A bioeconomic model for Uganda's Lake Victoria Nile Perch Fishery

By

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Master of Science in International Fisheries Management, May 2002

Thesis submitted in partial fulfillment of the requirements of the Master of Science in International Fisheries Management, Universitetet i Tromsø. Tromsø, Norway,

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DEDICATION

This work is dedicated to all those who believe that a better day will come to them no matter what. CARRY ON! This work is also dedicated to the memory of Dr. Isaac Nsamba.

ACKNOWLEDGEMENTS

My sincere gratitude goes to my supervisor Arne Eide without whose remarkable patience and understanding this work would not have come to fruition.

I also extend my appreciation to all lecturers in this course, Florence Kakolwa and Frank Mugweri at the FIRI library, Jinja and to Jackson Wadanya at the UFD, Entebbe.

Lastly, I wish to express my genuine gratitude to NORAD, my generous sponsors for this course in International Fisheries Management.

MAY THE LORD ALMIGHTY BLESS YOU ALL

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LIST OF ABBREVIATIONS:

FAO – Food and Agricultural organisation of the United Nations.

EAFFRO – East African freshwater fisheries research organisation.

NORAD – Norwegian Agency for Development Co-operation.

KMFRI – Kenya Marine Fisheries Research Institute.

COMESA - Common Market for Eastern and Southern Africa.

ABSTRACT

After an evaluation of this Nile perch fishery for the period 1986 – 2000, when it constituted more than 60% of the catch, it is evident that a severe over fishing problem exits and that the fishery has never been managed for economic efficiency. All economic rent from this fishery has been and continues to be dissipated. The effort in 2000 is 64% higher than that required to take MEY and 44% higher than that required to harvest MSY. The total cost of fishing effort at OAE is 44% higher than that at MSY and 62% higher than that at MEY. The total cost of fishing effort at MSY is 33% higher than that at MEY.

This open access fishery is the victim of excess fishing effort which, seems to be growing even further whilst harvests plummet. The objectives of fishery management often based but not entirely on political considerations, should be subjected to economic analysis to determine their consequences on the fishery. The resultant optimal management strategy should in addition incorporate views of all stakeholders in both design and implementation.

1. Introduction

Background

Uganda is one of the three East African states among which Lake Victoria is apportioned, the other two being Tanzania and Kenya. It is richly endowed with natural fresh water bodies which account for 15% of the countries surface area as open water and 2% as permanent wet lands (NEMA, 1998), and fisheries play a very important role as a foundation for subsistence and commercial livelihood. Lake Victoria is by far the largest and economically most significant of the national fisheries (FAO, 1999). It is worth noting however, that other lakes, including George, Albert, Edward and Kyoga, not forgetting the river Nile and numerous swamps and streams, also contribute substantially to the annual national catch.

Traditional capture methods using baskets, traps and hook and line are still in use in a great many areas essentially for subsistence. Today, most fishing is commercial. Artisan fishers utilise various gear, including gill nets, long-lines, beach seines and "mosquito" nets. Dugout canoes are the traditional fishing vessel but are increasingly being replaced by plank or fibre -glass canoes (FAO, 1999).

Fisheries in the Ugandan economy

Uganda's economy relies heavily on the agricultural sector which currently accounts for about 43% of gross domestic product (GDP), and provides the main source of livelihood for over 80% of the Ugandan population. Uganda's economy which has been growing steadily since 1987, and registered it's highest growth rate of 10.5% in 1994/95. During 1997/98 the GDP growth rate and the per capita growth rate were 5.5% and 2.7% respectively; compared to GDP growth rate and per capita growth rate of 5.2% and 2.4% respectively, during the period 1996/97. The labour force employed in agriculture is about 82% of the national labour force (NEMA, 1998). The GDP growth rate was about 6% in 2000. Uganda has one of the fastest growing economies in sub Saharan Africa. In 1999, fish and fish product exports accounted for 1.7% of GDP and 5.2% of total exports. The fisheries sub sector employs between 0.7 to 1 million people (COMESA, 2000). The contribution of the fisheries sub-sector to GDP was 2.1% during 1997/98, which, was a slight decline from 2.2% registered in 1995/96. The slight decline is largely attributed to the effects of El Niño weather phenomenon, while the increase in export earnings is due to heavy private investment in this industry. In 1996 per capita consumption of fish was about 12.5kg per year (NEMA, 1998). Fish exports have been booming since the export ban to the EU was lifted. Exports are expected to soar above US $ 100m in the next few years making fish the greatest foreign exchange earner after coffee.

