are variable iso-profit curves, i.e. loci of biomass and harvests which represent constant variable profits measured in Nile perch volume units. Any point where these curves intersect the biomass growth curve represents a sustainable fishery with the corresponding variable profits. The highest sustainable profits are obtained where an iso-profit curve is a tangent to the biomass growth function. As the two diagrams suggest, this occurs at a biomass of some 892,9 thousand t for logistic. The corresponding harvest would be about 281,0 thousand and 282,0 thousand t for the logistic distribution if harvest is made at 0,5*MSY. At this point, annual variable profits from the fishery (approximately rents) amount to 216,4 million US$ per year.

5.1.2 Sustainable biomass curves

From Figures 14 and 15 below, it is apparent that the fishery was operating very close to the bionomic equilibrium point (E_{OA}) The current fishing effort is 94,7 thousand boats while the bionomic equilibrium point is about 98 thousand boats for logistic and about 105 thousand boats for Fox. At bionomic equilibrium point, the profits equal the total operating cost and no profits are made. At that point the stock is over exploited and risks collapse. The optimum fishing effort that maximises profits is 56,9 thousand boats for logistic (Figure 14) and 44,9 thousand boats (Figure 15) for Fox. Accordingly, there is a need to put deliberate management measures to move the fishery effort from point A_1 to A_2 as depicted in Figure 14_1 below for logistic and from point B_1 to B_2 as sketched in Figure 15 for Fox.

It was also observed that it would require a higher fishing effort for the Fox distribution to reach the open access competitive point (bionomical equilibrium point) at about 105 thousand boats while in logistic it would take 98 thousand boats to reach the same critical point. Likewise it would require few fishing boats for the Fox distributed population to reach maximum economic yield (MEY) at 44,9 thousand boats while that of logistic would require 56,9 thousand boats to achieve the same harvest.

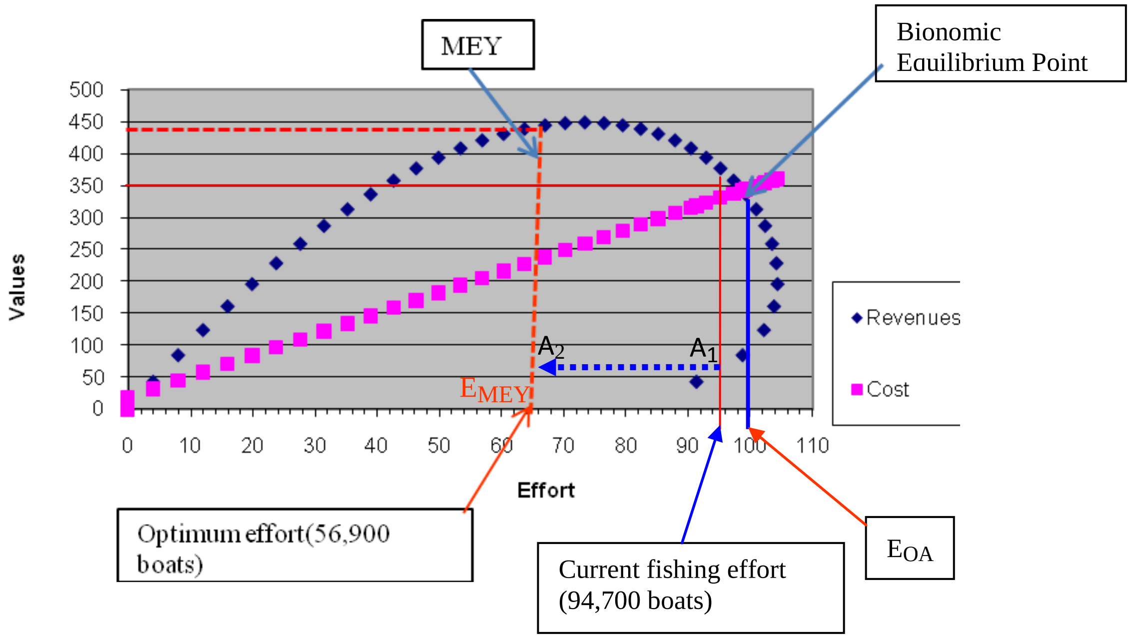


Figure 14: Logistic function sustainable fishery in terms of revenues and costs with effort as the x-axis showing the fishery critical points. From the graphical outcome the current and optimal fishing effort levels can be determined

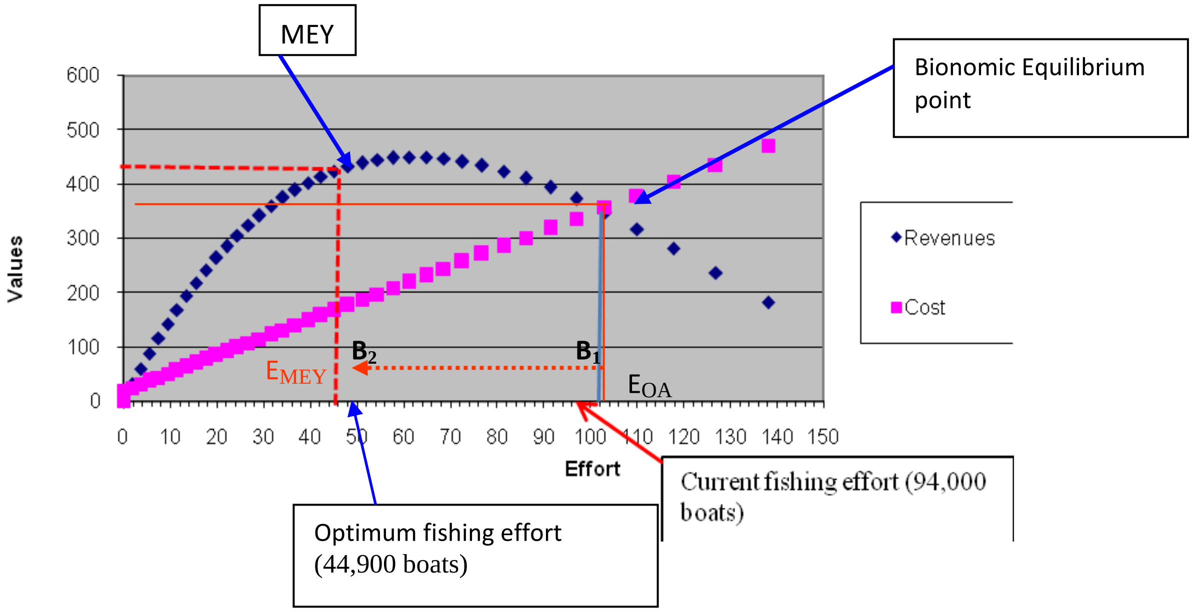


Figure 15: Fox function sustainable fishery in terms of revenues and costs with effort as the x-axis showing the fishery critical points. From the graphical outcome the current and optimal fishing effort levels can be determined

However, despite the slight differences, the results depicted in the Figures 14 and 15 are at a common convergent point that there is excessive fishing effort deployed in the fishery beyond the optimum (E_{MEY}) required to give maximum profits and thus the necessity to substantially reduce the fishing effort by about 30% to achieve an economically sensible fishery.

5.1.3 Rent and rent drain: efficiency results

Table 8 below is a summary of outputs on current and optimal biomass, harvest, effort, profits and rents of the Nile perch fishery. The outputs were generated using the base data of the year 2006. It appears that in spite of its biologically depressed state, the Nile perch fishery is currently generating some economic rents as well as profits. However, compared to maximum attainable profits, the fishery suffers from rents losses of some US $163,5 million if it follows a logistic distribution or US $204,1 million in the case of Fox (Table 8). In terms of current rents and the size of the fishery this rents loss is very substantial. It was observed that the rents drain was more than double the current rents in the base year, 2006. It was notable, however, that to realise these potential rents requires intensive rebuilding of the Nile perch stock and a substantial reduction in fishing effort in the long term. Rebuilding of the stock will lead to a slight increase in sustainable catches which are responsible for most of the economic gain, while reduction of fishing effort will substantially reduce the operation costs which depress the profits.

Table 8: A summary of the main results on current and optimal biomass, harvest, effort, profits and rents

Main results							
		Current		**Optimal**		**Difference**	
	Units	Logistic	Fox	Logistic	Fox	Logistic	Fox
Biomass	1000 t	436,3	264,3	892,9	717,0	456,6	452,7
Harvest	1000 t	254,7	254,7	281,1	282,1	26,4	27,4
Effort	1000 boats	94,7	94,7	56,9	44,9	-37,8	-49,8
Profits	m. US$	52,9	52,9	216,4	257,0	163,5	204,1
Rents	m. US$	72,0	72,0	235,5	276,1	163,5	204,1

5.2 Sensitivity analysis

The model used to calculate the optimal Nile perch fishing effort that would give optimum profits and economic rents is subject to considerable uncertainty. This is due to the randomness of the data collection method and possible error in making assumptions. It is possible that a lot of fish harvested goes unrecorded due to landings made in undesignated fish landing sites with no personnel to collect the data. The likelihood of illegal fishing done by unlicensed fishermen would also alter the status of the harvest and effort values used in this study. Adjustment of fishermen who exit or enter the fishery in between the frame survey period is not made immediately until the next survey or normally every two years. This would likewise alter the number upward or downward of the fishing effort from one used in the study. Other parameters used in the estimation of total fishing cost are never collected nor documented in the of fisheries statistics. Such information was gathered through enquiries and thus subject to error.

