IDAF/Technical Report/97/I

INTEGRATED DEVELOPMENT OF ARTISANAL FISHERIES (IDAF)
(GHA/93/008)

CATCH AND FISH STOCK ASSESSMENT IN STRATUM VII OF LAKE VOLTA

By

G.J. DE GRAAF and P.K. OFORI -DANSON

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS
ROME, 1997

PREFACE

This report presents the results of a fisheries monitoring programme executed from March 1995 till December 1996 in Stratum VII of Lake Volta (Ghana) by the project, Integrated Development of Artisanal Fisheries (IDAF) under the aegis of FAO/UNDP. The major goals were to determine the total catch of Stratum VII , to gain insight into the present status of the exploited fish stocks in Stratum VII and to develop an appropriate method which can be used for the whole of Lake Volta.

A full frame survey was carried out; a traditional Catch and Effort monitoring programme established and Fish Stocks Assessment done with a length-based monitoring programme. Considering that several aspects of the different monitoring programmes were quite new for Ghana and that some professionals concerned may not be familiar with the different methods, the results in this report are not presented as a complete technical/scientific report. Background information is provided whenever needed and advantages/disadvantages of the different methods are discussed. However, analysis of fisheries related data cannot exclude statistics and this could not be avoided. No background information is given for the different statistical analyses used, but where possible the results are discussed in a non-scientific way to provide indication of how fisheries data can be analysed.

No final conclusions are drawn from the obtained results on the status of the stocks and possible management options as only Stratum VII of Lake Volta was covered. The main purpose of this report is to provide information on the different methods which could be used for the whole of Lake Volta.

Yeji, Ghana, February, 1997

G.J. de Graaf
(NEFISCO FOUNDATION, Amsterdam, the Netherlands)
deGraaf@nefisco.org
www.nefisco.org
www.netfish.org

P.K. Ofori-Danson
ofdan@yahoo.com
Water Research Institute,
C.S.I.R,
P.O.Box 38,
ACHIMOTA, GHANA

TABLE OF CONTENTS

i SUMMARY

In 1995/1996 IDAF carried out a fisheries monitoring programme in stratum VII of Lake Volta. The programme encompassed a full frame survey, a catch and effort monitoring programme and a length-based stock-assessment programme.

This report summarises[1] the results of the frame survey and presents the results of the catch and effort monitoring programme and the stock-assessment.

The frame survey indicated that at present 288 villages are located in stratum VII, with 8068 canoes, 358 winchboats, with a total population of 100,000 and 40,000 fishermen. In comparison with the socio-economic survey of 1992 the number of canoes had increased 23% from 6,500 to 8,068, the number of fishermen increased by 122% from 18,000 to 40,000 while the number of winchboats slightly declined from 380 to 358**.**

Analysis of catch data clearly indicated differences in catches on basis of the geographical zonation, with the highest catches in the South and the lowest catches in the Central part of stratum VII. Therefore it was decided not to stratify for "Large, Medium or Small" fishing villages as was done in earlier monitoring programmes but to use the geographical location of the landing sites as stratification criteria.

The total catch of stratum VII of Lake Volta was estimated with and without stratification and the results are presented below;

.

	Non stratified (t/year)	*Stratified (t/year)*
Average gillnets	22422	27843
Max. gillnets	26065	34056
Min gillnets	18779	20988
Average winch	5559	6005
Max. winch	7054	6511
Min winch	4064	5745
Average all	**27981**	**33848**
Max. all	33119	40567
Min all	22843	26743

Stratum VII of Volta produced between 28.000 and 33,800 tonnes in 1996 depending on the method used for the estimation. Due to the impact of the lower catches in the Central area it was concluded that stratification is indeed necessary and **33,800 tonnes is the total catch estimate for Stratum VII of Lake Volta for 1996**.

[1] The full results of the frame survey were presented in a separate report; de Graaf, G.J. and Ofori-Danson, P.K., 1996, Results of a full frame survey in stratum VII of Lake Volta, FI:DP/GHA/93/008, Field document, FAO, Rome, 1996.

