THE ECONOMIC DEVELOPMENT OF THE KAPENTA FISHERY LAKE KARIBA (ZIMBABWE/ZAMBIA)

By

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DEDICATION

To my father with love

Makaita moyo ndizvo,
zvirambe zvakadaro.

Ndinovimba ndirikuzadzikisa
shungu dzemoyo wenyu!!

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To my son, Panashe, you have been the rock and pillar of my strength and dreams; I am blessed to have you. I could never thank the Lord enough for having you. For you my dear, the sky is the limit and I hope that my achievements will challenge you to go beyond. I Love so very much sweetheart.

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Abstract

Kapenta (Limnothrissa miodon) was introduced from Lake Tanganyika into the man-made Lake Kariba, where it now supports a large and viable fishery for Zimbabwe and Zambia who share the lake. The challenge for this paper has been to investigate whether the viability of the kapenta fishery is dependent upon biological factor or economic parameters. The Pella and Tomlinson surplus production model (Pella and Tomlinson, 1967) was used, and parameterised by historical catch and effort data in addition to individual growth parameters. 1994 data was referred to as the current data.

In the analysis three reference points were used, Maximum sustainable yield (MSY), Maximum economic yield (MEY) and Open access (OA) equilibriums. Prices and costs were varied to see the sensitivity of the fishery to these two variables, based on the reference points. MSY yield and effort which is the same for both countries was found to be 23 336 tonnes and 725 rigs at the age of first capture of four months. MEY yield and effort is 22 854 tonnes and 475 rigs for Zimbabwe and 22 181 tonnes and 500 rigs for Zambia. Resource rent at MSY is ZW$273 000 and ZK26Million and at MEY it is ZW$316 000 and ZK28Million. Current (1994) effort levels were shown to be close to MSY effort levels. OA effort levels are shown to be three times the current effort; trends in the fishery also show that effort levels are on the decrease, indicating that OA is not a threat to this fishery.

Key words: Kapenta, Bioeconomics, Lake Kariba.

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CHAPTER 1

1.1 Introduction

Kapenta (Limnothrissa miodon) is a small sardine successfully introduced into Lake Kariba from Lake Tanganyika. The fish now supports a large and viable fishery for Zambia and Zimbabwe who share the lake. It is the intention of this paper to assess the economic viability and importance of this fishery to the two countries. Looking into the extent of investment in the fishery in terms of effort based on sustainability and profitability. The following question will therefore serve as a guideline for this paper:

Is the viability of the Kapenta industry dependent upon economic parameters rather than biological parameters?

- Is there over fishing or not?
- Is there an overcapacity or not?
- Is maximum economic yield reached or not?

A bioeconomic analysis of the fishery was carried out by the two countries in 1997, which made use of the Beverton-Holt model, with the aim of identifying levels of fishing effort that would yield optimum economic rent to the kapenta industry. The group concluded that economic factors rather than biological factors would eventually limit further expansion of the fishing effort in the kapenta fishery.

In reaching the specified objectives, this study will make use of the Pella and Tomlinson model (1967), which is a surplus production model. With the hope of gaining some new knowledge in the areas pointed out above.

1.2 Historical background of the fishery

1.2.1 *Construction of the dam*

The construction of the Kariba dam wall between 1955 and 1959 on the mighty Zambezi River bordering Zimbabwe and Zambia produced a vast man-made lake that changed the region. The primary objective for constructing Lake Kariba was to harness water for hydroelectricity to supply electricity to the copper mines in Zambia as well as to support the emerging agricultural and industrial sector in Zimbabwe. Besides the major purpose of electricity generation other benefits including fishing were expected.

1.2.2 The environment

Lake Kariba (277 km long; 5364 km^2; 160 km^3; 29 m mean depth and 120 m max. depth) is located on the Zambezi River between latitudes 16 28' to 18E 04'S and longitudes 26 42' to 29E 03'E. It was the largest man-made reservoir in the world at the time of construction, and is today the second largest reservoir in Africa by volume. The catchment area covers 663 817 km^2 extending over parts of Angola, Zambia, Namibia, Botswana and Zimbabwe. The dam wall (128 x 580 m) was completed in 1960 and the filling phase lasted from December 1958 to September 1963 when the water reached the mean operation level around 485 m a.m.s.l.. The lake is naturally divided into 5 basins (Fig. 1.0) and is almost equally shared by the two riparian countries Zambia and Zimbabwe.

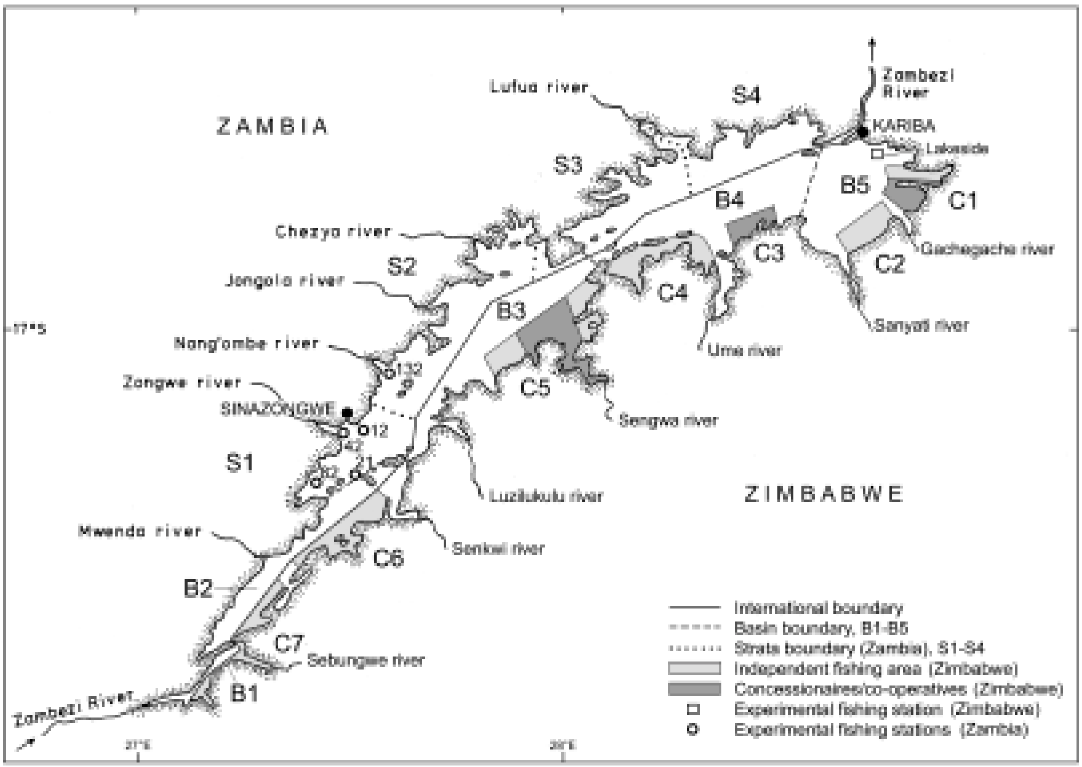

Figure 1.0. Map of Lake Kariba showing the five natural basins (B1..B5), the designated inshore fishing grounds on the Zimbabwean side (C1..C7), the sampling strata in Zambia (S1..S4), the selected experimental fishing stations in Zambia around Sinazongwe (open circles), and the experimental fishing station (Lakeside) in Zimbabwe near Kariba town (open square).