To check how much the results in the summary in Table 8 above are dependent on the basic empirical assumptions of the model used, a simple sensitivity analysis was made. The analysis was also conducted to check the robustness and reliability of the calculated optimal policy to parameter misspecification. The basic empirical assumptions were altered by ± 30%, ± 20% and ± 10% and recalculation made to establish effects on the rent loss and optimal fishing effort. The results are reported in Tables 9-11 and Figures 16 -18 below. It is worth noting that the higher the slope of the sensitivity curves, in absolute value, the higher the sensitivity of profits, rents loss and fishing effort to the assumptions in the reference.

5.2.1 Sensitivity of optimal profits

The sensitivity results for optimal economic rents (profit) of a managed Nile perch fishery based on changes in assumptions of the current (base year 2006) year indicate that the profits are in the range of US $159,6 million to US $359,6 million. The lowest value of US $159,6 million was when the assumption of MSY was decreased by 10% and the highest at US $359,6 million was when the same assumption was increased by +30%. Apart from the MSY, the other parameters which the optimal profits are highly sensitive to are quantity of fish landed and the price of landed fish. When the quantity of landed fish was decreased by 30% the optimal profit of the managed fishery changed to US $302,7 million instead of the calculated value of US $216,4 million while increasing the same assumption by 10%, the optimal profit decreased to US $178,7 million. Changes in landing fish price between -30% and +30% showed that of the base year 2006 had a corresponding change in optimal profit between US $161,5 million and US $271,5 million against the calculated value of US $216,4 million. It was observed that the optimal profits have little or no sensitivity on the changes made on the base year's profits, fishing effort and virgin stock status (Figure 16).

The sensitivity analysis findings further indicate that even if the biological parameter estimations and information on price and costs are wrong or have errors, the Nile perch fishery has the potential to generate economic rents (profits) ranging between US $159,6 million and US $359,6 million if managed (Table 9).

Table 9: Sensitivity analysis of Nile perch fishery optimal profits (economic rents) sensitivity to different percentage changes of biological parameters, price, effort and profits in the base year 2006

		Change						
Parameters		-30%	-20%	-10%	0%	10%	20%	30%
Maximum sustainable yield (,000 t)	MSY	N/A	N/A	159.626	216,411	266.131	313.447,4	359.588,8
Virgin stock (,000 t)	*Xmax*	216,41	216,41	216,41	216,41	216,41	216,41	216,41
Schooling parameter	*b*	179,11	192,31	204,73	216,41	227,41	N/A	N/A
Biomass growth (,000 t)	*x(t*)*	N/A	N/A	143,64	216,41	256,98	N/A	N/A
Harvest (,000 t)	*y(t*)*	302,73	275,98	247,63	216,41	178,72	N/A	N/A
Price (m US$/1000 t)	p(t*)	161,48	179,76	198,07	216,41	234,75	253,12	271,49
Effort (,000 boats)	e(t*)	216,41	216,41	216,41	216,41	216,41	216,41	216,41
Profit (m. US$)	prof(t*)	206,58	209,84	213,12	216,41	219,71	223,04	226,38

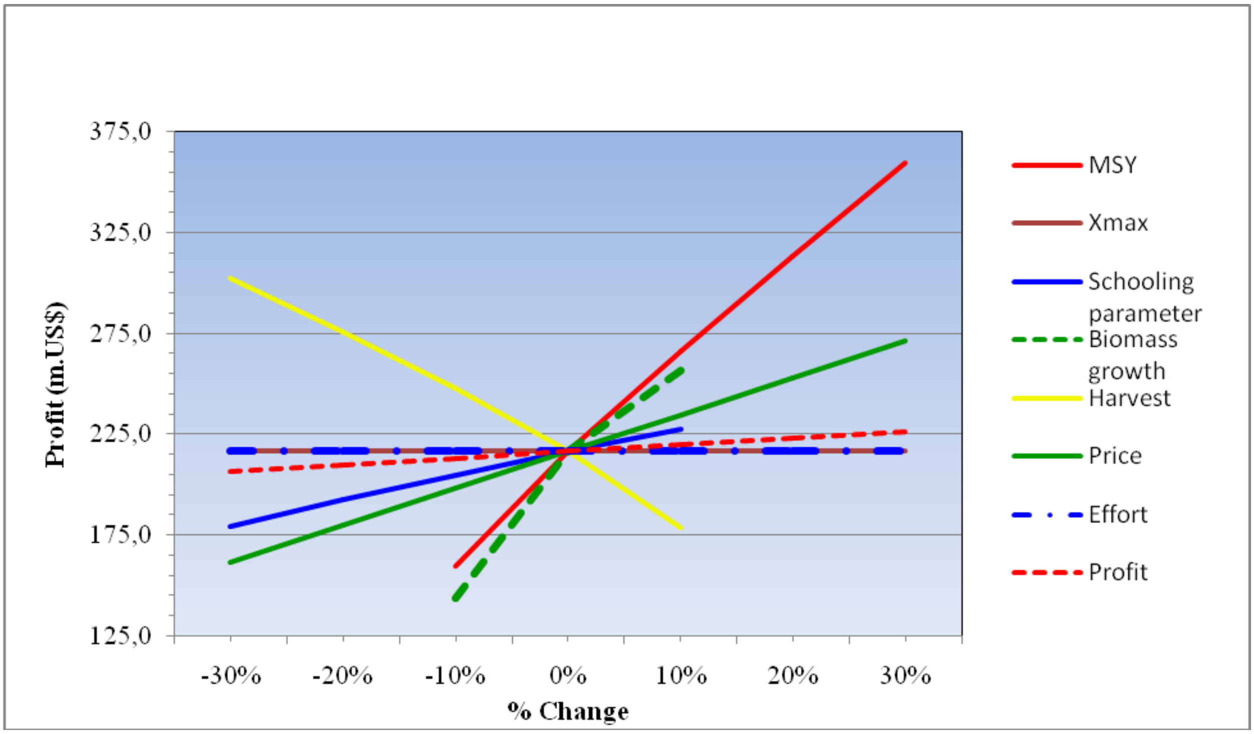


Figure 16: Sensitivity analysis chart of optimal profits sensitivity to changes in empirical assumptions

5.2.2 Rents drain sensitivity

The sensitivity results of conducting the Nile perch fishery indicate that at the current management inefficiency relative to a managed fishery, the fishery rent loss ranges between US $108,56 million and US $306,66 million depending on the empirical assumptions made in Table 10. The greatest sensitivity of estimated rent loss is to the assumed maximum sustainable yield (which has similar sensitivity with as biomass growth), the assumed initial price of landed fish, the quantity of landings and schooling parameters. An increase of 30% on the assumed MSY value caused the rents drain to become US $306,7 million instead of the calculated value of US $163,5 million. When the fish landing price was decreased by 30% the rents drain value dropped to US $108 million. Virgin stock size, fishing effort, base year’s profits have little or no sensitivity on the rents drain as illustrated in the sensitivity chart in Figure 17.

The study noted that these are the same assumptions that are highly sensitive to profits. The higher the profits in the optimally managed fishery the higher the rents drain when compared with the current open access fishery. This is the opportunity cost of operating an open access Nile perch fishery.

Table 10: Sensitivity analysis of the Nile perch fishery absolute rent drain on different percentage changes of biological parameters, price and profits in the base year (2006)

		Change						
		-30%	-20%	-10%	0%	10%	20%	30%
MSY (,000 t)	MSY	N/A	N/A	106,70	163,49	213,21	260,52	306,66
Virgin stock (,000 t)	Xmax	163,49	163,49	163,49	163,49	163,49	163,49	163,49
Schooling parameter	B	126,19	139,39	151,80	163,49	174,48	182,45	N/A
Biomass growth	*x*(t*)	N/A	N/A	90,72	163,49	206,15	N/A	N/A
Harvest (,000 t)	y(t*)	249,81	223,05	194,72	163,49	125,79	N/A	N/A
Price (m US$/1000 t)	p(t*)	108,56	126,84	145,15	163,49	181,83	200,20	218,57
Effort (,000 boats)	e(t*)	163,49	163,49	163,49	163,49	163,49	163,49	163,49
Profit (m. US$)	prof(t*)	169,54	167,50	165,49	163,49	161,50	159,53	157,58