A brief history and current situation of the fishery

By the 1950s and the early 1960s popular species such as *ngege (Oreochromis esculentus*), had diminished so severely that they had become commercially extinct. Therefor to remedy this sad situation, the piscivorous Nile Perch (*Lates niloticus.*) was introduced into Lake Victoria from its natural habitat in Lake Albert and Lake Turkana. During the following twenty years the Nile perch were only caught in small quantities. In the early 1980s an explosive increase of Nile perch and a simultaneous decline of the stocks of most other fish species were reported for several areas of the lake (Witte et al, 1991, Kitchell et al, 1997). Also introduced at the time, along with the Nile perch, was the fast growing omnivorous tilapiine, Nile tilapia (*Oreochromis niloticus*.). The objective of this introduction of the two fish species was to increase the economic value and use of fishes from this lake (Kitchell et al, 1997).

Between 1969 and 1977, the East Africa Fresh water Fisheries Research Organisation, EAFFRO, initially in collaboration with UNDP/FAO, carried out a fish stock survey of Lake Victoria. A comparison of the trawl catch data made in the Nyanza Gulf in 1976 with earlier records of 1969/1970 shows a reduction in stock densities of the most important species, tilapiines as well as L. *Victorinus*, *Barbus* species, mormyrids and S. *mystus* were virtually absent. The only abundant species being caught at that time were haplochromine cichlids and R.*argentea*, which contributed 34.1% and 30.3% respectively to the commercial landings in 1976. The tilapiine species contributed only 5.5%. By this time the Nile Perch was not well established and comprised only 0.5% of the catch (Ogutu, 1990).

After the reduction in the stocks of the larger commercial species, fishing effort became more directed towards the smaller species. Gill nets of 38 to 46mm (1,5 to 1.8

inches) were introduced to harvest haplochromines. A mosquito seine net of 10 mm (0.4 inches) mesh was also introduced for cropping R.*argentea.* These small mesh nets crop juveniles of larger species. The dragging of seines near the lake margins may further more destroy nests on the breeding grounds and disrupt courtship of the cichlids. Some breeding females are also caught which results in the loss of the parent as well as its eggs or young. The mosquito seines have a sufficiently small mesh to take a heavy toll on juveniles of larger species and even those of haplochromines (Ogutu, 1990).

Unregulated fishing contributed almost entirely to the decline of the native fisheries of Lake Victoria. The fisheries administration was poor in as neglecting advice from scientists. In 1977, EAFFRO, which was the only remaining regional unifying body, was also disbanded and it's research activities were transferred to national research institutions (Ogutu, 1990).

The ecological health of Lake Victoria has been affected profoundly as a result of a rapidly increasing human population due to migration to the area by plantation workers, clearance of natural vegetation along the shores to establish plantations of coffee, tea and sugar, a booming export industry, disappearance of indigenous fish species, prolific growth of algae and dumping of untreated effluent by several industries. Much of the damage is extensive and irreversible. Traditional lifestyles of lake - shore communities have been disrupted and are crumbling. Agricultural chemicals applied on the plantations are washed into the rivers during the rainy season and end up in the lake providing nutrients for unwanted, unsightly algal bloom As the population grew and fishing methods advanced, over – fishing also became a problem and catch sizes began to drop (Chege, 1995).

Before stocks of introduced species (Nile perch and Nile tilapia) started to increase rapidly, twelve to fourteen species occurred regularly among commercial catches. Two tilapiines (O.*esculentus* and O.*variabilis*), *Bagrus docmac*, *Protopterus aethiopicus*, *Clarius gariepinus* and haplochromine species were the main commercial species. Others included; *Labeo victorianus, R.argentea, Schilbe intermedius, mormyrids, Synodontis sp*, *Barbus sp* and *Brycinus* spp (Ogutu, 1994).