The lake levels fluctuate annually from 1 to 5 m (mean = 2.9 m) as a function of inflowing floods between December and June and continuous drawdowns through the turbines and, before 1981, spillage through the sluice gates. Since 1982 the lake levels have declined due to a series of droughts and the lowest levels recorded was in December 1992 and January 1997 at 476 m (Fig. 1.1). Since 1997 the lake levels have again risen rapidly and the sluice gates were opened again for the first time in 19 years in April 2000.

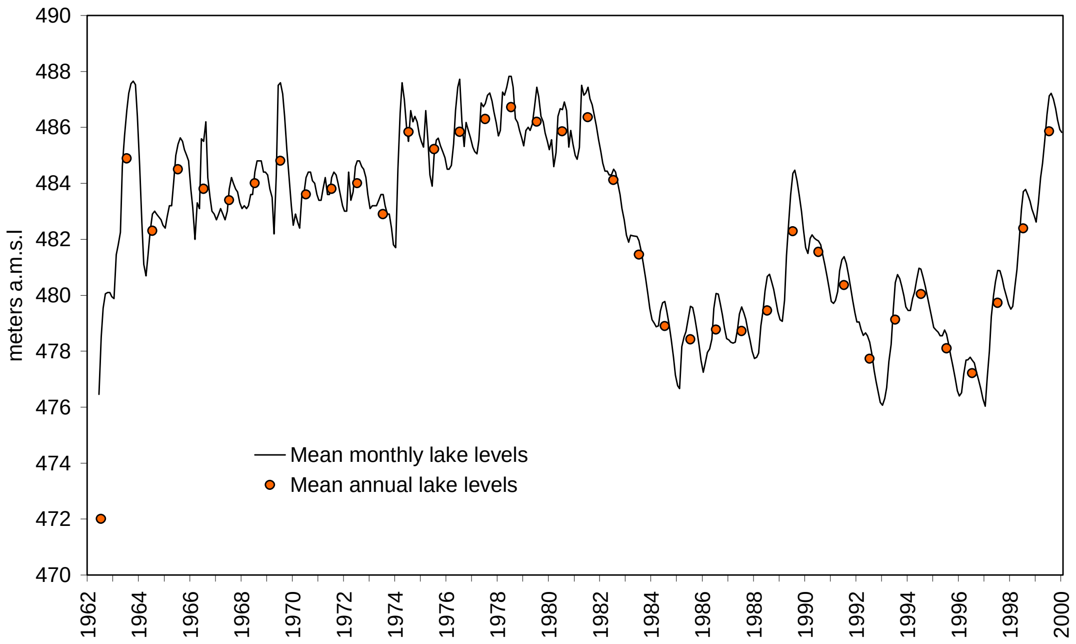

Figure 1.1. Mean monthly and mean annual lake levels (m a.m.s.l.) in Lake Kariba from 1962 to 2000. Between 1981 and 2000 no surplus spillage through the dam wall floodgates have been performed.

The limnological and various biological characteristics of Lake Kariba are well described elsewhere (see e.g. Coche 1968, Balon and Coche 1974, Marshall 1984, and Moreau 1997 for comprehensive reviews). However, a short preview is given here. The main source of nutrients in the oligotrophic Lake Kariba is the summer run off of rivers draining directly into the lake. As a result of the summer input of nutrients, biological production in the epilimnion increases. Since the lake stratified then the production in March is still limited by nutrients that sink to the bottom of the lake. Between May and July, the stratification in the lake breaks down and nutrients are released to the surface waters resulting once again in increased biological production From September up to summer, stratification intensifies resulting in loss of nutrients to the bottom and hence fish production starts declining. There are two distinctively different fisheries in Lake Kariba: the low cost, non-mechanised, multi-species, inshore artisanal fishery, and the highly mechanised, capital intensive, industrial single-species offshore fishery on the introduced pelagic clupeid Kapenta (*Limnothrissa miodon*). The biological, technical, and socio-economic interactions between these two fisheries are so small (Bourdillon et al 1985) that they can be easily treated separately. However, as the particular problems of the inshore artisanal fishery are not the main focus of this study, it will not be described and analysed here.

1.2.3 Kapenta introduced

The introduction of fish species into fresh waters is common practice around the world. There are many examples of well-defined successes (e.g. kapenta, Limnothrissa miodon, into Lake Kariba, and Lake Kivu). Some projects had questionable economic successes (e.g. Nile perch, Lates niloticus, into Lake Victoria or tilapia into Sri Lanka). However there were abject failures (e.g. ruffe, Gymnocephalus cernuus, into the Great Lakes of North America and carp, Cyprinus carpio into Australia), (Cowx 1997).

The construction of the Lake Kariba produced vast pelagic waters, which were left unexploited. It was predicted that the pelagic habitat of Lake Kariba would remain non-colonised since the species present in the Zambezi River had evolved in a riverine habitat and would therefore only inhabit the shallow littoral zones. According to Matthes 1968, a number of studies were carried out to identify suitable candidate species to introduce into the lake to fill up the open niche. Following Jackson's recommendation Kapenta, *Limnothrissa miodon,* (a small pelagic clupeid, which in Kariba reaches a size of around 5 cm) was introduced by the Zambian government into Lake Kariba between 1967 and 1969 from Lake Tanganyika.

The introduction was a success and, although the colonial Rhodesian (Zimbabwean) government was not informed about the introduction, the researchers at the Lake Kariba Fisheries Institute (Zimbabwean side) observed the widespread presence already in 1969. Studies were then carried out to investigate the distribution, abundance and spawning of kapenta and also to assess whether commercial exploitation was possible (Begg, 1974). Various experiments were undertaken by Lake Kariba Fisheries Research Institute in catching this fish, based on traditional techniques used on Lake Tanganyika. In July 1973, however, the first commercial fishing enterprise formed, pioneering purse seine and square lift net techniques. It was first issued a temporary licence, which was later converted to a fishing permit. Since then, effort grew rapidly (Fig 1.2) and from 1976 this fishery changed to using lift nets from pontoons at night with light attraction, which considerably increased the catch rates. From 1978 the fishery started to expand along the Zimbabwean shoreline to 6 different bases, and in 1981, after the termination of the civil war in Zimbabwe, this fishery started in Zambia. The predominantly white-owned, capital-intensive

Kapenta fishery has now developed into a million dollar industry, with between 20-30 000 t landed annually, vastly outstripping the inshore fishery, and with theoretical potential for further expansions (Kolding 1994). The Kapenta fishery alone, through its profitability, is according to Bourdillon et al. (1985) directly responsible for most of the infrastructural development that has occurred on the Zimbabwean shoreline. Cheater (1985) gives a detailed account of the development of this fishery in Zimbabwe until the mid 1980s. From the early 1990s no new licenses were issued in Zimbabwe and the effort development seemed also to stabilise in Zambia around this time (Fig. 1.2) with a corresponding stabilisation in catch rates of 150-200 kg per rig per night in both countries. From 1998 there has been a decrease in the reported Zimbabwean effort.