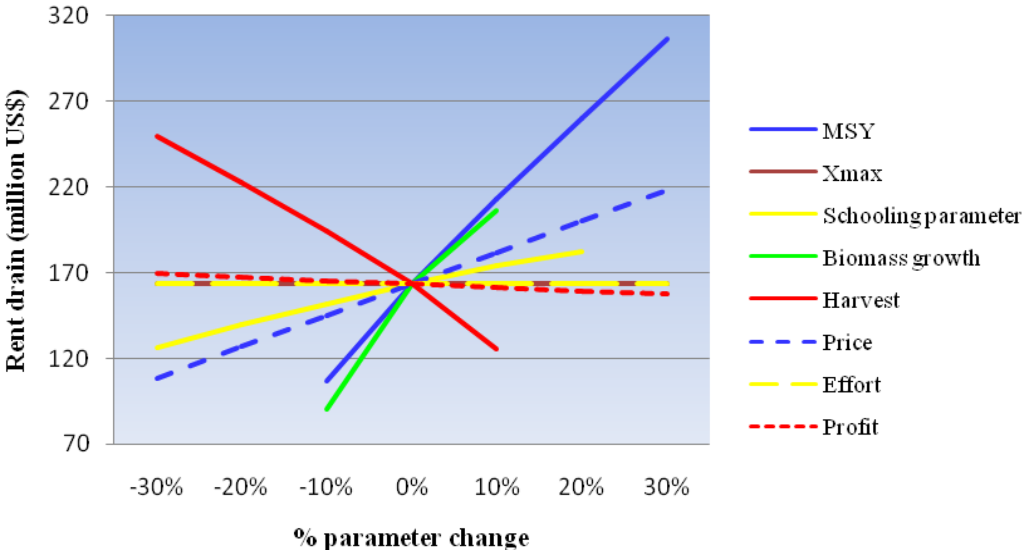


Figure 17: Sensitivity analysis chart of absolute rent drain sensitivity to changes in empirical assumptions

5.2.3 *Sensitivity of optimal fishing effort*

Sensitivity analysis for optimal fishing effort indicated that it is highly sensitive to biomass growth and the Nile perch schooling parameter. When the schooling parameter was decreased by 30% the optimal fishing effort changed to 68 thousand standardised fishing boats instead of the calculated value of 56,8 thousand boats. Increasing the same assumption by 20% which is biologically possible from 0,85 to 1,0, the value changed to 50,6 thousand boats. The increase of biomass growth by 10% changed the optimal fishing effort to 47,4 thousand boats and reducing the same estimation by 10% increased the effort value to 68,9 thousand fishing boats. Thus, to maximise the economic rents and ensure good biomass growth of the Nile perch fishery, the optimal fishing effort must be in the range between 47,4 thousand and

68,9 thousand standardised boats if the parameters are subjected to percentage change between -30% and +30% (Table 11 below). This proves that even if the assumptions used are wrong, the current fishing effort of 94,69 thousand standardised boats is too high for the fishery to yield maximum rents.

Table 11: Sensitivity analysis of Nile perch fishery optimal fishing effort on different percentage changes of biological parameters, price and profits of the base year (2006)

		Change						
Parameters		-30%	-20%	-10%	0%	10%	20%	30%
Maximum sustainable yield (,000 t)	MSY	N/A	N/A	57,40	56,80	57,00	57,20	57,60
Virgin stock (,000 t)	Xmax	56,80	56,80	56,80	56,90	56,90	56,90	56,80
Schooling parameter	*b*	68,00	64,00	60,10	56,90	53,40	50,60	N/A
Biomass growth (,000 t)	x(t*)	N/A	N/A	68,90	56,80	47,40	N/A	N/A
Harvest (,000 t)	y(t*)	58,80	57,90	57,20	56,80	56,90	N/A	N/A
Price (m US$/1000 t)	p(t*)	58,10	57,60	57,20	56,80	56,60	56,30	56,10
Profits (m. US$)	prof(t*)	55,90	56,20	56,50	56,80	57,10	57,40	57,70

The sensitivity of the fishing effort is also illustrated by the chart in Figure 18 comparing fishing effort sensitivity to changes made on the various assumptions. Graphically, the curves for the biomass growth and schooling parameter are relatively steeper than the rest, indicating that the fishing effort has a higher sensitivity on both of these assumptions than the others.

It is worth noting that the fishing effort was less sensitive to the fish landing price, quantity of landed fish, base year profits, virgin stock status and even the maximum sustainable yield level as illustrated by their gentle slopes in Figure 18 below.

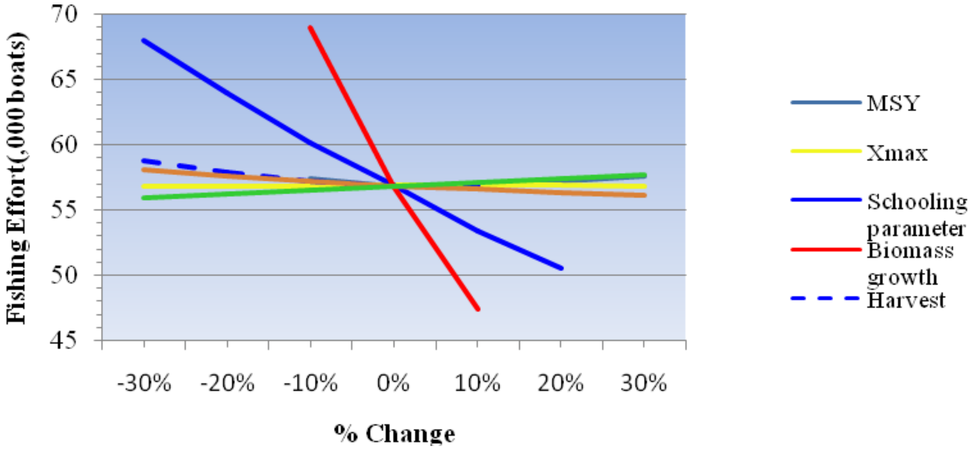


Figure 18: Fishing effort sensitivity to changes in empirical assumptions

5.3 Fisheries over time

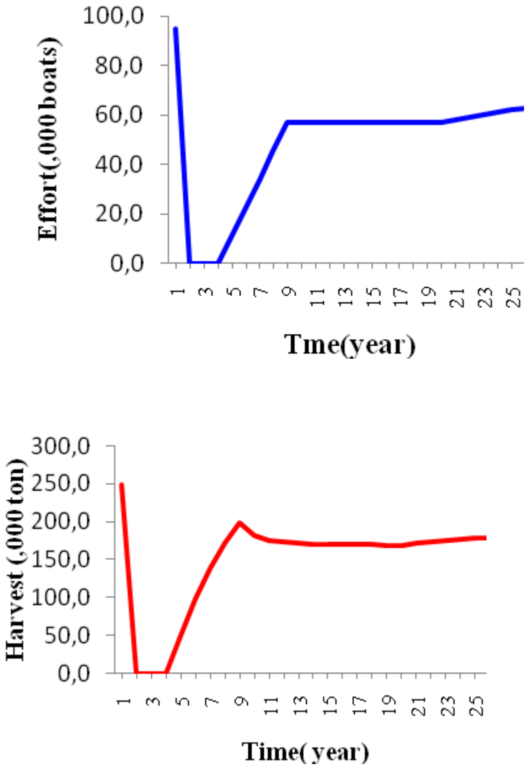
The model for sustainable efficient equilibrium cannot be attained instantaneously. It requires a long-run management plan to move the fishery from its current status to the targeted optimal level. The strategy chosen involves investment decisions as it has opportunity costs of the capital in the form of discount rates when considering what the long-run level of the fish stock to target should be. Thus, the investment strategy is subject to annual rates of discounting and the investment output is measured as present value (PV). A discrete time model of discounting was used in this study due to the regular time intervals used in the Nile perch stocks assessment. To attain this efficient optimal level, the fish stock biomass needs to be double the current status and the fishing effort reduced by a third, thus the need to rebuild the fish stock.

There is a need to devise an appropriate dynamic path to move the fishery from its current situation. The path would be the transitional management strategy linking the fishery in its current status to the long-run optimal sustainable equilibrium. Therefore, the study worked out two types of dynamic paths to achieve the targets of an efficient fishery. These are:

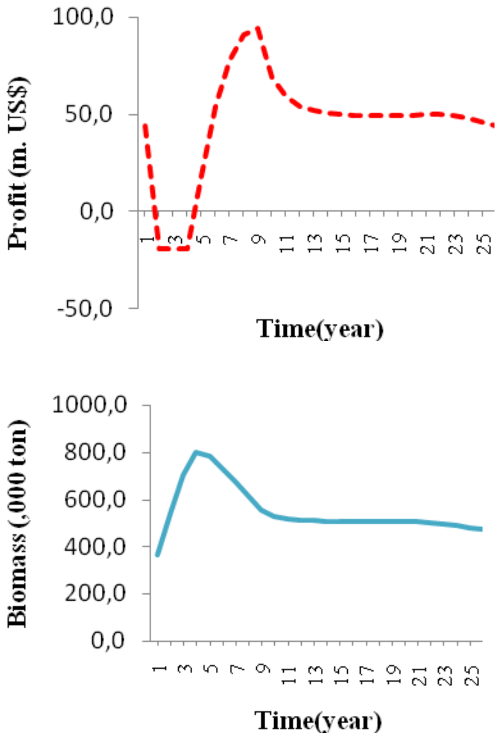
(a) Present value maximisation path
(b) "Reasonable adjustment path"

5.3.1 Present value maximisation path

This path involves complete closure of the fishery during the initial period of three years. The size of the fishing effort is reduced to zero for a continuous duration of three years. The fish stock is allowed to recover at its maximum potential, limited by its natural rate of growth until an optimal or close to optimal level is achieved. This also allows reinvestment of the total natural growth back into the stock with the aim of increasing the potential harvest in succeeding years. After three years, harvesting is re-introduced gradually at a rate of 20% (11,4 thousand boats) of the targeted fishing effort until the optimal effort of 56,9 thousand boats is attained. Thereafter, a long-run fishery fishing effort is maintained in order to bring the fish stock biomass to a stable equilibrium. For purposes of evaluating the efficiency of this recovery path and also for comparison with other alternatives, it was subjected to a discounting rate of 7,05% (Central Bank of Kenya 2008). The outcome of this recovery strategy is as shown in Figure 19 (a), (b),(c) and (d) below and Appendix 2.