Now the dominant components of the fish community are Nile Perch, Nile Tilapia, and a small zooplanktivorous cyprinid, *Rastrineobola argentea* (Kitchell et al, 1997; Ogutu et al, 1990). The life history strategies of Nile Tilapia and of R. *argentea* allow their persistence. Nile Tilapia was sympatric with Nile Perch and appears not to have been affected by predation due to its high growth rate and large adult size. In contrast, *Rastrineobola* has a small adult size. Its evasive and schooling behaviour allows it to occupy surface waters of the pelagic zone. Local fishermen estimate that its abundance has increased 4 – 5 times since Nile Perch appeared.

Demand for and the amount of fish landed have increased and so has the fishing pressure. Several fish processing plants have now been set up and with the rapid increase in fishing effort, there is real danger of the collapse of this fishery (Ogutu et al, 1990).

Nile perch is the fish species dominating Lake Victoria today comprising about 41% of the catch (Personal comment, Oct 2001). The average size of fish landed has decreased, as have the catch rates (Ogutu et al, 1990). Most of the fishing canoes that target Nile Perch on the lake are using methods that catch predominantly immature Nile Perch. Bad fishing habits including beach seining and gillnets of illegal mesh sizes usually 4 inch and below as opposed to the hitherto recommended 5 inch mesh size, have been incriminated in this.

The Nile Perch catches which peaked in the period 1985 – 1990 are on the decline whilst fishing effort seems to be increasing relentlessly. There has been a shift to smaller mesh size gillnets and juvenile Nile Perch are increasingly exploited by beach seine fisheries in many areas (Kitchell et al, 1997). Reliable quantitative measures of abundance and age structure are hard to come by for the Nile Perch fishery of Lake Victoria (Kitchell et al, 1997). Management decisions have as a matter of fact, to rely on what other available information there is, hence the need for the development of a bio-economic model as a means of proposing management options more suited to save this fishery from eventual collapse (Kitchell et al, 1997).

Fisheries laws are outmoded and in need of revision because of not protecting those entities for which they were enacted. Fishing malpractices carry a maximum sentence of two years or a fine of about US$6 and a minimum fine of US$ 0.3 (Tumushabe, 1999). The objectives of management should include working towards economic efficiency in as maximising the net present value of fish catches over an indefinite time period and the limitation of use of labour and capital in the fishery.

The biology of the Nile Perch (*Lates niloticus*):

Habitat

Depth range 0 – 60m Lake Victoria has a maximum depth of 100m and a mean depth of 40m. Highest catch rates have been recorded in waters between 16 – 50m deep. The littoral rocky habitat is one of the few habitats that has not been invaded by *Lates*. (Witte et al, 1992).

Food

Until the haplochromine cichlids disappeared from the lake, they were the main prey. Presently, the main food consists of Caridina, Rastrineobola and its own young. Small ammounts of insects and molluscs are also eaten. The smallest juveniles feed on zooplankton and chironomids. Caridina is the dominant prey for fish of sizes up to 50 – 70 cm TL.

Reproduction

Occurs around the year with peaks in the rain season. Spawning occurs mainly in shallow sheltered areas. Females produce 3 to 18 million eggs depending on size (Ogutu et al, 2000). Generally, Nile perch reach sexual maturity when between 60 and 80 cm TL that is when they are about 3 – 4 years old (Schofield et al, 1999).

Growth

The growth rate estimate for juvenile Nile Perch of between 20 to 40 cm in Lake Victoria is 18.9cm ± 1.4 cm per year (Ogutu, 1994). The current mean growth rate of Nile Perch in Lake Victoria is close to the mean values reported for several of its native habitats. *Lates niloticus* attained a length of 19.5 cm to 23.9 cm at the end of the first year in Lake Mariout and a mean length of 21.1 cm in Lake Chad (Ogutu, 1994). Maximum length is about 193 cm TL (male/unsexed) and the maximum weight has been estimated at about 200kg (Fish base, 2002).