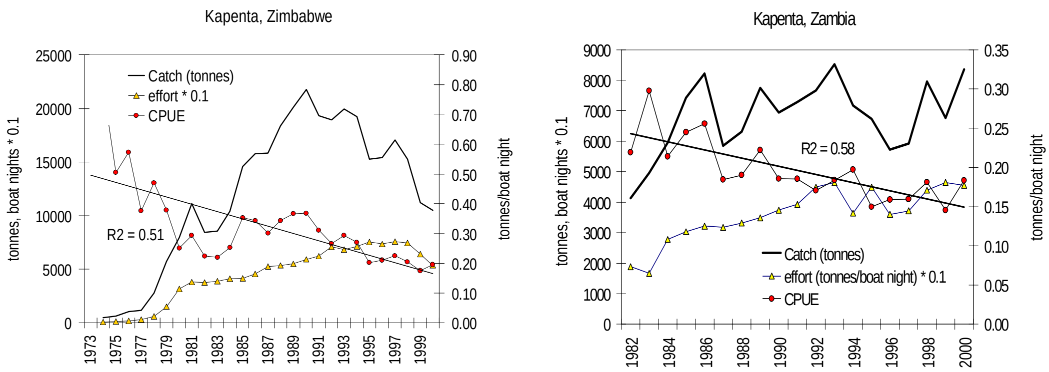

Figure 1.2. Development in the offshore Kapenta fishery in Zimbabwe (1974-2000) and Zambia (1982-2000). CPUE in tonnes/boat night. Source: Zambia-Zimbabwe Fisheries Joint Annual Statistical reports.

It is of interest to note that the size and life cycle of this species has adapted to harvesting over the years. Lake Kariba kapenta are smaller than their Lake Tanganyika brothers, reproducing at a smaller size and more frequently. Starting with one fishing company operating a large purse seine net, the fish now supports a major fishery for the two countries. Zimbabwe and Zambia share the same kapenta stock, because of this reason fishing regulations and management of the fishery is almost the same.

CHAPTER 2

2.0 THE MODEL

2.1 The biological part

The growth in the kapenta stock is assumed to follow the Pella and Tomlinson surplus production model (Pella and Tomlinson, 1967). The per period surplus production then can be expressed as:

$$f(x) = \frac{MSY_{t_c}}{m^{\frac{1}{1-m}} - m^{\frac{m}{1-m}}} \frac{x}{K}\left[1 - \left(\frac{x}{K}\right)^{m-1}\right] \qquad (1)$$

x being the stock biomass at the start of a period, MSY the annual maximum sustainable yield, m a constant related to the form of the growth curve and K being the carrying capacity of the environment. The subscript tc indicates that the MSY value is related to a specific tc value, tc being the age of first catch. By involving MSY at this stage, the use of the growth function is indicated.

Assuming equilibrium conditions in the fishery, the short- term production function is assumed to follow:

$$h(E, X) = q.E.X \qquad (2)$$

Where h is the harvest, E is the effort employed in the fishery, X is the stock and q is the catchability coefficient (constant).

The equilibrium condition requires that:

$$f(x) = h(E, X), \qquad (3)$$

meaning that the annual surplus production in the stock is removed by harvest.

In the long term, however, the production function will be determined to a large extent by the environmental carrying capacity (K), (m) a constant, the sustainable yield at specific age of first capture (MSY_{tc}) as well as effort (E) and the catchability coefficient (q). Substituting equations (1) and (2) into (3), the long-term harvest equation is obtained:

$$h(E) = qKE\left[1 - \frac{qKE(m-1)m^{-\frac{m}{m-1}}}{MSY_{t_c}}\right]^{\frac{1}{m-1}} \qquad (4)$$

2.2 The economic part

Assuming that both the demand for harvested kapenta and supply of the combined labour and capital services constituting fishing effort are perfectly elastic, let us introduce prices and costs. Let p, a constant, and a, a constant, denote the price of harvested kapenta and the unit cost of fishing effort respectively.

The cost of fishing can then be obtained as follows:

$$TC(E) = a.E \qquad (5)$$

Where TC(E) is the total cost of fishing effort and a is the constant unit cost of fishing effort, including the opportunity cost of labour and capital.

And the revenue from fishing can be obtained as follows:

$$TR(E) = p.h(E) \qquad (6)$$

Where TR is the total revenue, E is fishing effort of fishing and p is the constant unit price of harvest, h(E) is the long-term production function in equation (4).

Having defined the cost and revenue functions of the fishery, resource rent from the fishery can then be obtained by:

$$\prod(E) = TR(E) - TC(E) \qquad (7)$$

Where $\prod$ is resource rent by subtracting total cost from total revenue.

CHAPTER 3

3.1 DATA

The model is based on the use of catch and effort data primarily. Hence the catch and effort data for the fishery since it started in 1974 is shown in table 3.1.1.

Table 3.1.1: Catch and effort data for the Kapenta Fishery, 1974-1999, catch in tonnes wet weight and effort in boat nights. (Songore et al, 2000)

Year	Zambia		Zimbabwe		Combined		
	Catch	Effort	Catch	Effort	Catch	Effort	CPUE
1974			488	616	488	616	0.79
1975			656	1298	656	1298	0.51
1976			1050	1833	1050	1833	0.57
1977			1172	3114	1172	3114	0.38
1978			2805	5973	2805	5973	0.47
1979			5732	15108	5732	15108	0.38
1980			7952	31747	7952	31747	0.25
1981			11137	37972	11137	37972	0.29
1982	4136	18874	8450	37776	12586	56650	0.22
1983	4965	16670	8548	38865	13513	55535	0.24
1984	5959	27832	10394	41234	16353	69066	0.24
1985	7422	30304	14586	41403	22008	71707	0.31
1986	8226	32163	15747	45790	23973	77953	0.31
1987	5858	31755	15823	52414	21681	84169	0.26
1988	6319	33218	18366	53403	24685	86621	0.28
1989	7758	34897	20112	54919	27870	89816	0.31
1990	6948	37413	21758	59193	28706	96606	0.30
1991	7284	39284	19306	62208	26590	101492	0.26
1992	7692	45004	18931	71066	26623	116070	0.23
1993	8526	46416	19957	68155	28483	114571	0.25
1994	7178	36402	19232	71249	26410	107651	0.25
1995	6736	44797	15280	75443	22016	120240	0.18
1996	5728	36033	15423	73524	21151	109557	0.19
1997	5927	37170	17034	75633	22961	112803	0.20
1998	7960	43965	15288	74770	23248	118735	0.20
1999	6766	46492	11208	64091	17974	110583	0.16

The commonly used measure of effort in the kapenta fishery is the number of rig nights. However, in order to be able to translate fishing effort into cost of effort the number of rigs in the fishery is used.