It is certain that the previously used production estimate of 44,000 t/year for the whole of Lake Volta is an under-estimation, as the actual total catch of Stratum VII is already 33.800 t/year**.**

The total production of Lake Volta most likely will be around 150,000 - 200,000 t/year (180-240 kg/ha) with a total annual value of 30 million USD This is a substantial quantity, if compared with the annual marine catches of 300,000-400,000 t/year, and it justifies that serious action be taken in order to protect the productivity of this natural resource**.**

Surplus production models such as Schaefer or Fox can only be used for the determination of the maximum sustainable yield and maximum fishing effort **if the frame survey is updated regular intervals.**

There is a distinct difference in species composition of the gillnets in the North or the South . In the North a large part of the catch consists of *O. niloticus, L. coubie* and *S. galileus*. While in the South the two tilapia species are almost absent and the bulk of the catch consists of *C. auratus, C. nigrodigitatus* and *H. membraceus*. This difference stresses the importance of stratification in North, Central and South.

The catch assessment survey and the market survey indicated that *Tilapia spp, Chrysichthys spp.* and *Hemisynodontis/Synodontis spp.* are the major species. There are however large differences between the two estimates. In the market survey the three mentioned species represent 79%, while in the catch assessment survey they represent only 43%. In the market survey *Tilapia spp*. are the most important, while *"Other species"* are the most important in the catch assessment survey. The differences are most likely caused by:

- the catch assessment survey covering mainly gillnets and winchboats. Traps and nifa nifa are not covered. The latter gears are however very site specific and are mainly catching *Tilapia spp.* It indicates that in the catch assessment survey more stratification types have to be used.

- *Tilapia spp* being the highest priced species and most likely sold, while the less valuable species are used for home consumption. A small survey could verify this phenomenon.

It seems that there is a relation between the water level and the fish catch. Therefore it could be concluded that the decline of the CPUE is caused by an increased number of canoes and a reduced waterlevel. A multi linear regression analysis of both factors on the CPUE indicated that both partial coefficients are significant ($P < 0.05$) and the relation can be described as;

$$CPUE = -0.00275 * No.\ of\ canoes + 0{,}0958 * Waterlevel + 10{,}0327$$

This analysis stresses again the importance of long-term data-series because the picture could become more clear if we have observations during a period of high water-levels**.**

Differences in the major factors influencing the CPUE-canoe in the three geographical sub-strata are analysed again using ANOVA and the results are presented in the table below.

Mean values of the average mesh size, the number of bundles, the number of days the gears are set and the number of assistants per canoe in the northern, central and southern area of Stratum VII of Lake Volta. (different superscripts indicate significant difference).

Stratum	*Mesh size*	*No of bundles*	*Days set*	*No. of assistants*
North	$2.14^{a}\pm0.05$	$1.56^{a}\pm0.05$	$1.03^{a}\pm0.03$	$2.02^{a}\pm0.04$
Central	$2.71^{b}\pm0.05$	$1.91^{b}\pm0.04$	$1.34^{b}\pm0.02$	$1.79^{c}\pm0.03$
South	$2.60^{b}\pm0.07$	$1.62^{b}\pm0.08$	$1.73^{c}\pm0.52$	$2.52^{c}\pm0.06$

Significant differences are found for the different areas of Stratum VII but they can not yet directly explain the difference in catches and it is recommended to carry out an in-depth analysis in the near future (World Bank project).

A length-based stock-assessment programme can be applied in Lake Volta. The results of such a programme in stratum VII provided important information on the stocks. A length-based programme can provide the needed information on the status of the stocks within a short time period, in comparison with the long time-series needed for the traditional surplus-production models. It is therefore strongly recommended to carry out a length-based programme in the whole of Lake Volta.

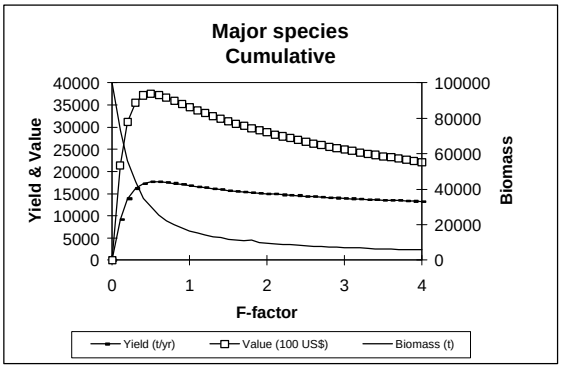
The quality of the results of length-based models depends on the obtained data-set (the length frequencies). Small sample sizes, as sometimes was the case in the programme executed in Stratum VII, seriously hampers the analysis and reduces the reliability of the results. A length-based programme for the whole of Lake Volta is a major exercise and will only provide reliable results if it is well supported, scientifically and financially.