(a) Fishing effort management (b) Harvest management



(c)Profit trend (d) Biomass growth trend

Total Present Value= 546

Figure 19: The transition of (a) effort, (b) harvest, (c) profit and (d) biomass as the Nile perch fishery moves from current levels to a long-run optimal fishery through the present value maximisation path.

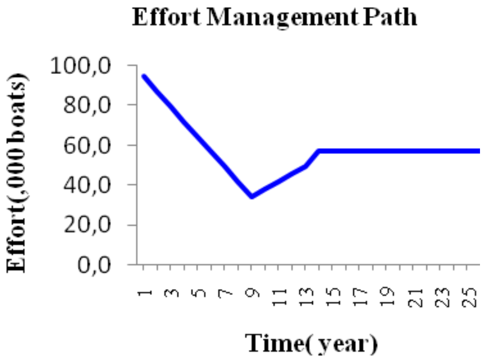
Figure 19 (a), (b) and (c) indicates that as the fishing effort is reduced from the current status of 94,7 to zero, it affects the harvest and the profits alike. With no fishing boats in operation in the lake, Nile perch harvests dropped to zero as well as the corresponding profits. However, the cost fell to minus levels due to the fixed costs. During the same initial period, Figure 19 (d) biomass showed an increase up to the third year when it achieved a maximum of 799,0 thousand t. Introduction of fishing from the third year, at an incremental rate of 20% of the optimal per year (Figure19 (a)) led to an increase in harvest (Figure 19(b)) and profits (Figure 19 (c)) but reduction in biomass (Figure 19 (d)) due to harvest, with the highest attainable harvest and profit in the eighth year. Through this path the fishery entered the long-run optimal fishery in its nineteenth year of transitional management with a sustainable harvest of 169,6 thousand t, at an optimal effort of 56,9 thousand standardised boats and giving sustainable profits of US $49,1 million. The biomass will stabilise at 505,9 thousand t during the same year. This path gives an investment profit value of 546 in terms of present value.

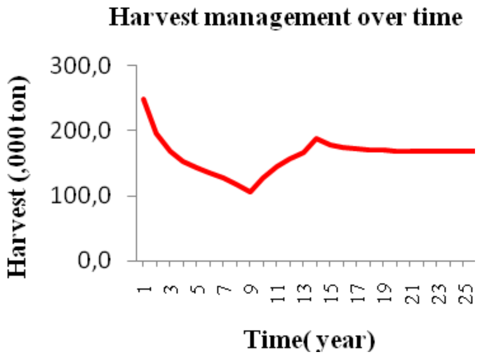
5.3.2 A reasonable adjustment path

The second adjustment path allows some harvesting during the stock recovery period. This harvesting goes on until the targeted optimal fishing effort is attained. The operation of the optimal fishing effort allows rebuilding of the stock due to harvesting at a level lower than the current one. This will enable the stock biomass to reach the sustainable optimal long-run fishery where the profits are maximised and stable. The recovery path strategy as an investment plan was also subjected to 7,05% annual rate of discounting to enable its efficiency evaluation and comparison with the other alternatives.

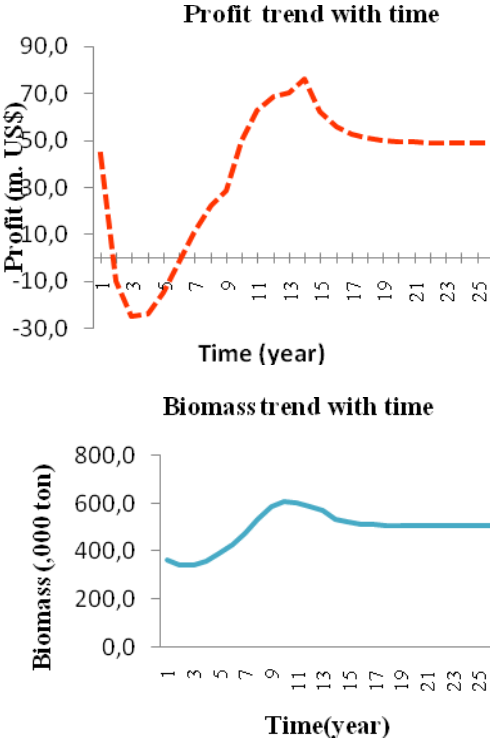
To attain the optimal long-run fishery, the fishery stock level had to be rebuilt and the fishing effort reduced to 56,9 thousand standardised fishing boats. To reach the target, the effort was first gradually reduced to a level below the optimal effort and thereafter rebuilt again to the target level. The purpose of reducing the effort below the optimal level in this transition process was to allow the rebuilding of the stock. Stock recovery can only occur when the natural growth exceeds mortality. The management decision made was to reduce the effort by 8% per year for the next eight years. Thus 7.8 thousand boats per year for eight continuous years exit the fishery until a moment in time when the operating effort drops to a low level of 34,2 thousand boats. The effort is then gradually rebuilt from the subsequent year at a rate of 4.0% until the optimal fishing effort of 56,9 thousand boats is attained. Thus 3,8 thousand boats are recruited annually into the fishery for the next six years to attain optimum level after which it will be maintained in the sustainable long-run fishery.

According to the output of the study (Figure 20 (a), (b) and (c)) reduction in fishing effort was followed with decline in harvest and profits. However, the stock biomass (Figure 20 (d) increased during the same period reaching a peak of 605,9 thousand t in the ninth year of the recovery period. The profits peaked during the same year (also refer to Appendix 2). It is noteworthy that this peak was attained one year after the fishing effort was reduced to its lowest level in the eighth year. The highest harvest was made five years after the highest biomass was attained and when the fishing effort was entering the long-run optimal phase (Appendix 2). The path gave a present value of 406.


Effort Management Path
Effort(,000 boats)
100,0
80,0
60,0
40,0
20,0
0,0
1
3
5
7
9
11
13
15
17
19
21
23
25
Time(year)



(a) (b)



(c) (d)

Total Present Value= 406

Figure 20: The transition of (a) effort, (b) harvest, (c) profit and (d) biomass as the Nile perch fishery moves from the current level to a long-run optimal fishery through the alternative adjustment path

Some observations were made between the two recovery paths. The present value maximisation path (path 1) took a short period of three years for stock rebuilding as compared to the alternative reasonable adjustment path (path 2) which took nine years. It took path 2 a period of 24 years to reach its optimal equilibrium against 19 years taken by path 1. With respect to evaluation of costs and gains, the alternative path 2 gave the highest harvest during the initial period of three years during which period path 1 demands a total close down of the fishery. The period between the fourth to the 25th year when the two paths enter long-run optimum, strategy path 1 gives a higher catch compared to path 2. Path 1 took eight years to reach optimal fishing effort as compared to 14 years for path 2. Path 1 had a higher present value of resource rent at 546 as compared to 406 of path 2. Path 1 also gave the highest maximum and minimum present value, harvest and biomass (Table 12 below). Thus if the price of fish is constant, regardless of the quantity harvested, and the unit cost of harvesting depends on stock level only, the present value maximisation path (path 1) is superior to the ealternative reasonable recovery path (path 2). This implies that any strategy postponing the moment for equilibrium harvesting beyond that of the present value maximisation path is an inferior solution.

Table 12: A comparative summary of the adopted fishery management paths on present value, effort, harvest and biomass

	Present value (PV)		**Effort**		**Harvest**		**Biomass**		
	Max.	Min	Max (,000 boats)	Min (,000 boats)	Max (,000 t)	Min (,000 t)	Max (,000 t)	Min (,000 t)	Total PV
Path 1	52,8	-14,5	56,9	0	199,6	0	799,0	505,9	546
Path 2	30,4	-20,0	87,1	34,2	196,3	106,6	609,5	341,9	406
Absolute difference	22,8	5,5	30,2	34,2	3,3	106,6	189,5	164	140

Key
Path 1: Present value maximisation path
Path 2: Reasonable adjustment path

Thus, if the price of fish is constant, regardless of the quantity harvested, and the unit cost of harvesting depends on stock level only, the present value maximisation path (path 1) is superior to the reasonable recovery path (path 2). This implies that any strategy postponing the moment for equilibrium harvesting beyond that of the present value maximisation path is an inferior solution.