Table 3.1.2: Number of rigs in both countries for the years 1994- 1999 (Songore et al, 2000*)*

Year	Zambia	Zimbabwe
1994	175	363
1995	208	298
1996	230	306
1997	212	285
1998	222	292
1999	313	292

The two countries, however, have a wide difference in the number of fishing concerns on their shores. In 1999, for example, Zimbabwe had 73 companies operating with 292 rigs while Zambia had 56 companies operating with 331 rigs. There is evidence that Zambian and Zimbabwean rigs are not equivalent in terms of efficiency (Zambia/Zimbabwe SADC Fisheries Project (Lake Kariba), Project No. 50).

Table 3.1.3. Catches per rig (tonnes per year). (Source: Zambia/Zimbabwe SADC Fisheries Project (Lake Kariba), Project No. 50)

	1994	1995	1996
Zambia	44	39	40
Zimbabwe	64	52	55
Zim/Zam	1.45	1.33	1.38

As shown in the above table, it is assumed that Zimbabwean rigs are 40% more efficient than Zambian rigs.

Effort is measured in both Zimbabwean and Zambian rig equivalents, with Zimbabwean rig equivalents being obtained by dividing the number of rigs in Zambia by 1.4 and adding to the number of rigs in Zimbabwe. According to the Zambia/Zimbabwe SADC Fisheries Project (Lake Kariba), Project No. 50, the number of rigs in Zambia was 234, and 345 in Zimbabwe in 1994. It should be noted here, however, that these figures are different from those obtained by (Songore et al, 2000) for the countries, refer to table 3.2 above. Hence the total number of rigs was 234 +345x 1.4 = 717 (683 using data from Songore et al, 2000) in Zambian rig equivalents, and 345 + 234/ 1.4 = 512 (488 using data from Songore et al, 2000) Zimbabwean rig equivalents. It is important to note here, that these number of rigs will be used as the number of rigs for 1994 and the yield for that year was 26 410 tonnes. For the purposes of analysis 1994 will be used as the base year.

3.2 Price and costs information

The price and costs information was obtained from the Zambia/Zimbabwe SADC Fisheries Project (Lake Kariba), Project No. 50 and is shown in table 3.1.4 below.

Table 3.1.4: Price, costs, catch and effort information 1994 baseline figures (Zambia/Zimbabwe SADC Fisheries Project (Lake Kariba), Project No. 50).

Country	Zambia	Zimbabwe
Price per Kg of kapenta	ZK1 750	ZW$21
Cost per rig	ZK21Millionn	ZW$300 000
Catch (thousand tonnes)	26 410	26 410
Effort (rigs) adjusted for equivalence	717	512

3.3 Biological parameters

The values of the biological parameters were taken from the report and are as follows:

Table 3.1.5. Biological parameters for the Beverton and Holt model (Source: Zambia/Zimbabwe SADC Fisheries Project (Lake Kariba), Project No. 50).

k	W	M	R
0.95	$0.012L^{2.86}$	3.5	111

Where W is weight in grams, M is the annual rate of natural mortality, and R is the annual recruitment at age 0 in billions of individuals and k is the individual length growth rate. These values will be used in parameter estimation.

The age at first capture (t_c) that will be used is in months rather than years since Kapenta is a small fast growing species.

3.4 Parameter estimates

The following parameters will be used to run the model:

Maximum sustainable yield

This is calculated on the basis of the Beverton and Holt model, using the individual growth parameters of table 3.1.5.

Table 3.1.6. Maximum sustainable yields (thousand tonnes) at different ages of capture (t_c).

t_c	MSY_{tc}
0	1.38391
1	1.56252
2	1.72956
3	1.85701
4	1.94484
5	2.01426
6	2.10614
7	2.36136

Where t_c is the age at first capture. MSY_{tc} is the maximum sustainable yield at that age of first capture.

Stock size at equilibrium: is calculated using the following equation from (Eide,1989):

$$\frac{K}{Xmsy} = 2.914$$

where Xmsy is the stock size at MSY.

Calculating for m

m is calculated as follows using equation from(Eide,1989):

$$m = \left(\frac{K}{Xmsy} \right)^{m-1}$$

The value obtained is m= 0.872944

Calculating for r:

The parameter r is a model parameter of the Pella and Tomlinson model which is the ratio of the stock size at the time when the fishery first comes under observation to the maximum stock size.

$$r_{tc} = \frac{Xmsy}{MSYtc} \cdot \frac{m-1}{m}$$

Table 3.1.7. The values of r at different t_cs.

t_c	r
0	-1.1730
1	-1.0389
2	-0.9385
3	-0.8741
4	-0.8347
5	-0.8059
6	-0.7707
7	-0.6874

CHAPTER 4

4.0 Results

The simulations were done for both Zambian and Zimbabwean price and cost parameters, one at a time, as if the entire lake was fished by only one country. This will be used to discuss the magnitude and direction of change in terms of the total number of rigs for the two countries.

The 1994 figures of 26 410 tonnes, 717 rigs for Zambia and 512 rigs for Zimbabwe will be used as reference points for discussion. The ages of first capture to be used are 3, 4 and 5 months mainly because below that the kapenta will be too small to catch. Above 5 months a large fraction of kapenta will die from natural mortality hence it is better to catch them before. In the fishery the age of first capture is set at 4 months, but it is reasonable to say that 3 and 5 months old kapenta are also caught in the process.

Three reference points have been chosen; Maximum sustainable yield (MSY), maximum economic yield (MEY) and open access yield (OA). With the intention of predicting and analysing the yield, effort and resource rent for the kapenta fishery.

MSY at different ages of capture was obtained by multiplying the MSY_{tc} values in table 3.1.6 by 12 in order to get the yearly values. While MEY was read off from the simulation at the point at which the fishery obtains the maximum profits. And OA is read off the simulations at the point at which the fishery seizes to gain resource rent.

The maximum sustainable yield is the same for both countries. Due to different catch prices and costs of effort in the two countries, the maximum economic yield and open access conditions are different.

4.1 Results for Zambia

The results for Zambia were calculated based on the price and cost information contained in table 3.1.4.