From a scientific point of view it is difficult to draw conclusions on the present status of the stocks in stratum VII of Lake Volta because; sample sizes were low; it was assumed that there was one unit of stock; growth parameters were not validated by ageing, otolith readings, etc. **However, if the data are reliable, the results indicate that the stocks are seriously over-exploited, therefore the preliminary analysis presented in this report should warn all policy makers involved**.

Parameters as estimated for the major species by the length-based stock-assessment programme are summarised below.

Species	***Growth parameters***			***Gillnets***						***Winch***					
				Rel Y/R		Y/R		T&B		Rel Y/R		Y/R		T & B	
	$L\infty$	K	φ	$E_{present}$	E_{max}	$F_{present}$	F_{max}	$F_{factor\ yield}$	$F_{factor\ value}$	$E_{present}$	E_{max}	$F_{present}$	F_{max}	$F_{factor\ yield}$	$F_{factor\ value}$
H. membraceus	44.0	0.55	3.02	0.72	0.62	2.82	2.0	1.1	0.6	0.72	0.52	2.91	2.0	0.5	0.2
C. auratus	31.0	0.60	2.76	0.61	0.54	2.00	1.5	1.6	1.0	0.68	0.59	2.74	1.6	1.1	0.6
C. nigrodigitatus	44.5	0.65	3.12	0.70	0.48	2.81	1.0	0.4	0.3	0.64	0.45	2.22	1.3	0.8	0.6
S. intermedius	30.0	0.80	2.85	0.65	0.57	2.90	1.4	2.0	1.7	0.51	0.57	1.64	2.0	1.4	1.1
L. coubie	75.0	0.70	3.50	0.52	0.41	1.21	0.8	0.3	0.2	0.77	0.46	3.87	1.0	0.4	0.4
O. niloticus	33.5	0.55	2.59	0.30	0.47	0.38	1.2	3.1	1.7						
S. galileus	32.5	0.25	2.42	0.60	0.46	1.11	0.9	0.4	0.2						

Cumulative Thompson and Bell analysis for the major species in stratum VII of lake Volta.



At the present fishing effort (F_{factor}=1) the annual cumulative catch (for the major species) is estimated 16,816 tonnes with a value of 3.440.000 USD/yr.
The optimal fishing effort considering yield is F_{factor}=0.6 (Yield=17,500 t/yr). The optimal economic fishing effort is F_{factor}=0.5 (Value=3.750.000 USD/yr). The optimal fishing effort considering the biomass is F_{factor} =0.3

1. INTRODUCTION

Lake Volta was formed as a result of the closure of the Akosombo dam in 1964. The created lake has a surface area of about 8,400 km^2 or 3.6% of the surface area of the country, a shoreline length of 4,800 km, a maximum depth of 70 m and a mean depth of 19 m. Trees were not removed before the creation of the basin and the existing tree stumps have a considerable impact on fisheries and navigation on the lake. It was early realized that the building of the dam would have major effects apart from power production. These effects were primarily the effects on public health, transportation and the development of a new fisheries.

Since the creation of Lake Volta several fisheries programmes/projects have been executed and a summary their activities is presented below.

1.1 Previous fisheries projects executed in Lake Volta

1964-1968; The Ghana Institute of Aquatic Biology and the Volta Basin Research Project of the University of Ghana executed basic studies on fish biology and limnological aspects during the formation of the lake. The shift of the fish community from a system dominated by "riverine" towards a composition which is dominated by the more "lacustrine" species and the changes in the limnology of the system were well monitored and documented by those projects. Within the same period research work on the used fishing gears was carried out by the Department of Fisheries.