5.4 Discussion

5.4.1 General overview

From the above results in the summary Table 8 and sensitivity analysis Table 9, Table 10 and Table 11, it is very clear that though the Nile perch fishery can yield very high economic rents under efficient management, the current management arrangement can only earn 20% of the optimal calculated. Under the optimal management strategy, profits could rise up to four times the current status of about US $53 million to about US $216 thousand. It was evident that the fishing capacity was very high for the fishery and there is urgent need to scale it down from 94,7 thousand to the calculated figure of 56,9 thousand boats. The number of standardised boats could even be reduced to a low of 47,4 thousand boats if the base year (2006) biomass growth is higher by 10%. However, the highest number of boats should not exceed about 68 thousand if the biomass growth was reduced by 10% from that of the base year. It is imperative to note that maximised profit would be attained if the base year's harvest was reduced by 30%, giving an economic rent of US $302,73 million. According to the supply –demand principle the market clearing price of fish would be higher, thus generating more revenue. This means that the profit maximising harvest biomass should be 178 thousand t. The biomass would also double under an efficient management system.

The observations made in this study are that massive rents of a magnitude of up to US $164 million per year was dissipated under the current fishery management policy of restricted open access. The study acknowledged the inefficiency of the open access policy as a tool of economic and resource management of the fishery. The rents drain was more than three times the profits accrued by the fishers (US $52,9 million). This underscores the significance of the fishery contribution to the poverty prevalent among the fisher community. If these rents, or part of them, are recovered, it could improve the socio-economic welfare of the fisher community.

To recover the rents dissipated and to ensure stock recovery, an efficient fishery policy and management system has to be developed and implemented urgently. This is the policy and management intervention that would be entrusted to reduce the fishing capacity to optimal or near optimal levels as well as scale down the quantity of fish harvested. While the mechanisms under open access have failed using biological management tools, it is appropriate that the new management system be designed giving a complete paradigm shift from the current system. The management system should offer fishers economic incentives for resource conservation as well as responsibility and accountability to the resource over-exploitation.

Putting up a new system may not be adequate enough to bring the necessary economic sense to the fishery. It should be understood that any new change will be seeking entry into a rigid socio-economic system that is hardly there to promote rational and optimal resource allocation for low cost harvesting. The existing system induces extremely low efficiency in resource exploitation and production. In this system, the social production functions do not comply with the least-input principal, namely, some factors are wasteful in social production activities. In this case, the excess fishing capacity, excess quantity of fish harvested than market demand and excess labour deployment is considered wasteful. Under such a scenario, the socio-economic growth and development of the community is very slow. In an efficient system these inputs should function in other social production. As long as the current management system is in place, any production technologies and technical change or innovation is subject to generate the same base year (2006) outputs in terms of rents and profits because of the low efficiency of the system.

If a completely efficient system is devised, the output level (economic rents) should be like the optimal values calculated in this study. However, any management change from the *status quo* would be welcomed with some resistance and reasonable coordination with other inter-dependent sectors. Some costs likewise would be incurred to improve and sustain an efficient social-economic system. This would cause some rents wastage making the production efficiency sub-optimal. Thus, the optimal outputs calculated in this study would not be achieved in practice. However, higher economic rents than those of the base year would be achieved. It should be appreciated that if no deliberate effort is made to improve the efficiency of the fishery from its current status, the economic output will be subject to decline as well as a high probability of fishery collapse.

To bring this fishery to the optimal level, first, two recovery path options to transit the fishery from the current status to the long-run optimal sustainable equilibrium were devised. Each strategy's efficiency against the potential socio-economic impacts on the fishing industry was evaluated for implementation consideration. Secondly, an efficient fishery management system option that gives fishermen more incentive to participate actively in a sensible fishery is proposed as a "vehicle" of implementing the fishery recovery strategy and thereafter in the management of the fishery at optimal equilibrium levels.

5.4.2 Transition fishery options: economic considerations

According to the two devised fishery recovery paths described above, the present value of resource rent from harvesting will be highest with the present value maximisation path (path 1) strategy, given the two crucial assumptions regarding the price of fish and the unit cost of harvesting. The assumptions were that there are no price and unit cost penalties from reduction of harvest and effort, neither from the market in the form of forgone opportunities for gaining a higher price with a smaller harvest, nor from any effort dependent unit cost of harvesting. If the price and cost characteristics are not true according to assumptions, then path 1 ceases to be the optimal leading for the search for an alternative path.

In empirical work and actual management it could be possible that several alternative paths are closer to optimum than path 1 described above. In this regard an alternative path referred to in this study as the "reasonable adjustment path" (path 2) was devised. In Figure 20(b), the path depicts a gradual decline in harvesting with reduction in fishing effort. The fishing effort was allowed to go below the optimal level for the long-run fishery to rebuild the stock to optimal level. Thus, unlike the strategy in path 1, the alternative strategy initially allowed limited harvest on a declining trend. This trend is up to a moment in time when the fishing effort is at its lowest after which increased harvesting is allowed though gradually by rebuilding of fishing effort.

If the price of fish varies with harvest, as is the case with the downward sloping demand curve, this may have an effect on the optimal transitional fishery. In such a case, the optimal path will be the one with a more gradual transition to the long-run equilibrium in order that the fishers benefit from the high price-low quantity combination. Thus, the present value maximisation (path 1) solution with complete closure of the fishery during transition period would no longer be optimal. The reason for this is that the positive economic effects of a small harvest at higher average prices throughout the transition period will be beneficial compared to the negative effect from delaying the moment of time required to reach a fully restored fishery. This means that the point in time when the optimal equilibrium stock level and harvest are reached would be postponed in path 2 as against path 1 (Appendices 2 and 3).

If the harvest costs are different from what we assumed above, this would imply that the benefits of an alternative reasonable adjustment path (path 2) should be considered.

If the unit cost of harvesting depends not only on the stock level, but also on effort or on harvest level, this may switch the optimal transition strategy from the present value maximisation path (path 1) to the more gradual stock recovery reasonable adjustment path (path 2). The existence of some fishermen, who are significantly more cost effective than the average, could be an argument to advance and let some effort to continue harvesting during the rebuilding of the fish stock. It may be an advantage for the realisation of resource rent, in present value terms, to operate a minor fishery with the most cost-effective effort rather than closing down the fishery during the transition period.

The transition costs and benefits would depend on the objectives of policy makers (for example economic, biological, social, and administrative) and on the characteristics of the instruments (technical measures, input and output controls) that will be used to achieve these objectives. The objectives pursued by the fishery managers, and the management measures that would be used to achieve the objectives would thus play an important role in determining the benefits and costs incurred in a transitional fishery.

Taking the development of the stock towards long-run target as a guiding principle, it is possible to evaluate the benefits and costs associated with the transition. If a stock is not realising its production potential because it is too small, then harvest opportunities are being forgone. Potential harvests that could be generated by the stock and are not realised could be due to its depleted state. Figure 19 (a), (b), (c), (d) and Figure 20 (a), (b), (c), (d) provide charts of the transition path based on present value maximisation and reasonable adjustment strategies. Charts (a) in both Figures 19 and 20 show the reduction in fishing effort; charts (b) in both Figures show harvesting trends of the stock; charts (c) show the change in profit in both strategies; and (d) shows the change in the stock level over time by the two strategies.

5.4.3 Forward and backward linkage of transition

We have seen that economically over-fished stock needs reduction or complete cession of the harvesting to recover and grow to the optimal level. Temporary reduction in harvest also requires a reduction in fishing effort. Since effort is composed of, or produced from labour, variable inputs like fuel, baits and gear, as well as vessel capital, the reduction of effort will have repercussions via the labour market and markets for other input. The consequences of these changes would be most severe in the Lake Victoria basin as the community is fishery dependent with few alternative employment opportunities. The same applies to the negative effects of reduced quantities of fish as raw materials for the fish processing and marketing industries, often called the post-harvesting sector. For owners and employees of this sector there may be both economic and social costs incurred because of fluctuations in landings of fish, in particular when landings are reduced. Therefore, rebuilding of fish stocks will not be possible without negative effects on employment, the boats service industry and post-harvest industry. However, the short and medium term costs of industries and society should be outweighed by future gains from higher stock levels; otherwise fish stock investment is futile.

The objectives of actual fisheries management often include other elements than resource rents or revenues of the industry. For example, such objectives are included in the Code of Conduct for Responsible Fisheries, adopted in 1995 by the Food and Agricultural Organization of the United Nations (FAO 1995) (Appendix 5).

The Code, which is voluntary, was developed by FAO and its member countries as a response to the economic and ecological failure of several fisheries worldwide. Certain parts of it are based on relevant rules of international law, including those reflected in the United Nations Convention on the Law of the Sea of 10 December, 1982. Through the code, it is expected that the fisheries manager, on his own or together with the industry and other stakeholders, will specify the management objectives and at the end arrive at a long-run target level for fish stock. This will be the target stock level, with the corresponding target harvest and effort as well. In the case of this study, these are the optimal estimates in Table 8 above. The target stock level may be above or below the optimal level indicated in the summary in Table 8. Thus, through transiting the fishery from the current over-exploited and uneconomical status to an optimal long-run sustainable equilibrium fishery, some FAO Code of responsible fisheries objectives will be fulfilled.