<u>Recruitment</u>

There is evidence of two recruitments in a year for Nile Perch in Lake Victoria. It generally occurs in March/April and September/October of every year (Asila, 2001).

Table 1: Types of fishing gear used on Lake Victoria

Types of Gear	Description
Gillnets	Commonest, very selective. Mesh size range is big (1 – 12 inches) because of the multi-species nature of the fishery. Easy to use since it does not need a big craft, can be operated several times over and not easy to steal. Suitable mesh size for Nile Perch should be 5 inches and above.
Mosquito Seine	Mainly used in the *Rastrineobola* fihery. Since the mesh sizes here (2-10mm) are very small, it should not be used near the shore line where juveniles of Tilapia and Nile Perch would be at risk.
Lift nets	Only recorded in Tanzania.
Beach seines	Most have a mesh size of 2-4 inches and have been incriminated in fishing juvenile Nile Perch and Nile Tilapia. Dragging these nets on the lake bottom and near the lake shores further disrupts courtship in Nile Tilapia and destroys nets on breeding grounds.
Trawls	Observed in Kenya (15) and Tanzania (75).
Long lines	There were 3,426,323 hooks on long line in Lake Victoria according to the 2000 survey. Most are between sizes 7 – 15 and target mainly the Nile Perch.
Hand line	Gaining more popularity in Kenya compared to the other two countries.
Traps	Mainly used where other gear types are not feasible like in river mouths and wetlands.

(Asila, 2001; Kamanyi, 1996; Ogutu et al, 1990)

The problem

The study seeks to identify a period in time dominated by the Nile perch and do some assessment of the fishery by, first setting up a bioeconomic model describing the Nile perch fishery based on that time period and then estimating the model parameters applying to that period. The study also seeks to identify the different key reference points of this model like MEY and MSY.

2. Methods

In order to investigate the population dynamics of the Nile perch the application of a surplus yield model has been necessary because this requires the use of only catch and effort data. This model is particularly useful when age determination and tagging are difficult, when such biological data do not exist or when knowledge of the biological system is insufficient to describe recruitment, growth or natural mortality if they cannot be assumed constant through all ranges of population size (Fox, 1970).

The model:

Assume biological growth of the Nile Perch to follow the Fox Gompertz growth model (Fox, 1970; Zhenming et al, 1998; Pitcher et al, 1982), which assumes that the annual growth of the population biomass has a Gompertz relationship with biomass itself:

$$F(X) = r \cdot X(\ln K - \ln X) \qquad (1)$$

Where X is the biomass,

H the harvest /catch

r the intrinsic growth rate and

K carrying capacity.

If fishing mortality $F = q \cdot E$ we can further assume the bilinear short-term catch equation:

$$H = q \cdot E \cdot X \qquad (2)$$

Where E is the effort and

q the catchability coefficient, a constant

Under conditions of exploitation, we have;

Rate of change of biomass, X`= $F(X) - H$ (3)

Where H is the harvest (catch)

However, at equilibrium fishing, removals in the form of harvest will be balanced exactly by growth i.e $F(X) = 0$ Therefore at equilibrium;

$$H = F(X) \qquad (4)$$

Substituting equations (1) and (2) into (4) we get;

$$H = q.E.X = r.X(\ln \frac{K}{X})$$

$$\frac{q}{r}.E = \ln\frac{K}{X}$$

Biomass at equilibrium X_E is;

$$X_E = K.e^{-\frac{q.E}{r}} \qquad (5)$$

Substituting equation (5) into equation (2) gives the long- run catch equation;

$$H(E) = q.K.E.e^{-\frac{q.E}{r}} \qquad \text{(Fox non-parabolic harvest equation)} \qquad (6)$$

$CPUE = \frac{H}{E}$ is catch per unit effort and;

$$CPUE = \frac{H}{E} = q.K.e^{-\frac{q.E}{r}}$$

$$\ln CPUE = \ln q.K - (\frac{q}{r}).E = a + b.E \qquad \text{which is a straight line.} \qquad (7)$$

Where $a = \ln q \cdot K$ and $b = \frac{q}{r}$

<u>Bioeconomic model:</u>

Introducing a simple bioeconmic model in which total cost (TC) is proportional to effort and total revenue (TR) is proportional to catch.