Table 4.1.1. Results for Zambia, of the Pella and Tomlinson model simulation at t_c=3 with market price of kapenta and the cost of running a rig as the variable parameters (yield in tonnes, effort in rigs and resource rent in million Kwacha).

t_c=3 Zambia					
	Reference point	P= ZK1200	P= ZK1750	P= ZK2500	C=ZK34Million
Yield	MSY	22 280	22 280	22 280	22 280
	MEY	20 430	21 149	21 668	19 985
	OA	19 464	16 788	14 164	20 360
Effort	MSY	675	675	675	675
	MEY	425	475	525	400
	OA	1200	1425	1700	1050
Resource rent	MSY	12 565	24 820	41 699	16 045
	MEY	15 591	27 037	43 145	21 373
	OA	0	0	0	0

Table 4.1.2. Results of the simulation with the model at t_c=4 with market price of kapenta and the cost of running a rig as the variable parameters. (yield in tonnes, effort in rigs and resource rent in million Kwacha)

t_c=4 Zambia					
	Reference point	P= ZK1200	P= ZK1750	P= ZK2500	C=ZK34Million
Yield	MSY	23 336	23 336	23 336	23 336
	MEY	21 044	22 181	22 694	21 044
	OA	20 426	17 507	14 883	21 321
Effort	MSY	725	725	725	725
	MEY	425	500	550	425
	OA	1200	1500	1775	1100
Resource rent	MSY	12 778	25 613	43 115	16 188
	MEY	16 327	28 316	45 192	22 377
	OA	0	0	0	0

Table 4.1.3. Results of the simulation with the model at t_c=5.

t_c=5 Zambia					
	Reference point	P= ZK1200	P= ZK1750	P= ZK2500	C=ZK34Million
Yield	MSY	24 169	24 169	24 169	24 169
	MEY	21 972	23 057	23 549	21 504
	OA	21 320	18 167	15 308	21 990
Effort	MSY	750	750	750	750
	MEY	450	525	575	425
	OA	1225	1550	1850	1150
Resource rent	MSY	13 253	26 546	44 673	16 796
	MEY	16 916	29 325	46 797	23 182
	OA	0	0	0	0

4.2 Results for Zimbabwe

The results for Zimbabwe were calculated based on the price and cost information in table 3.1.4.

Table 4.2.1. Results for Zimbabwe, of the Pella and Tomlinson model simulation at t_c=3 with market price of kapenta and the cost of running a rig as the variable parameters (yield in tonnes, effort in rigs and resource rent in thousand dollars).

t_c=3 Zimbabwe					
	Reference point	P=ZW$15	P=ZW$21	P=ZW$26	C=ZW$400 000
Yield	MSY	22 280	22 280	22 280	22 280
	MEY	19 980	20 817	21 149	19 985
	OA	20 360	18 020	16 542	20 144
Effort	MSY	675	675	675	675
	MEY	400	450	475	400
	OA	1050	1300	1450	1075
Resource rent	MSY	132	265	377	198
	MEY	180	302	407	260
	OA	0	0	0	0

Table 4.2.2. Results of the simulation with the model at t_c=4 with market price of kapenta and the cost of running a rig as the variable parameters (yield in tonnes, effort in rigs and resource rent in thousand dollars).

t_c=4 Zimbabwe					
	Reference point	P=ZW$15	P=ZW$21	P=ZW$26	C=ZW$400 000
Yield	MSY	23 336	23 336	23 336	23 336
	MEY	20 550	21 854	22 181	21 044
	OA	21 321	18 985	17 262	21 105
Effort	MSY	725	725	725	725
	MEY	400	475	500	425
	OA	1100	1350	1525	1125
Resource rent	MSY	133	273	389	200
	MEY	188	316	427	273
	OA	0	0	0	0

Table 4.2.3. Results of the simulation with the model at t_c=5.

t_c=5 Zimbabwe					
	Reference point	P=ZW$15	P=ZW$21	P=ZW$26	C=ZW$400 000
Yield	MSY	24 169	24 169	24 169	24 169
	MEY	21 504	22 745	23 057	21 505
	OA	22 203	19645	17 921	21 771
Effort	MSY	750	750	750	750
	MEY	425	500	525	425
	OA	1125	1400	1575	1175
Resource rent	MSY	138	287	403	208
	MEY	195	328	442	282
	OA	0	0	0	0

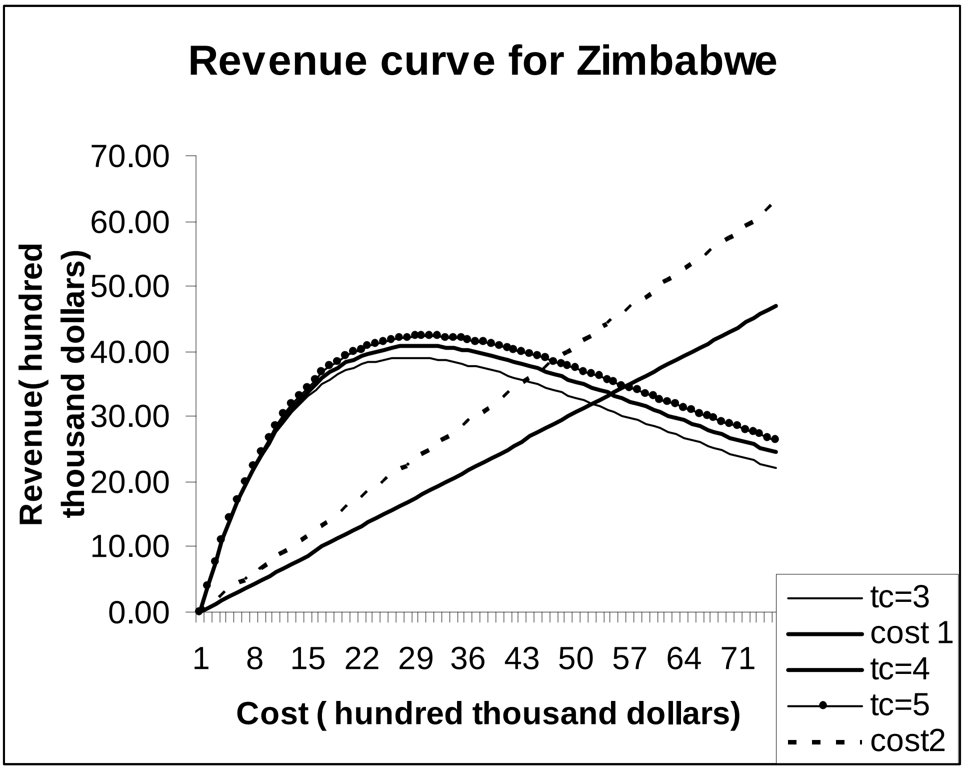

Figure 4.2. Revenue curves for t_cs 3-5 showing open access at each level of intersection with the cost curves (cost 1= $300 000 and cost2= $400 000).

CHAPTER 5

5.0 DISCUSSION AND CONCLUSION

5.1 Discussion and Analysis of results

According to the catch and effort statistics (Table 3.1.1), the fishery shows a general increase in both catch and effort over the years for both Zambia and Zimbabwe. The fishery, however, experienced some slight decreases in some years but these coincided with the drought years. The drought affects kapenta production since the main nutrients for kapenta are a result of the river flows.

For Zambia, while effort in terms of boat nights could be seen to have slight decreases due to the drought factor, capital investment in rigs shows steady increases for the period 1994-1999 (Table 3.1.2). Contrary to the Zambian case, the number of rigs for Zimbabwe has been decreasing since 1994 (Table 3.1.2).