5.4.4 Policy implementation

All fisheries management tools or systems fall under four categories namely: biological management methods, direct economic restriction, taxes/subsidies, and property rights. Biological and direct economic control systems can be grouped together as direct control methods that attempt to directly control the behaviour of fishermen. Taxes and property rights are indirect control methods that alter the operating conditions of the fishers and thus indirectly influence their behaviour. This study will briefly describe the first three systems but will give more emphasis to the property rights system.

5.4.5 Biological management tools

These are tools designed to increase the productivity of the resource. They involve mesh size regulations, gear restrictions, closed seasons and restricted fishing areas. Their immediate effect is to shift the biomass growth function upward and since they impose added controls on the fishers, reduce the instantaneous benefit function.

Direct economic restrictions

These are restrictions designed to increase the profitability of the fishing operations through restricting effort, capital, investment and power. Their immediate effect is to make fishing operations less profitable and thus reduce the instantaneous benefits function.

Taxes

This is a tool used to regulate fishing through imposition of a specific tax based on the harvest volume. The tax system reduces the benefits to the fishers.

Property rights system

Included in this system are various models of property rights management systems namely: sole ownership, territorial user rights (TURFS) regime, individual quota/individual transferable quota (IQ/ITQ), and community property rights (Ragnar 2007). In simplicity, the property rights management system can be at individual and at group or community level. As has been mentioned before in this report, fishers need to be given more incentives to fish sustainably. The property rights management arrangement has the potential to offer exactly that. This system creates incentives for more sustainable behaviour by providing fishers more secure harvesting or territorial rights to fish. The fishers enjoy a sustainable flow of benefits from fishing with an enforceable right to exclude others from these benefits. However, these rights do not give ownership over the resource stock. At times, particularly when the holders of rights are in large numbers and with diffuse interests, sustainability cannot be guaranteed. Incentives may still remain to cheat and “free-ride” on the conservation of others (Grafton *et al.* 2005). This type of incentive-based approach make management more robust by ensuring that those with the greatest impact on fisheries have an increased interest in their long run conservation and directly bear the costs of over-exploitation.

Individual harvesting right are often referred to as a "revocable privilege" but in actual sense they are economic property rights. Control and enforcement ensure that the holders of the harvesting rights meet their responsibilities and those without are excluded from harvesting. Secure and durable harvesting or territorial rights provide fishers with incentives to protect the value of their assets and also obtain the greatest possible sustainable flow of benefits from fishing. Individual efforts by fishers to maximise their net returns indirectly contribute to sustainable fisheries by improving economic performance and reducing the problems of overcapacity. Collective actions would ensure sustainability by improving management decision-making, the quality of scientific advice and monitoring of fishers' behaviour. At an individual level, quantified fishing rights encourage fishers to harvest their fixed catch at the lowest cost, to increase the value of the landings through better handling and care of fish, or change products through value addition. Such efforts, and the transferability that allows more profitable fishers to harvest large shares of the total catch, improve efficiency and increase productivity (Grafton *et al.* 2005).

To be successful in implementing the above fishery recovery measure, fishers must have adequate incentives to accept and be part of change management. The property rights system is the way to go in the Lake Victoria Nile perch fishery. Each fisher and each co-management group, or so-called Beach Management Unit (BMU), must have their quantified volume of fish they should harvest per year. Each country should also have its total allowable catch (TAC) that its fishers should harvest per year.

As the three East African countries have a common management programme co-ordinated by the Lake Victoria Fisheries Organization (LVFO), which is the regional fisheries body, the fishery managers should allocate each country its quota. Each country quota can be derived from the agreed known Nile perch catch history. In the case of this study, Nile perch landings from the years 1976 to 2005 indicate that going by the fishing history Kenya should get 20% of the TAC, Tanzania 35% while Uganda gets 41% (Appendix 6). However, catch history should not be the only criteria in quota allocation to each country. Survey information data can also be issued. The data indicates that 50% of the Nile perch are in Tanzania, 30% - 40% in Uganda and 8% -16% in Kenya. This is essential information that should be used in the quota negotiation and allocation. Each country should then allocate its TAC quota to its BMUs which are distributed all along the lake. Each BMU has its own fishing history and the same basis can be used in quota allocation to BMUs which would have the responsibility to share it amongst its fishermen. The quota allocated to individual fisher should have permanence to guarantee flow of income.

The smallest management entity should be the BMU composed of individual fishers with a common interest. Every fisherman should belong to one BMU in a designated region and should not shift to another if he decides to fall out from his original grouping due to management or harvesting arrangements he cannot abide to. The option allowable should be to exit the fishery in totality. Individual fishermen should have the right to transfer parts of his quota to another within the same BMU if he is unable to utilise it for any particular year. A BMU in a particular fishing region should have the responsibility of overseeing fishing effort and harvest adjustment during the transit period and optimal sustainable management thereafter in the optimal long-run fishery. Each BMU should have a mechanism of monitoring its members and data collection. They should also keep away illegal fishermen in their fishing area jointly with the administration. At the national level, there should be a coordinating team to monitor the management implementation progress. A regional forum should be established under LVFO, to monitor and coordinate the three countries activities as well as arbitrating Lake Victoria fisheries conflicts amongst the three countries. This arrangement will be able to induce efficiency in the Nile perch fishery operation, maximise profits and improve the fishers' social welfare.

6 CONCLUSION AND RECOMMENDATIONS

In comparison with a fishery being managed at its target levels, the current Nile perch fishery is characterised by a lower harvest, higher effort and smaller stock size. If the stock were given time to rebuild, a larger harvest with a lower level of fishing effort (boats) could be realised. The difference between the target harvest of a Nile perch fishery at an optimal sustainable equilibrium and the current level shows that considerable harvest and economic rents are forgone due to depleted stock.

If the fishery managers enact remedial measures to allow fish stocks to rebuild, then harvest and effort need to be reduced during the transition period. A recovered fishery will be characterised by relatively higher catch levels, larger stock size and lower effort. The benefits and costs of transition to the targeted fishery will depend on the resource’s biological characteristics. Nile perch has a very fast growth rate and high fecundity. Thus overfished Nile perch fish stock would rebound to target levels in a relatively short period of time if allowed to recover.

As the purpose of this study was to estimate the economic inefficiency of the Nile perch fishery and determine efficient policies that would maximise the economic benefits and ensure sustainable biomass growth, the following fishery policies are recommended:

The fishing effort should be reduced to 56.9 thousand standardised boats from the current 94.7 thousand to enable the rebuilding of the stock biomass from 436 thousand to 892 thousand t. The reasonable adjustment path (path 2) is optimal over path 1 as the option to transit the fishery from its current level to the long-run optimal sustainable equilibrium. Though the present value maximisation path (path1) is superior to the reasonable adjustment path, it should not be used due to the socio-economic hardships it is likely to subject the fishers’ community to. Path 2 offers social stability by mitigating against the socio-economic hardships that the fishery dependent fishers’ community would go through if the drastic strategies of the present value maximisation path were used.

To increase efficiency in the fishery and to give incentive to fishers to accept and participate in the proposed fishery changes, a rights based management approach at BMU level should be adopted. Efficiency will be increased as each BMU tries to reduce the fishing cost in harvesting its quota.

The government can use the auction system in selling its TAC to prospective rights holders and generate funds. A chargeable levy based on unit quota can also be administered as alternative instead of an auction system to generate funds for fisheries management research, data collection, surveillance and administrative work. A Fisheries Levy Trust Fund can be established to administer the revenues for the purpose of fishery development without relying on financial transfers from the central governments.

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Appendix 1: CPUE for Lake Victoria 1968 - 2000(Catch and effort data (Asila, 2001)

Year	All Lake Fisheries harvest (M.ton)	Effort (,000 boats)	CPUE (ton/boat)	Nile perch harvest (,000 ton)	% of Nile
1968	111,8	9,2	-	-	-
1969	116,6	9,5	-	-	-
1970	107,6	10,4	-	-	-
1971	95,5	10,7	-	-	-
1972	90,9	9,6	-	-	-
1973	97,4	10,1	-	-	-
1974	73,8	10	-	-	-
1975	77	10,5	0,03	0,3	0,4
1976	80,1	10,5	0,06	0,6	0,8
1977	98	10,1	0,07	0,7	0,7
1978	86,4	10,1	0,15	1,6	1,8
1979	105,3	12,2	0,37	4,5	4,3
1980	95,2	11,7	0,38	4,4	4,7
1981	125,8	11,9	2,01	23,9	19
1982	108,1	11,9	3,13	37,2	34,4
1983	167,4	12,5	6,82	85,2	50,9
1984	214,4	12,6	9,89	124,5	58,1
1985	242,1	12,1	10,27	124,2	51,3
1986	395,2	15,8	14,55	229,8	58,2
1987	390,8	15,1	17,28	260,9	66,8
1988	494,2	15,5	20,81	322,6	65,3
1989	587,6	16,7	22,89	382,2	65,1
1990	562,7	22,7	16,74	380,0	67,5
1991	487,2	23,3	13,10	305,3	62,7
1992	481,3	23,3	11,47	267,2	55,5
1993	525,1	23,4	15,01	351,2	66,9
1994	475,7	23,5	11,69	274,7	57,7
1995	406,8	29,3	9,97	292,1	71,8
1996	394,8	30,3	9,44	286,2	72,5
1997	410,5	31,4	8.37	262.7	64
1998	404,5	31,5	8.46	266.3	65,9
1999	428,1	32,7	8.15	266.3	62,2
2000	428,1	41,6	6.40	266.3	62,2