Assuming;

a = a constant unit cost of fishing effort. The unit cost includes the value of labour, capital, materials and energy inputs used in fishing. Then;

$$TC(E) = a \cdot E \text{ and} \qquad (8)$$

$$TR(E) = p.H(E) = p(q.E.K.e^{-\frac{q.E}{r}}) \qquad (9)$$

Where $p =$ price per kilogram of Nile Perch.

The level of effort and the corresponding harvest at maximum sustainable yield (MSY) can be obtained from equation (6) by differentiation and setting the result to zero to give;

$$E_{MSY} = \frac{r}{q} \qquad (10)$$

$$H_{MSY} = -\frac{r}{q}.K.q.\frac{1}{e} \tag{11}$$

Assume the marginal revenue of effort MR (E), to be the change in total revenue when production of effort changes by one unit and the marginal cost of effort MC (E), to be the change in total cost when the level of fishing effort changes by a unit. The maximum economic yield (MEY) is then the yield obtained at the profit – maximising level of effort which, occurs when, $MR(E) = MC(E)$. That is, when the difference between total revenue and total cost is at a maximum.

When w (z) is the Lambert's function of $z = a.e^{\frac{(1-\ln q.K)}{p}}$

$$E_{MEY} = w(z) - \frac{1}{b} \tag{12}$$

w is therefore a function of a, p and α.

When a > 0 then $E_{MEY} < E_{MSY}$, $X_{MEY} > X_{MSY}$ and $H_{MEY} < H_{MSY}$

Under open access or in an unregulated fishery, individual fishers attempt to maximise their income by expanding effort. This they do as long as their average revenue of effort AR (E) that is, the revenue per unit of effort is greater than their marginal cost of effort MC (E). The fishery settles at an equilibrium level, called the bionomic or open access equilibrium (OAE), when TC (E) = TR (E) or AR (E) = MC(E).

$$E_{OAE} = r.\frac{\ln(\frac{a}{p}) - \ln q.k}{q} \tag{13}$$

At this point, resource rent is totally dissipated and no economic rent is obtained from the resource.

3. Data and Parameter estimates

The effort on the lake is measured in terms of fishing boats. This being a mixed fishery, it is assumed that all effort will target the Nile perch in one way or another. There is for the moment, no clear separation of effort between the different fishery types on Lake Victoria. Catch and effort time series data is the easiest to work with in the kind of situation existent in East Africa and in Uganda in particular. Whereby, data collection and compilation is still a problem. Therefore, data where available has been cast in a shadow of doubt. Nonetheless, it is useful in helping us to further our understanding of the Nile Perch fishery.

In the period prior to 1983 when it constituted 50% of the catch for the first time, the Nile Perch was not as important economically as it is today.

Table 2: CPUE for Lake Victoria 1968 – 2000(Catch and effort data; Asila, 2001)