1968-1971 The Volta Lake Research Project Phase I. This UNDP financed project was executed by FAO with the Volta River Authority as government co-operating agency. During this project an effort was made to monitor fisheries more thoroughly. A complete frame survey was carried out in order to determine the number of canoes and fishermen operating on the Lake (12,000 canoes and 18,300 active fishermen). A preliminary catch assessment programme was initiated which was set up with a stratified sampling technique, Fish marketing was followed at three recording centres along the lake (Yeji, Kpandu Tokor and Kete Krachi) biological parameter such as feeding habits, reproduction and growth were determined and an experimental fish stock-assessment programme was initiated.

1971-1977 The Volta Lake Research Project Phase II. (UNDP/FAO/VRA). The second phase of the Volta Lake Research Project aimed at the strengthening of research on fisheries, hydrobiology, public health and the resettlement of the people displaced by the Volta Lake. The earlier projects were carried out during the period the lake was formed and during which several changes in hydrobiology and fisheries and fish

stocks took place. In 1970 the lake system became more or less stable and the data obtained in that year could be considered as a baseline of the lake.

The project carried a complete new frame survey in 1975 which indicated that 13,800 canoes were operated by 20,600 active fishermen, or the fishing effort had increased with approximately 12% since the previous survey in 1970. The project strengthened the catch assessment survey, the whole lake was divided into eight strata, and within each of these strata ten villages were visited every three month. During three consecutive days the fishermen were interviewed and the catch weighed. Averages of these selected villages were used to obtain quarterly estimates of the catch for each strata, and these were added up to give the total of the whole lake. Annual estimates were calculated by adding up the quarterly estimates. In a later stage of the project it was decided to reduce the number of sample villages to 4 per stratum. The survey was continuously carried out from 1969 till 1977 and the yearly total catch estimates are presented below:

Year	Estimated total catch (t)
1969	61,700
1970	39,200
1971	39,000
1972	36,000
1973	35,900
1974	37,300
1975	41,900
1976	40,700
1977	38,300

A Fish Stock Assessment Programme based on regular sampling with a set of gillnets (mesh sizes 12,5-200 mm) of 30 sampling sites, located in all the strata of the lake, was carried out from 1969 till 1977. The project concluded that there was no sign of over fishing of the stocks and that the fishing effort could be increased.

The project set up a fish marketing survey. At the major market places along the lake the total quantity of processed fish was estimated by counting the number of baskets landed. This allowed comparison of the total quantity of processed fish from the lake with the total quantity of fish caught in the lake. The survey was executed from 1970 till 1977.

1977-1989 After termination of the Volta Lake Research Project, phase II, the Fisheries Department continued the monitoring programme

1989-1993 Integrated Development of Artisanal Fisheries (IDAF) Phase I. The project aimed at improving the living conditions of over 75,000 inhabitants to the Lake Volta through the construction of a Community Fisheries Centre (CFC) with facilities for fish preservation, marketing and the provision of training for 15,000 fishermen. The Town of Yeji, located in stratum VII of the lake was selected as a pilot area for the construction of a CFC. The project included a monitoring programme on catch, effort and stocks and the following surveys were executed.

Two socio-economic surveys in the villages of stratum VII were carried out. The surveys indicated that the number of fishermen and canoes operating in stratum VII had increased by 300% since the mid 70's as shown in Table 1 below:

Table 1: The number of villages, the number of canoes and the number of fishermen as registered in stratum VII since the creation of Lake Volta.

	1970	*1975*	*1989*	*1992*
No. of villages	169	202	190	342
No. of Fishermen	?	?	15,500	18,300
No. of Canoes	1,700	1,900	4,300	6,500

The same surveys indicated that active fishing gears, as purse seines and beach seines started to operate in the lake and were creating social conflicts between the different types of fishermen;

Since 1991, the so called “fresh fish survey” involving sampling 3 days a week of the canoe catches at 4 stations in the vicinity of Yeji has been carried out. On the average 15 canoes per day are sampled. From each canoe the geartype and the mesh size is recorded, after which the total catch is measured and its distribution over 20 species is measured. This survey allows the calculation of the Catch per Unit of Effort (CPUE) of the canoes and for the different gears and allows to indication of seasonal fluctuations

A new system was developed in order to estimate the quantity of processed fish landed at the weekly market of Yeji. The system counts the number of different baskets landed and calculates the total quantity of smoked or dried fish landed. The Fresh Fish Weight Equivalent (FWE) is calculated by multiplying the different categories with a conversion factor. By this method it was estimated that 2,300 ton of smoked fish and 2,300 ton of dried fish was landed at Yeji in 1993. This quantity amounts to 8,200 ton of fresh fish.