Source: Kyomuhendo. P, 2002: A bioeconomic model for Uganda's Lake Victoria Nile Perch Fishery

Appendix 2: Calculation matrix table used in simulating Present value Maximization path for long-run Nile perch management

Present Value Maximization Path

Time	Biomass 01-Jan.	Effort	Attempted harvest	Biomass 31Dec.	Corrected Biomass 31-Dec.	Corrected harvest	Revenues (m. US$)	Costs (m. US$)	Profits (m.US$)	Discount factor	PV of profit
0	436,3	94,7	249,0	363,9	363,9	249,0	373,5	329,1	44,4	0,9	
1	363,9	0,0	0,0	537,5	537,5	0,0	0,0	19,1	-19,1	0,9	-16,7
2	537,5	0,0	0,0	700,6	700.6	0,0	0,0	19,1	-19,1	0,8	-15,6
3	700,6	0,0	0,0	799,0	799.0	0,0	0,0	19,1	-19,1	0,8	-14,5
4	799,0	11,4	50,0	782,5	782,5	50,0	75,0	56,3	18,7	0,7	13,3
5	782,5	22,7	98,3	730,0	730,0	98,3	147,4	93,6	53,8	0,7	35,8
6	730,0	34,1	139,0	672,1	672,1	139,0	208,4	130,8	77,6	0,6	48,2
7	672,1	45,5	172,7	612,9	612,9	172,7	259,1	168,0	91,0	0,6	52,8
8	612,9	56.9	199,6	553,1	553,1	199,6	299,4	205,3	94,2	0,5	51,0
9	553,1	56,9	182,9	529,4	529,4	182,9	274,4	205,3	69,1	0,5	35,0
10	529,4	56,9	176,2	518,1	518,1	176,2	264,4	205,3	59,1	0,5	27,9
11	518,1	56,9	173,0	512,4	512,4	173,0	259,6	205,3	54,3	0,4	24,0
12	512,4	56,9	171,4	509,3	509,3	171,4	257,1	205,3	51,9	0,4	21,4
13	509,3	56,9	170,5	507,7	507,7	170,5	255,8	205,3	50,6	0,4	19,5
14	507,7	56,9	170,1	506,8	506,8	170,1	255,1	205,3	49,9	0,4	17,9
15	506,8	56,9	169,8	506,4	506,4	169,8	254,8	205,3	49,5	0,3	16,6
16	506,4	56,9	169,7	506,1	506,1	169,7	254,6	205,3	49,3	0,3	15,5
17	506,1	56,9	169,6	506,0	506,0	169,6	254,4	205,3	49,2	0,3	14,4

18	506,0	56,9	169,6	505,9	505,9	169,6	254,4	205,3	49,1	0,3	13,5
19	50,9	56,9	169,6	505,9	505,9	169,6	254,4	205,3	49,1	0,3	12,6
20	505,9	57,9	172,5	502,8	502,8	172,5	258,8	208,5	50,3	0,2	12,0
21	502,8	58,9	174,6	498,3	498,3	174,6	262,0	211,8	50,1	0,2	11,2
22	498,3	59,9	176,2	492,8	492,8	176,2	264,3	215,1	49,3	0,2	10,3
23	492,8	60,9	177,5	486,9	486,9	177,5	266,2	218,4	47,9	0,2	9,3
24	486,9	61,9	178,6	480,7	480,7	178,6	267,9	221,6	46,2	0,2	8,4
25	480,7	62,9	179,5	474,4	474,4	179,5	269,3	224,9	44,4	0,2	7,5
										PV=	431,4
									PV(remainder)=		114,6
										Total	546,0

Appendix 3; Calculation matrix table used in simulating Reasonable Adjustment Path for long-run Nile perch management

Reasonable Adjustment Path									
Time	Biomass 01-Jan.	Effort	Attempted harvest	Biomass 31Dec.	Corrected Biomass 31-Dec.	Corrected harvest	Revenues (m. US$)	Costs (m. US$)	Profits (m.US$)
0	436,3	94,7	249,0	363,9	363,9	249,0	373,5	329,1	
1	363,9	87,1	196,3	341,2	341,2	196,3	294,4	304,3	-9,8
2	341,2	79,6	169,8	341,9	341,9	169,8	254,8	279,7	-24,9
3	341,9	72,0	153,9	358,6	358,6	153,9	230,8	254,8	-24,0
4	358,6	64,4	143,4	388,3	388,3	143,4	215,0	229,9	-14,9
5	388,3	56,9	135,5	428,5	428,5	135,5	203,3	205,4	-2,1
6	428,5	49,3	127,7	477,6	477,6	127,7	191,5	180,5	11,0
7	477,6	41,7	118,4	532,7	532,7	118,4	177,6	155,6	22,0
8	532,7	34,2	106,6	590,4	590,4	106,6	159,9	131,1	28,8
9	590,4	37,9	128,9	609,5	609,5	128,9	193,3	143,2	50,1
10	609,5	41,7	145,7	604,9	604,9	145,7	218,5	155,6	62,9
11	604,9	45,5	158,0	589,8	589,8	158,0	236,9	168,1	68,9
12	589,8	49,3	167,5	570,4	570,4	167,5	251,2	180,5	70,7
13	570,4	56,8	187,8	537,0	537,0	187,8	281,6	205,2	76,4
14	537,0	56,9	178,4	521,9	521,9	178,4	267,6	205,3	62,3
15	521,9	56,9	174,1	514,3	514,3	174,1	261,2	205,3	55,9
16	514,3	56,9	172,0	510,4	510,4	172,0	257,9	205,3	52,7
17	510,4	56,9	170,8	508,3	508,3	170,8	256,3	205,3	51,0
18	508,3	56,9	170,2	507,1	507,1	170,2	255,4	205,3	50,1
19	507,1	56,9	169,9	506,5	506,5	169,9	254,9	205,3	49,6
20	506,5	56,9	169,8	506,2	506,2	169,8	254,6	205,3	49,4
21	506,2	56,9	169,7	506,0	506,0	169,7	254,5	205,3	49,2
22	506,0	56,9	169,6	505,9	505,9	169,6	254,4	205,3	49,1
23	505,9	56,9	169,6	505,9	505,9	169,6	254,4	205,3	49,1
24	505,9	56,9	169,6	505,8	505,8	169,6	254,3	205,3	49,1
25	505,8	56,9	169,6	505,8	505,8	169,6	254,3	205,3	49,1
									PV (rema

Appendix 4: Detailed explanation on estimates calculation to get fishing total cost calculation

(i) Revenue

The revenue indicated was the product of the fish weight harvested in thousand M tons and the landing price in million US$/1.000 M tons of fish in the base year. In the base year under reference, 254.666 M tons of Nile perch was harvested and sold off at a landing price of US $ 1,5/ kg. For the purpose of this calculation the weight was converted into thousand (, 000) M tons and the unit price was adjusted into million US$ /1000 M tons

Harvest conversions

- 254.666 M tons= 254,67 (base year)
- 643.600,000 M tons= 643,6 (Optimal -logistic)
- 645. 600. 000 M tons = 645,6 (Optimal- Fox)

Fish sale price

US$ 1.5/kg= 1,5 million US$/ 1000 M ton

The current fish beach market value was used across the board for estimating the revenue generated from the sale of harvested fish for the base year as well as optimal situation - both for logistic and Fox calculation.

Revenue calculation

- Base year=254,67 *1,5= million US$ 382.005
- Optimal (Logistic)= 643,6*1,5 = million US$ 965.400
- Optimal (Fox)= 645,6 *1,5 = million US$ 968,4

(ii) Variable cost

Labor cost

The labor charge was 0,5% of every unit weight of fish harvested. The sale of fish was 1,5 million US$ / 1000 M ton of fish. Thus, the unit cost of1abor is US$ 0,75/1000 M ton of fish during the base year. The total labor cost was the product of the unit labor cost and the weight of fish sold. Thus, the labor cost during the base year was the cost was;

US$ 0,75(million) /1000 M ton* 254,67(, 000) M tons= US$ 191million

However, this mode of allocating labor cost was found to be faulty as it increases with the harvest status and tends to take a very high proportion of the revenue. Thus, for optimal fishery management, the cost of labor was fixed to a value just approximately to labor cost in other alternative industries that the laborer would move to for employment. This was adjusted for both logistic and Fox calculation. The value was fixed to US$ 1.134 per year. Equivalent skills in the labor market are paid 971 per year.

It is worth noting that there will be reduction of fishing effort, which in this case we used the fishing boats. The boats were chosen as they are the determinant of the workforce and gears deployed in the water. The boats were also used to differentiate who is a fisherman and who is a laborer. Those with boats also happen to be the owner of the fishing nets and fishing line. Rarely do those who own boat also do the fishing. By average every boat was calculated to have 2,3 laborers during the base year. This average of 2,3 was readjusted so that each boat will be managed by two (2.0) laborers in managed fishery in estimating the labor cost.