Kapenta as a fast growing, short-lived species, is probably difficult to put into cohorts, but all the same it is important to determine the age at which to start fishing it (t_c), for sustainability, food production maximisation as well as resource rent maximisation. As pointed out in the introduction, biological sustainability, however, does not seem to present much of a challenge since commercially valuable kapenta are those that would have reached spawning maturity hence the choice of the model. Catches are also seasonal. During summer (September to March) the sardines move inshore to protected waters to breed and the open water population is depleted. Commercial catches rise again after March as adults return to open waters.

When thinking in terms of maximising food production, it would be wise to set the t_c at that stage at which not too many kapenta have died from natural mortality and also not before they reach maturity. Higher tcs, that is, from 6 months onwards might seem desirable on the onset, due to higher biomasses of kapenta. However, these levels are not viable when considering capital investments. You would have to have the rigs lying idly for most part of the year and in the process losing some kapenta to natural mortality. And also according to the tables, the cost of effort in this case seems to be higher. They might be need to change mesh sizes and the like in terms of gear. Hence the tcs here have been set from 3months to 5months, with 4months as the focal point.

The results of the simulation with the model indicate both catch and effort values that are less than the 1994 levels except for the open access number of rigs. This could imply that there is potential for increasing kapenta yields. Or that 1994 was a good flood year hence there was a lot of nutrients for kapenta production. This could be evidenced in table 3.1.1 where catch levels fluctuate from year to year, showing a downward trend from 1994 to 1999, towards the levels predicted by the model.

It is interesting to note that the model predicts catch values of MSY, MEY, and OA, which are not very different from each other. The first (MSY close to MEY) could indicate that fishing costs are not very high for this fishery. However, the OA catch levels although close to both MSY, they are highly uneconomic, as they are sustained by three times the fishing effort at all levels zero resource rent.

Close as it might be to MSY in catch terms, MEY still presents resource rent for the fishery at all price and cost levels. Thus, the government can earn revenue through regulation such as licence fees, since the fishery is not very sensitive to cost increases. Even in terms of yield, they could still produce more under increased costs since the current effort is below the level of maximum sustainable yield effort. However, this could be to offset the cost effect and if not checked could lead to serious problems in the fishery, such as reduced fishing seasons as pressure on the kapenta out runs its recovery rate. In the long term it could have negative impact on the investment when capital investments run idle for some periods and also the social and economic well being of the workers both in the fishery and related activities are out of work.

On the overall, kapenta presents a lot of potential in terms of resource rent for the fishery. Biological over fishing is not a threat, assuming ecological stability and the constant regenerative capacity of kapenta. However, it is difficult to put down the projected resource rent due to the inadequacy of the economic data. But it is suffice enough that the model predicts that resource rent is being realised and there is potential for increasing it. On the Zimbabwe side this is evidenced by the developments along the lake. The kapenta fishing companies have managed to diversify into a number of related businesses over the years. Some have gone into the construction of fish boats and houseboats. While others have gone into tourism, building lodges and the like. The cooperatives that also venture in this fishery have also their profitability by diversifying into commercial farming and large-scale retailing. Some have also been able to build houses for their members.

The government has however, not been very effect in terms of collecting revenue from this fishery. Licence fees although implemented from the time the fishery begun have been very minimal or negligible. Taxation was always under reported. Hence the government or local authority has not been able to do much with rent from the fishery.

While for Zambia it is very difficult to ascertain what they have been able to do with their resource rent. Not much if any developments on their lakeshore can be attributed to Kapenta. In fact the Zambia lakeshore is under developed in comparison to the Zimbabwean one. The resource rent could have been invested elsewhere. It has been said that Zambian catch efficiency is very low in comparison due to underutilised capacity. The Zambians catch for less time than their Zimbabwean counterparts. They also do not invest in technology; most of their boats have no fish finding devices. And some have also resorted to leasing their boats and permits to Zimbabweans. While others prefer illegal trading, when they go at night to buy kapenta from the workers on Zimbabwean rigs, resulting in one of the major problems of underreporting of catches.

As such it can be seen that suppose the fishery becomes open access, it would be very difficult for both countries to breakeven at the same time. Zimbabwe would definitely maintain an upper hand in the fishery for a long-time. Hence the Zambia/Zimbabwe SADC Fisheries Project (Lake Kariba), where the two countries are working towards a unified common management strategy. To date the cooperation has seen a lot of research and documentation being carried out which is a big step towards management planning and implementation.

5.2 Conclusion

The results of the model have shown that the viability of the kapenta industry is more dependent on economic parameters rather than biological parameters. The fishery remains profitable even in the case of relatively large changes in price and cost parameters. There is need for more complete data in order to understand this fishery well, in particular the estimation of costs need to be improved. The fact that data are not readily available or companies are not willing to divulge such information might indicate that they do not want other entrants into the fishery. They also try to keep it closed so that government does not get enough information to effectuate any regulatory system that could erode their profits. This could explain a very interesting phenomenon of why the Cahora Bassa kapenta from Mozambique is cheaper than the Kariba kapenta, while it is the same companies from Kariba going down to fish in Cahora Bassa and bringing it back up for sale in Zambia/Zimbabwe. As such there is need for both countries to implement a more comprehensive and workable data collection system, which provides accurate and reliable data.

According to the model and the empirical data, neither biological nor economic over-fishing is prevalent in the kapenta fishery yet. Biologically it could be because of the resilience of kapenta, which could be perpetual assuming equilibrium conditions in the environment. After all it only took a bucketful of this fish to fill Lake Kariba. On the other hand, however, due to insufficient data it is difficult to be conclusive about economical over fishing, but judging from the current and past performance trends there is no threat of economic over fishing yet.

Resource rent is close to being maximised in this fishery and open access is not yet a threat. Theoretically, the model predicts resource rent at MSY of ZK26Million and at MEY of ZK28Million for Zambia at 4 months age of first capture. For Zimbabwe it predicts MSY resource rent of ZW$273 000 and at MEY of ZW$316 000. In both cases it is shown that resource rent is more than 100% of the cost of fishing effort. Which leaves the biggest mystery of the fishery's profitability under reduced prices as well as under increased costs? Are the costs in this fishery that much low, is the market price justified, who is exploiting who? It goes without saying; there is obvious and urgent need for further research and study of this fishery. There is substantial resource rent that could be gained by the governments in both countries that could be used to benefit both the industry and the society.

It should not be forgotten, however, that Lake Kariba, like most other small or medium sized lakes in Africa, is not a stable system. Karange and Kolding (1995b) showed that the environment, in terms of the changing hydrological regime, seemed to explain a large proportion of the variability in catch rates (CPUE). They concluded that Lake Kariba was an allotropic riverine lake where productivity was largely driven by the nutrient pulses carried by the annual floods. On the other hand, in highly variable systems such as allotropic lakes, susceptibility to increased fishing effort is thought to be low, resilience is high and recovery potential is rapid. Kapenta has after all, outlived the deprivations of drought and has endured being sucked through Kariba's churning turbines and spewed out into the stilling pool below. From there they have survived 220km of waters infested with predators and devoid of plankton, to establish new shoals in Mozambique's Lake Cahora Bassa, which presents yet another challenge. In essence management must be robust in order to take advantage of the good years to offset the bad years.