Year	Yield (Tons)	Effort (000) Boats	CPUE	Ln CPUE	Yield Nile Perch (Tons)	%Nile Perch
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	10.0	-	-	-	-
1975	77.0	10.5	29	3.4	302	0.4
1976	80.1	10.5	61	4.1	637	0.8
1977	98.0	10.1	66	4.2	663	0.7
1978	86.4	10.1	154	5.0	1,550	1.8
1979	105.3	12.2	367	5.9	4,476	4.3
1980	95.2	11.7	378	5.9	4,425	4.7
1981	125.8	11.9	2,009	7.6	23,908	19.0
1982	108.1	11.9	3,127	8.1	37,214	34.4
1983	167.4	12.5	6,815	8.8	85,187	50.9
1984	214.4	12.6	9,885	9.2	124,547	58.1
1985	242.1	12.1	10,268	9.2	124,245	51.3
1986	395.2	15.8	14,546	9.6	229,824	58.2
1987	390.8	15.1	17,279	9.8	260,910	66.8
1988	494.2	15.5	20,812	9.9	322,582	65.3
1989	587.6	16.7	22,885	10.0	382,180	65.1
1990	562.7	22.7	16,739	9.7	379,973	67.5
1991	487.2	23.3	13,103	9.5	305,287	62.7
1992	481.3	23.3	11,466	9.4	267,152	55.5
1993	525.1	23.4	15,008	9.6	351,193	66.9
1994	475.7	23.5	11,688	9.4	274,662	57.7
1995	406.8	29.3	9,970	9.2	292,107	71.8
1996	394.8	30.3	9,444	9.2	286,152	72.5
1997	410.5	31.4	8,366	9.0	262,685	64.0
1998	404.5	31.5	8,455	9.0	266,344	65.9
1999	428.1	32.7	8,145	9.0	266,344	62.2
2000	428.1	41.6	6,403	8.8	266,344	62.2

Table 3: Catches of Nile Perch in Lake Victoria 1975 – 2000 (tons)

Year	Kenya	Uganda	Tanzania	Victoria
1975	52	250	-	302
1976	97	540	-	637
1977	203	460	-	663
1978	1,066	460	24	1,550
1979	4,286	190	-	4,476
1980	4,310	100	15	4,425
1981	22,834	800	274	23,908
1982	33,134	2,040	2,040	37,214
1983	52,337	16,425	16,425	85,187
1984	41,319	41,614	41,614	124,547
1985	50,029	37,608	37,608	124,245
1986	64,929	41,000	123,895	229,824
1987	86,832	76,600	97,478	260,910
1988	82,019	92,000	148,563	322,582
1989	119,276	101,300	161,604	382,180
1990	118,503	86,200	175,270	379,973
1991	122,780	86,200	96,307	305,287
1992	105,979	86,200	74,973	267,152
1993	109,195	86,200	155,798	351,193
1994	88,837	86,200	99,625	274,662
1995	102,426	86,200	103,481	292,107
1996	96,471	86,200	103,481	286,152
1997	73,004	86,200	103,481	262,685
1998	76,663	86,200	103,481	266,344
1999	76,663	86,200	103,481	266,344
2000	76,663	86,200	103,481	266,344

(Asila, 2001)

Table 4: Regression analysis results applying equation (7) in methods and Ln CPUE vs E in table 2 for the years 1986 – 2000.

Parameter	Value
Ln q.K (a)	10.539
$\frac{q}{r}$ (ß)	-0.0452
Statistics:	
R square	0.86
Significance F (x 10^7)	5.44
P value (X variable 1) (x10^7)	5.44
P value (intercept) (x10^{19})	5.87

The regression analysis results shown in table 4 above were obtained from time series catch and effort data of the Nile perch obtained from table 2. It was done for the years 1986 to 2000. The period starting 1986 is the earliest a correlation coefficient of at least 0.8 could be obtained when a regression analysis on this data was done. However, it should be noted that Nile perch catches were already 50% composition of the total fish catch composition by 1983. So therefore, whereas it would have been preferable to do a regression analysis on this data for the period starting 1983, it was not possible for the reason already cited.

The price (p) of the Nile perch in Uganda used in this study is Ug. Shs. 1,500 per kilogram of Nile perch (Personal comment, 2001).

The unit cost of fishing per boat per year (a), held constant in this study and incorporating the value of labour, capital, materials and energy inputs used in this fishery is not documented anywhere in the three East African states sharing the Nile perch fishery. It was therefore necessary to estimate it by making the assumption that the fishery was at an open access equilibrium in the year 2000 thereby setting the effort of 41,600 boats to be the effort at open access equilibrium for this fishery. The unit cost of fishing effort for this fishery was therefore estimated to be Ug. Shs. 9,604,460 per annum as shown here below;

Using equation (13):

$$E_{OAE} = r.\frac{\ln(\frac{a}{p}) - \ln q.k}{q}$$

$p = 1{,}500(Ug.Shs), E_{OAE} = 41{,}600(Boats)$, $\frac{q}{r} = -0.0452$ and $\ln q \cdot K = 10.539$.