In the base year, there were 56.395 non-motorized and 12.765 motorized boats. To standardize them for ease of calculation this study investigated the effectiveness of motorized boats in the three countries- Kenya, Uganda and Tanzania. It was found that a motorized boat using a gill net is about three times more effective in fishing in Kenya and Uganda and slightly less than three in Tanzania. The number of motorized boats was multiplied by three to get 38.295 boats. The figure was summed up with the original non-motorized to come up with the figure 94.690 non-motorized boats.

Under optimal fishery management the fishing effort is recommended to be reduced to 61.000 non-motorized boats. The study developed an index of reduction as follows;

Reduction factor= New fishing effort/ Original fishing effort
= 61.000/94.690
= 0,64420741

To get new optimized figure of “true” non-motorized boats, and motorized boats, the study reverted back to the number of the true non-motorized and motorized boats and multiplied the figure by the reduction index. Thus;

Fuel cost

The gasoline fuel prices were different in different countries. It was lowest in Kenya and highest in Uganda. The average fuel price in the three countries was US$ 1,34 including a standardized Value Added Tax (VAT) of 18% in the three East African Community States.

Country	Tax	Pump price (US$)	(Tax excluded)
Tanzania	18%	1,27	1,04
Uganda	18%	1,47	1,21
Kenya	18%	1,18	0,97
Average price		1,31	1,07

International Exchange Rate was US$ 1= Ksh 68
Tanzania and Uganda currency was converted into Kenya Shilling at the rate of 15,0 and 23,0 for Tanzanian and Ugandan shilling respectively for one Kenyan shilling.

To calculate the total cost of fuel used I used the average fuel price including VAT as well as without. It is also worth to note that the types of motorized boats differ with the size of outboard engine used. They range from 6HP, 10HP, 15HP, 25HP, 45HP and 75 HP. The motorized boats were dominated with 25HP and 45HP engines. Operators' information (Frame survey 2006) indicates that a single boat consumes an average of 20,0 liters per day. Logistically each boat is out fishing for an average 250 days per year. A total number of 12.765 boats operated in the lake in the base year (2006) . Based on this information this study estimated the cost of fuel as;

Fuel consumed per year= Av. Fuel/boat* No. of boat* Operational days
=20*12.765*250
=63.825.000 liters

Fuel cost (with tax) = Fuel Price* Total fuel consumed
=US$ 1,31*63.825.000
=US$ 83.610.750 (Base year)

(iii) Fixed Cost

Fixed cost is the money spent by the fishers in maintenance of fishing gears, boat and jetties. It also covers “group insurance policy” for more organized fishing groups. The fund can also be utilized in the payment of landing fee to another co-management (Beach Management Unit) group’s jetty. This amount is calculated at 5% of the fish landed value. Normally this value should be as close as possible to zero for a long time basis calculation. Thus the rate was used to estimate the fixed cost for the base year, optimal (logistic) and Optimal (Fox) as follows;

0,05*382.010.000= US$ 19.100.500 (Base year)

(iv) Depreciation costs

This value was based on the interest rate in the country to service the bank loan. It is also the amortization value of the fishing equipments which are the boats and outboard engines. These equipments need replacement on average after every six years. Thus, the equipment owners need to cater for by saving approximately 16% of his earnings. The calculation of the value of the boats and engine is as follow;

Average value of the standard boat-----------------------------------US$ 735,00
Average value of dominant outboard engine (25 HP & 45HP) -----US$ 2.940,00
Actual number of boats --69.160
Number of Outboard Engines--12.765

Thus, depreciation cost for base year:
Total Cost of boats is= Cost of One boat * No. of boats
= US$ 735*69.160
=US$ 50.832.600

Cost of Outboard Engines= Cost of unit outboard engine*No. of engines
=US$ 2.940*12.765
=37.529.100

Total cost of fishing fleet = Total cost of boat + Total cost of Engines
=US$ 50,832,600 + US$ 37.529.100
= US$ 88.361.700

Depreciation cost at 16% rate= 0.16* Value of the fleet
= 0,16* US$ 88.361.700
=US$ 14.137.872 (Base year)

(v) Other Costs

There are other costs that are incurred by boat owners. These are charges by the County Council, Beach middlemen, and Co-management organizations called Beach Management Units (BMUs). The total amount chargeable was US$ 1.23/ boat / day broken down as follow;

County Council------------US$ 0,31
Beach Middlemen---------US$ 0,77
Co-management (BMU)—US$ 0,15
Assuming an operation year of 250 days,

Then total cost per boat= Daily cost* No. of operational days
= US$ 1,23*250 day
=US$ 307,5/ boat /year

Total cost for the fishing fleet= Total cost/ boat/year * Total No. of boats
=US$ 307,5*69.160
=US$ 21.266.700 (Base year)

Appendix 5: FAO Management objectives under Code of conduct for Responsible fisheries

Management objectives

Recognising that the long-term sustainable use of fisheries resources is the overriding objective of conservation and management, States and sub regional or regional fisheries management organizations and arrangements should, inter alia, adopt appropriate measures, based on the best scientific evidence available, which are designed to maintain or restore stocks at levels capable of producing maximum sustainable yield, as qualified by relevant environmental and economic factors, including the especial requirements of developing countries
Such measures should provide inter alia that:

a. Excess fishing capacity is avoided and exploitation of the stocks remain economically viable;
b. The economic conditions under which fishing industries operate promote responsible fisheries;
c. The interests of the fishers, including those engaged in subsistence, small-scale and artisanal fisheries, are taken into account;
d. Biodiversity of aquatic habitats and ecosystems is conserved and endangered species are protected;
e. Depleted stocks are allowed to recover or, where appropriate, are actively restored;

f. Adverse environmental impacts on the resources from human activities are assessed and, where appropriate, corrected and
g. Pollution, waste, discard, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species, and impacts on associated or dependent species are minimised, through measures including, to the extent practicable, the development and use of selective, environmentally safe and cost-effective fishing gear and techniques

Appendix 6: Nile perch harvest trend from 1976 to 2005 in Kenya, Tanzania and Uganda (FAO database, 2008)

States should assess the impacts of the environmental factors on target stocks and species belonging to the same ecosystem or associated with or dependent upon the target stocks, and assess the relationship among the population in the ecosystem.

FAO (1995), pp.9-10

Year	**Kenya**	**Tanzania**	**Uganda**	**Total**
1976	97	4.174	55.000	**59.271**
1977	203	3.815	76.080	**80.098**
1978	1.066	2.031	76.100	**79.197**
1979	4.286	7.935	69.100	**81.321**
1980	4.310	0	72.450	**76.760**
1981	22.834	3.250	71.020	**97.104**
1982	33.134	3.929	95.660	**132.723**
1983	55.572	21.558	90.550	**167.680**
1984	44.698	46.802	100.300	**191.800**
1985	53.011	43.440	80.700	**177.151**
1986	58.806	44.775	95.900	**199.481**
1987	69.545	99.625	100.900	**270.070**
1988	62.612	152.664	109.394	**324.670**
1989	56.945	164.813	118.076	**339.834**
1990	71.930	179.262	120.334	**371.526**
1991	57.262	98.770	103.500	**259.532**
1992	77.599	100.000	130.000	**307.599**
1993	100.037	156.401	95.005	**351.443**
1994	104.102	123.557	101.208	**328.867**
1995	102.546	155.860	92.722	**351.128**
1996	97.145	121.161	81.253	**299.559**
1997	73.555	152.000	91.706	**317.261**
1998	76.663	150.000	98.800	**325.463**
1999	103.014	100.000	89.203	**292.217**
2000	109.815	90.000	87.257	**287.072**
2001	78.534	96.000	88.881	**263.415**
2002	58.432	92.000	90.698	**241.130**
2003	55.175	98.500	112.804	**266.479**
2004	57.235	98.500	156.301	**312.036**
2005	53.051	98.500	175.205	**326.756**
TOTAL	**1.743.214**	**2.509.322**	**2.926.107**	**7.178.643**
% of Total	**24**	**35**	**41**	**100**

Appendix 7: A quote of the proceeding of in a conference on“First Lake Victoria Fisheries Organization and FAO Regional Technical Workshop on Fishing Effort and Capacity on Lake Victoria” conference held in Dar-es- Salaam (Tanzania) in December, 2005 (FAO, 2005) as quoted here-below:

Permanent Secretary (PS), Ministry of Natural Resources and Tourism, Tanzania “*urged the participants to determine optimum levels of catch and effort to produce optimal yields and economic benefits without affecting long-term production.”* The Commissioner for Fisheries, Uganda “*cautioned about the need to have a human face when reducing or controlling effort because some fishers totally depend on fishing.*” The Regional Fisheries Consultant, FAO Sub region Office for Southern an Eastern Africa noted several key elements of “*managing capacity, including the means to assess the current levels of fishing effort and capacity; the means to identify desired level of capacity; and need to identify the mechanism to move from the current fishing effort situation to desired situation* (FAO, 2005).

The conference concluded and resolved among others, the need to update the information on the current status of Nile perch.