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APPENDICES

Appendix 1

ILLUSTRATIONS OF THE PELLA AND TOMLINSON MODEL SIMULATION USING NUMERICAL EXAMPLES

Part 1: Zambia

Catch value and costs in million Zambian Kwacha

Price: 1750ZK, cost per rig: 21mZK

Catch per rig proportional to fishing mortality. (Except for effort all other values are monthly values, thus must be multiplied by 12 to get the yearly values).

z4	0.678486
z5	0.702702
ptm	0.872944
ptr	-1.76585
ptK	32.4976
q	0.000244

Z0	0.482796
Z1	0.545106
Z2	0.603381
Z3	0.647845
Z4	0.678486
Z5	0.702702
Z6	0.734757
Z7	0.823793

Part 1a:

Age at first capture at 4 months.

		tc=4			
Increase	Effort	Catch	Revenue	Cost	Profit
25	0	0	0.00	0.00	0.00
	25	0.190528	1428.96	43.75	1385.21
	50	0.366195	2746.46	87.50	2658.96
	75	0.527975	3959.81	131.25	3828.56

100	0.676781	5075.86	175.00	4900.86
125	0.813467	6101.00	218.75	5882.25
150	0.938829	7041.22	262.50	6778.72
175	1.053616	7902.12	306.25	7595.87
200	1.158527	8688.95	350.00	8338.95
225	1.254216	9406.62	393.75	9012.87
250	1.341296	10059.72	437.50	9622.22
275	1.42034	10652.55	481.25	10171.30
300	1.491885	11189.13	525.00	10664.13
325	1.556433	11673.25	568.75	11104.50
350	1.614457	12108.43	612.50	11495.93
375	1.666396	12497.97	656.25	11841.72
400	1.712663	12844.97	700.00	12144.97
425	1.753645	13152.33	743.75	12408.58
450	1.789703	13422.77	787.50	12635.27
475	1.821178	13658.84	831.25	12827.59
500	1.848387	13862.90	875.00	12987.90
525	1.871626	14037.20	918.75	13118.45
550	1.891176	14183.82	962.50	13221.32
575	1.907296	14304.72	1006.25	13298.47
600	1.920232	14401.74	1050.00	13351.74
625	1.930212	14476.59	1093.75	13382.84
650	1.937451	14530.88	1137.50	13393.38
675	1.942149	14566.12	1181.25	13384.87
700	1.944495	14583.71	1225.00	13358.71
725	1.944664	14584.98	1268.75	13316.23
750	1.942822	14571.16	1312.50	13258.66
775	1.939123	14543.42	1356.25	13187.17
800	1.933711	14502.84	1400.00	13102.84
825	1.926723	14450.42	1443.75	13006.67
850	1.918283	14387.13	1487.50	12899.63
875	1.908512	14313.84	1531.25	12782.59
900	1.897519	14231.40	1575.00	12656.40
925	1.885409	14140.57	1618.75	12521.82
950	1.872279	14042.09	1662.50	12379.59
975	1.858218	13936.64	1706.25	12230.39
1000	1.843313	13824.84	1750.00	12074.84
1025	1.827641	13707.31	1793.75	11913.56
1050	1.811278	13584.59	1837.50	11747.09
1075	1.794293	13457.20	1881.25	11575.95

1100	1.776749	13325.62	1925.00	11400.62
1125	1.758708	13190.31	1968.75	11221.56
1150	1.740226	13051.69	2012.50	11039.19
1175	1.721354	12910.16	2056.25	10853.91
1200	1.702143	12766.07	2100.00	10666.07
1225	1.682637	12619.78	2143.75	10476.03
1250	1.66288	12471.60	2187.50	10284.10
1275	1.64291	12321.83	2231.25	10090.58
1300	1.622765	12170.74	2275.00	9895.74
1325	1.602478	12018.59	2318.75	9699.84
1350	1.582082	11865.62	2362.50	9503.12
1375	1.561606	11712.05	2406.25	9305.80
1400	1.541078	11558.08	2450.00	9108.08
1425	1.520522	11403.92	2493.75	8910.17
1450	1.499963	11249.72	2537.50	8712.22
1475	1.479422	11095.66	2581.25	8514.41

Part 1b:

Same as above but starting fishing at the age of 5 months.

		tc=5			
Increase	Effort	Catch	Revenue	Cost	Profit
25	0	0	0	0	0
	25	0.19079	1430.926	43.75	1387.176
	50	0.367198	2753.984	87.5	2666.484
	75	0.530135	3976.015	131.25	3844.765
	100	0.680458	5103.432	175	4928.432
	125	0.818967	6142.249	218.75	5923.499
	150	0.946414	7098.106	262.5	6835.606
	175	1.063506	7976.293	306.25	7670.043
	200	1.170903	8781.771	350	8431.771
	225	1.269226	9519.195	393.75	9125.445
	250	1.359058	10192.93	437.5	9755.431
	275	1.440944	10807.08	481.25	10325.83
	300	1.515397	11365.48	525	10840.48
	325	1.582899	11871.74	568.75	11302.99

350	1.6439	12329.25	612.5	11716.75
375	1.698825	12741.19	656.25	12084.94
400	1.74807	13110.53	700	12410.53
425	1.792011	13440.08	743.75	12696.33
450	1.830995	13732.46	787.5	12944.96
475	1.865354	13990.15	831.25	13158.9
500	1.895394	14215.46	875	13340.46
525	1.921407	14410.55	918.75	13491.8
550	1.943664	14577.48	962.5	13614.98
575	1.96242	14718.15	1006.25	13711.9
600	1.977916	14834.37	1050	13784.37
625	1.990376	14927.82	1093.75	13834.07
650	2.000012	15000.09	1137.5	13862.59
675	2.007022	15052.66	1181.25	13871.41
700	2.011592	15086.94	1225	13861.94
725	2.013897	15104.23	1268.75	13835.48
750	2.0141	15105.75	1312.5	13793.25
775	2.012357	15092.68	1356.25	13736.43
800	2.008811	15066.08	1400	13666.08
825	2.003597	15026.98	1443.75	13583.23
850	1.996843	14976.32	1487.5	13488.82
875	1.988668	14915.01	1531.25	13383.76
900	1.979184	14843.88	1575	13268.88
925	1.968496	14763.72	1618.75	13144.97
950	1.956702	14675.26	1662.5	13012.76
975	1.943894	14579.2	1706.25	12872.95
1000	1.930159	14476.19	1750	12726.19
1025	1.915578	14366.83	1793.75	12573.08
1050	1.900226	14251.7	1837.5	12414.2
1075	1.884175	14131.32	1881.25	12250.07
1100	1.867492	14006.19	1925	12081.19
1125	1.850238	13876.79	1968.75	11908.04
1150	1.832472	13743.54	2012.5	11731.04
1175	1.814249	13606.87	2056.25	11550.62
1200	1.795619	13467.15	2100	11367.15
1225	1.776631	13324.73	2143.75	11180.98
1250	1.757328	13179.96	2187.5	10992.46
1275	1.737753	13033.15	2231.25	10801.9
1300	1.717945	12884.58	2275	10609.58
1325	1.697939	12734.54	2318.75	10415.79

1350	1.677769	12583.27	2362.5	10220.77
1375	1.657467	12431.01	2406.25	10024.76
1400	1.637063	12277.97	2450	9827.974
1425	1.616584	12124.38	2493.75	9630.627
1450	1.596054	11970.41	2537.5	9432.908
1475	1.575499	11816.24	2581.25	9234.991

Part 2: Zimbabwe

Catch value and cost in thousand Zimbabwe Dollars.