4. Results

The harvest equation

The harvest equation for the Nile Perch fishery of Lake Victoria is equation (6) in methods incorporating parameter estimates from table 4. That is;

$$H = E \cdot e^{10.539 - 0.0452E}$$

E is the number of boats.

Figure 1: Fox harvest curve for the Lake Victoria Nile Perch fishery and catch and effort for the fishery 1986-2000.

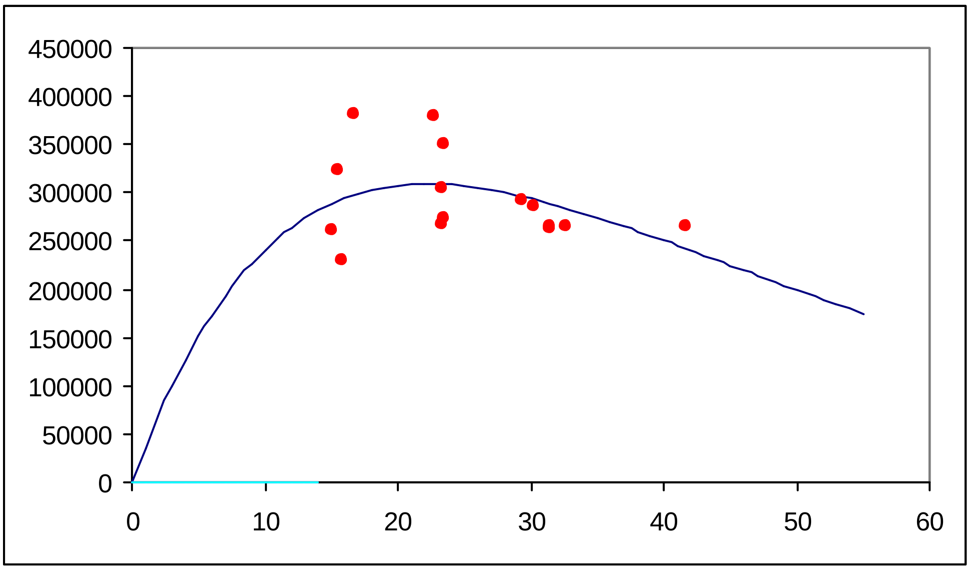

Table 5: Calculated values for the critical points of the Fox/Gompertz model for the Lake Victoria Nile Perch fishery: The values for effort at MSY and MEY have been calculated using equations (10) and (12) in chapter two. Harvest at MSY, MEY and OAE were all calculated using this fishery's harvest equation above.

Economic rent is the difference between total revenue and total cost and these two, that is, total cost and total revenue were calculated using equations (8) and (9) from methods, respectively.

Harvest condition	MSY	MEY	OAE
Effort(fishing boats)	22,104 Equation (10)	14,785 Equation (12)	39,215
Harvest (Tons of Nile Perch) $H = E \cdot e^{10.539-0.0452E}$	306,934	285,886	251,094
Total revenue (TR) Billion Ug.Shs. Equation (9)	460.4	428.8	376.6
Total cost (TC) Billion Ug.Shs. Equation (8)	212.3	142	376.6
Economic (TR-TC) Billion Ug.Shs.	248.1	286.8	0

5. Discussion, Recommendations and Conclusion

The study has been applied to the entire Nile perch fishery of the Lake Victoria. On this lake, it is not easy to distinguish which boats are involved in which fishery. All effort was assumed to affect the Nile perch. This is not necessarily true because even if boats are more or less uniform in size and design, different fishermen may use different gears and so actually target different fish species. These include the Nile tilapia and the small pelagic cyprinid, *Rastrineobola argentea.* Catchability could also be different in different lake areas. This leads to differences in harvests. A large number of boats would not necessarily mean big harvests. A lower number of boats with better gear could yield higher harvests. In turn, this means that the number of boats and therefore harvests at the different critical points of the model could easily be over or under estimated.