The utmost priority in 1995 was fisheries management and the development of a sustainable monitoring system which can be executed by the Fisheries Department without

external funding. Therefore IDAF decided to start several different monitoring programmes

Five types of survey were carried out in Stratum VII of Lake Volta by the IDAF project:

- A fish market survey aimed at determining the total quantity of processed fish landed at the Yeji market.
- A processing programme for determining the conversion factor of smoked and dried fish and its seasonal fluctuation.
- A full frame survey, to determine the actual total fishing effort.
- A catch assessment survey to determine the monthly average catch of the different fishing units.
- A stock-assessment survey in order to assess the present situation of the stocks and to predict future changes.

This report presents the results of the Catch and Stock Assessment Programme with a summary of the results of the Frame Survey.

2. **STRATUM VII OF LAKE VOLTA**

The study area, known as Stratum VII of Lake Volta lies between longitude 0^o 10' to 1^0 05'W and latitude 8^0 8' to 8^0 20'N and extends for about 60 km south and 50 km north of Yeji (see Figures 1, 2 and 3).

Vertical profile measurements of temperature, dissolved oxygen and pH showed decreasing values with increasing depth. Estimated average values of the parameters however, were 29.8^0 C (Temperature); 7.0 mg/L (Dissolved Oxygen) and 7.0 (pH) all of which were considered suitable for normal fish life activities. Concentration of nutrients in the Stratum was found to be generally low. Ionic pattern recorded was Na>Ca>K>Cl>Mg .

The peculiar feature about the climate is the harmattan. The air masses that cause this state traverse the Sahara Desert before reaching Ghana. They are dry, have a relatively low humidity, and therefore give a general feeling of low temperature from November to February when they blow over most of Ghana. The vegetation back drop is wooded savannah-grassland prone to bush fires in the dry season.

3. THE FRAME SURVEY

The socio economic surveys of 1989 and 1991 were based on stratified sampling of the villages. The last full frame survey has been carried out in 1975. A new full frame was needed especially if the differences in the total catch, estimated at present, is considered. All the villages in stratum VII were visited and information gathered through direct observation and through interviews with the chiefs of the villages and the fishermen**.**

Within the frame survey, the previous (1970-1977) village classification was used;

- Large size village, more than 51 canoes
- Medium size village, 11-50 canoes
- Small size village, 0-10 canoes

The survey indicated that at present 288 villages are located in stratum VII, with 8068 canoes, 358 winchboats, with a total population of 100,000 and 40,000 fishermen. A breakdown of these data for the East, West bank and for the classification of large, medium and small sized villages is presented in Table 2.

Table 2: Results of the frame survey for the east and the west bank of Stratum VII.

Location	*No of villages*	*No of canoes*	*No of winchboats*	*Population*	*Fishermen*
East-Large	13	1,276	61	20,978	8,317
East-Medium	59	1,479	62	15,501	6,424
East-Small	50	275	5	4,163	1,560
West-Large	25	2,451	91	24,622	9,426
West-Medium	92	2,285	128	32,335	12,366
West-Small	49	302	11	4,281	1,8,37
TOTAL	288	8,068	358	101,883	39,934

In comparison with the socio-economic survey of 1992 the number of canoes increased 23% from 6,500 to 8,068, the number of fishermen increased by 122% from 18,000 to 40,000 while the number of winchboats slightly declined from 380 to 358**.**

Small sized villages represent 34.1% of the total number of villages and 7.1% of the total number of canoes are located in the small sized villages. For medium and large sized villages these figures are respectively 52.0 % and 13.2% for the villages and 46.6 and 46.1 for the canoes.