Price per Kg of kapenta = $21; cost per rig = $300 000

Part 2a: The age at first capture is 4 months.

Increase	Effort	Catch	Revenue	Cost	Profit
25	0	0	0.00	0.00	0.00
	25	0.190528	4.00	0.63	3.38
	50	0.366195	7.69	1.25	6.44
	75	0.527975	11.09	1.88	9.21
	100	0.676781	14.21	2.50	11.71
	125	0.813467	17.08	3.13	13.96
	150	0.938829	19.72	3.75	15.97
	175	1.053616	22.13	4.38	17.75
	200	1.158527	24.33	5.00	19.33
	225	1.254216	26.34	5.63	20.71
	250	1.341296	28.17	6.25	21.92
	275	1.42034	29.83	6.88	22.95
	300	1.491885	31.33	7.50	23.83
	325	1.556433	32.69	8.13	24.56
	350	1.614457	33.90	8.75	25.15
	375	1.666396	34.99	9.38	25.62
	400	1.712663	35.97	10.00	25.97
	425	1.753645	36.83	10.63	26.20
	450	1.789703	37.58	11.25	26.33
	475	1.821178	38.24	11.88	26.37

500	1.848387	38.82	12.50	26.32
525	1.871626	39.30	13.13	26.18
550	1.891176	39.71	13.75	25.96
575	1.907296	40.05	14.38	25.68
600	1.920232	40.32	15.00	25.32
625	1.930212	40.53	15.63	24.91
650	1.937451	40.69	16.25	24.44
675	1.942149	40.79	16.88	23.91
700	1.944495	40.83	17.50	23.33
725	1.944664	40.84	18.13	22.71
750	1.942822	40.80	18.75	22.05
775	1.939123	40.72	19.38	21.35
800	1.933711	40.61	20.00	20.61
825	1.926723	40.46	20.63	19.84
850	1.918283	40.28	21.25	19.03
875	1.908512	40.08	21.88	18.20
900	1.897519	39.85	22.50	17.35
925	1.885409	39.59	23.13	16.47
950	1.872279	39.32	23.75	15.57
975	1.858218	39.02	24.38	14.65
1000	1.843313	38.71	25.00	13.71
1025	1.827641	38.38	25.63	12.76
1050	1.811278	38.04	26.25	11.79
1075	1.794293	37.68	26.88	10.81
1100	1.776749	37.31	27.50	9.81
1125	1.758708	36.93	28.13	8.81
1150	1.740226	36.54	28.75	7.79
1175	1.721354	36.15	29.38	6.77
1200	1.702143	35.75	30.00	5.75
1225	1.682637	35.34	30.63	4.71
1250	1.66288	34.92	31.25	3.67
1275	1.64291	34.50	31.88	2.63
1300	1.622765	34.08	32.50	1.58
1325	1.602478	33.65	33.13	0.53
1350	1.582082	33.22	33.75	-0.53
1375	1.561606	32.79	34.38	-1.58
1400	1.541078	32.36	35.00	-2.64
1425	1.520522	31.93	35.63	-3.69
1450	1.499963	31.50	36.25	-4.75
1475	1.479422	31.07	36.88	-5.81

Part 2b: Age at first capture is set at 5 months.

		tc=5			
Increase	Effort	Catch	Revenue	Cost	Profit
25	0	0	0	0	0
	25	0.19	4.01	0.63	3.38
	50	0.37	7.71	1.25	6.46
	75	0.53	11.13	1.88	9.26
	100	0.68	14.29	2.50	11.79
	125	0.82	17.20	3.13	14.07
	150	0.95	19.87	3.75	16.12
	175	1.06	22.33	4.38	17.96
	200	1.17	24.59	5.00	19.59
	225	1.27	26.65	5.63	21.03
	250	1.36	28.54	6.25	22.29
	275	1.44	30.26	6.88	23.38
	300	1.52	31.82	7.50	24.32
	325	1.58	33.24	8.13	25.12
	350	1.64	34.52	8.75	25.77
	375	1.70	35.68	9.38	26.30
	400	1.75	36.71	10.00	26.71
	425	1.79	37.63	10.63	27.01
	450	1.83	38.45	11.25	27.20
	475	1.87	39.17	11.88	27.30
	500	1.90	39.80	12.50	27.30
	525	1.92	40.35	13.13	27.22
	550	1.94	40.82	13.75	27.07
	575	1.96	41.21	14.38	26.84
	600	1.98	41.54	15.00	26.54
	625	1.99	41.80	15.63	26.17
	650	2.00	42.00	16.25	25.75
	675	2.01	42.15	16.88	25.27
	700	2.01	42.24	17.50	24.74
	725	2.01	42.29	18.13	24.17
	750	2.01	42.30	18.75	23.55
	775	2.01	42.26	19.38	22.88
	800	2.01	42.19	20.00	22.19
	825	2.00	42.08	20.63	21.45

850	2.00	41.93	21.25	20.68
875	1.99	41.76	21.88	19.89
900	1.98	41.56	22.50	19.06
925	1.97	41.34	23.13	18.21
950	1.96	41.09	23.75	17.34
975	1.94	40.82	24.38	16.45
1000	1.93	40.53	25.00	15.53
1025	1.92	40.23	25.63	14.60
1050	1.90	39.90	26.25	13.65
1075	1.88	39.57	26.88	12.69
1100	1.87	39.22	27.50	11.72
1125	1.85	38.86	28.13	10.73
1150	1.83	38.48	28.75	9.73
1175	1.81	38.10	29.38	8.72
1200	1.80	37.71	30.00	7.71
1225	1.78	37.31	30.63	6.68
1250	1.76	36.90	31.25	5.65
1275	1.74	36.49	31.88	4.62
1300	1.72	36.08	32.50	3.58
1325	1.70	35.66	33.13	2.53
1350	1.68	35.23	33.75	1.48
1375	1.66	34.81	34.38	0.43
1400	1.64	34.38	35.00	-0.62
1425	1.62	33.95	35.63	-1.68
1450	1.60	33.52	36.25	-2.73
1475	1.58	33.09	36.88	-3.79