Catch and effort time series data on the lake is collected differently for the different countries and in some cases effort data may not be collected for several years due to financial constraints. The accuracy of this kind of data is always affected by several factors not least, the way it is gathered. Therefore, the data spanning the period 1986-2000 was used because it includes a period when the percentage composition of the Nile perch in the total catch was in excess of 60%. It also represents a period of Nile perch domination of fish harvests from this lake. Dealing with data in this time period should help to improve the quality of the results, or so it was hoped.

There are no references for unit costs of fishing effort or indeed for bio-economics as far as this fishery is concerned. This is a groundbreaking study and as such, the results could be affected by under estimation of the model parameters.

It should also be pointed out that the boats have different prices and there are differences in catch and management depending on which of the three countries one is in operation. There are also other differences including the price of fuel, power of engines (if any) and labour. All these differences will affect the outcome of estimates of unit cost of fishing effort. If the unit cost is underestimated, then the revenues from this fishery relating to the different critical points of the model will be much less.

MSY for the Fox/Gompertz model of the Nile perch fishery of Lake Victoria has been calculated using equation (10). It occurs when the number of boats on the lake is about 22,104 as shown in table 5. This is about 53% of the number of boats on the lake in 2000. Effort almost doubled in the 10 years starting from 1990 to 2000. We assume that there is little difference between the situation in 2000 and that at OAE. Effort at MEY is only 36% of that in 2000. Effort at MEY last occurred in 1985. This speaks volumes about the economic inefficiency of this fishery and for how long this has been going on.

The model developed in this study is a single species equilibrium model that assumes a constant environmental situation. However, the Nile perch stock depends on several ecological conditions like food supply, water temperature, disease, pollution, currents and so on. The model goes on to assume both a constant unit cost of fishing effort and price of harvest. For purposes of this study, the economic rent in 2000 was assumed be zero.

It is tempting at this time to consider management objectives that hinge on reduction of effort in this fishery considering that the model suggests that a shift from OAE to MEY effort will improve the profitability and economic efficiency the fishery. This reduction is not easy to achieve because there will be a decrease in employment whereas most fishermen are not equipped for other types of work, high unemployment, political repercussions, amount of welfare benefits, availability of incentives to change occupation and so on and so forth. Reducing effort will not immediately translate into increased yield and revenues. It will initially lead to decreased yield because sufficient time must be allowed for the Nile perch stock to reach a new larger equilibrium size and during that period, there will actually be a decrease in net revenues (Anderson, 1977).

There are differences in the values of the three currencies in use in this fishery. There are also differences in the prices offered per kilogram of Nile perch with those selling fish in Kenya earning most.

While analysing this fishery it could be interesting to know what the value of future revenues from this fishery would be worth today. This is possible through a process of discounting or getting present value. The interest rate acts as the crucial link between periods, for instance annual periods. The interest rate in Uganda is about 10% (Bank of Uganda, 2000). Therefore, the annual potential resource rent of Ug.Shs.286.83 billion forever is worth Ug.Shs. 2,868.3 billion as a lump sum today. This is the value of the fishery today. (1US$ = Ug.Shs.1802).

Conclusion;

After an evaluation of this Nile perch fishery for the period 1986 – 2000, when it constituted more than 60% of the catch, it is evident that a severe over fishing problem exits and that the fishery has never been managed for economic efficiency. All economic rent from this fishery has been and continues to be dissipated. The effort in 2000 is 64% higher than that required to take MEY and 44% higher than that required to harvest MSY. The total cost of fishing effort at OAE is 44% higher than that at MSY and 62% higher than that at MEY. The total cost of fishing effort at MSY is 33% higher than that at MEY.

This open access fishery is the victim of excess fishing effort which, seems to be growing even further whilst harvests plummet. The objectives of fishery management often based but not entirely on political considerations, should be subjected to economic analysis to determine their consequences on the fishery. The resultant optimal management strategy should in addition incorporate views of all stakeholders in both design and implementation.

The potential resource rent from this fishery is Ug. Shs.286.83 billion per annum.

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