Stratification in Large, Medium and Small size villages was done in the early 70's. The major purpose of this stratification was to obtain sound statistical data which could facilitated later frame surveys, based on sub-sampling. For a Catch Assessment/Stock Assessment Programmes such a stratification is regarded inappropriate[2], because differences in catches are more likely dependent on factors such as habitat, species, fishing effort, etc. Within Stratum VII a preliminary stratification was made based on geographical location of the villages (see Figure 2);

Northern area: Westbank from Agbokope (vilno 1) to Degbesu (vilno. 38)
Eastbank from Nkwanta (vilno. 1) to Sabonjida (vilno. 50)

Central area: Westbank from Medee (vilno. 39) to Hutideke (vilno 56)
Eastbank from Watehkope (vilno 51) to Gbetekpo (vilno 85)

Southern area: Westbank from Tonkakope (vilno. 57) to Gakope (vilno 184)
Eastbank from John kope (vilno 86) to Maamata (vilno 158)

[2] This will be discussed in detail in Chapter 4.

Figure 1: Map of Ghana

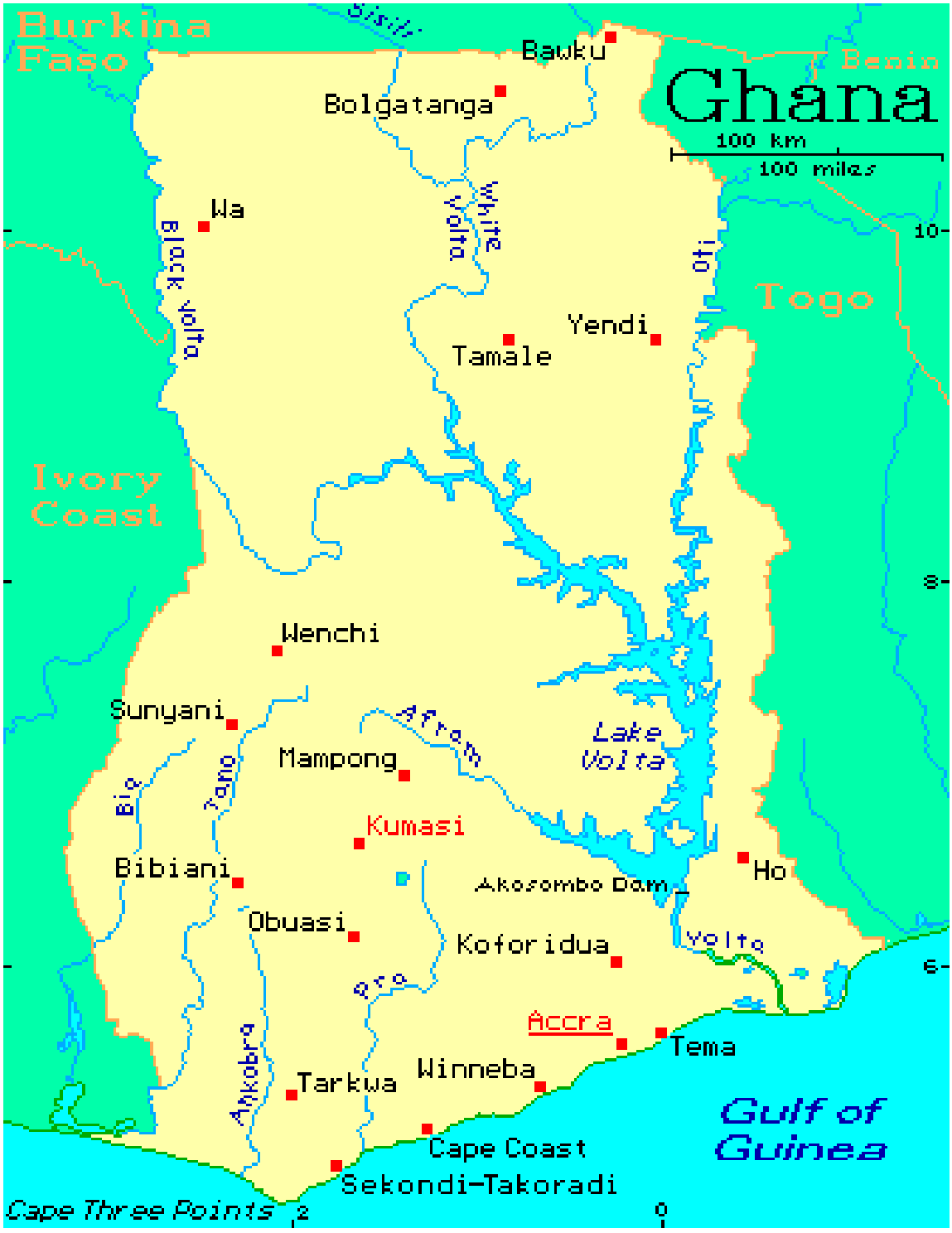


Figure 2: Lake Volta and its stratification

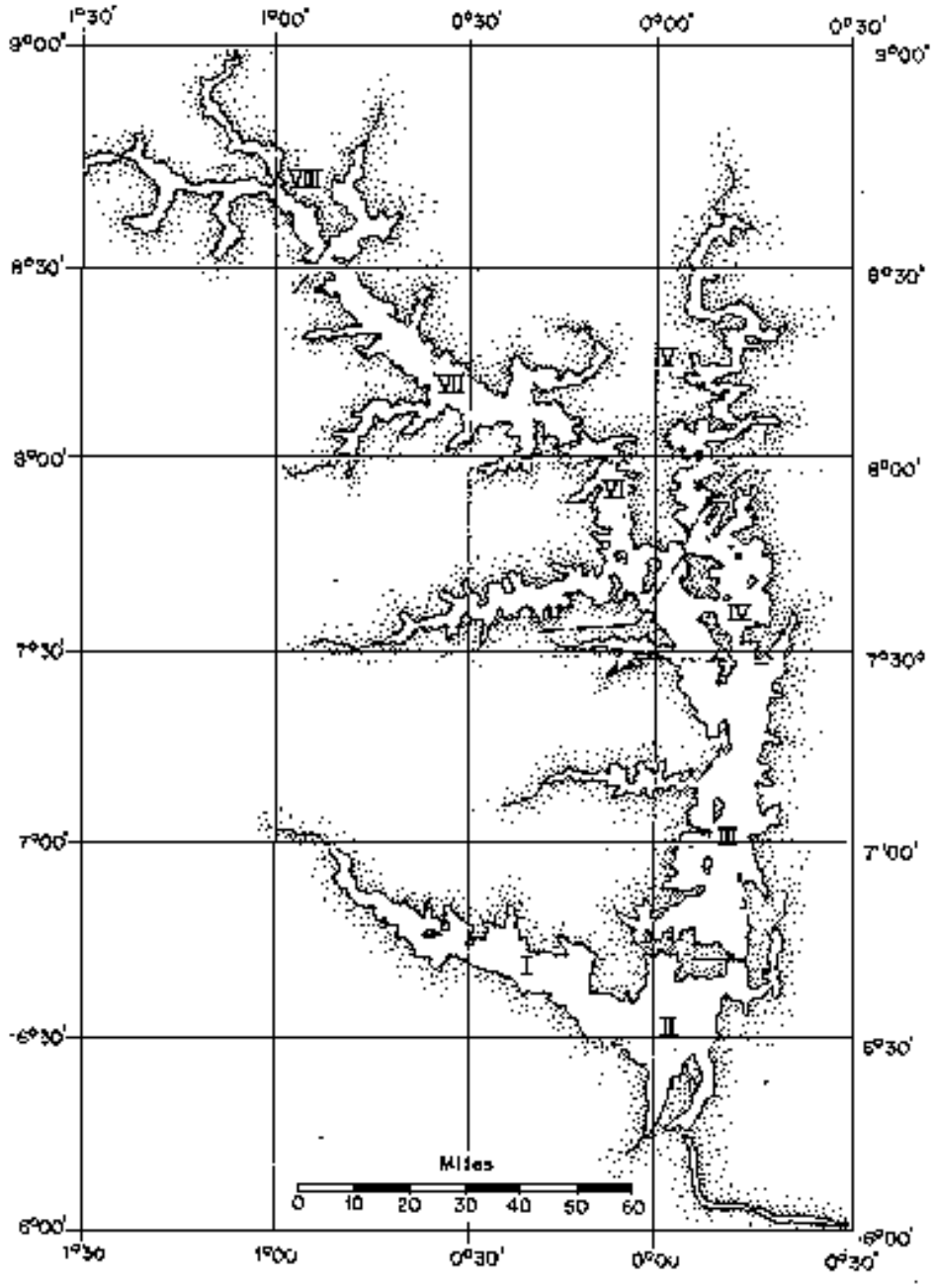


Figure 3: Stratum VII of Lake Volta and its geographical stratification.

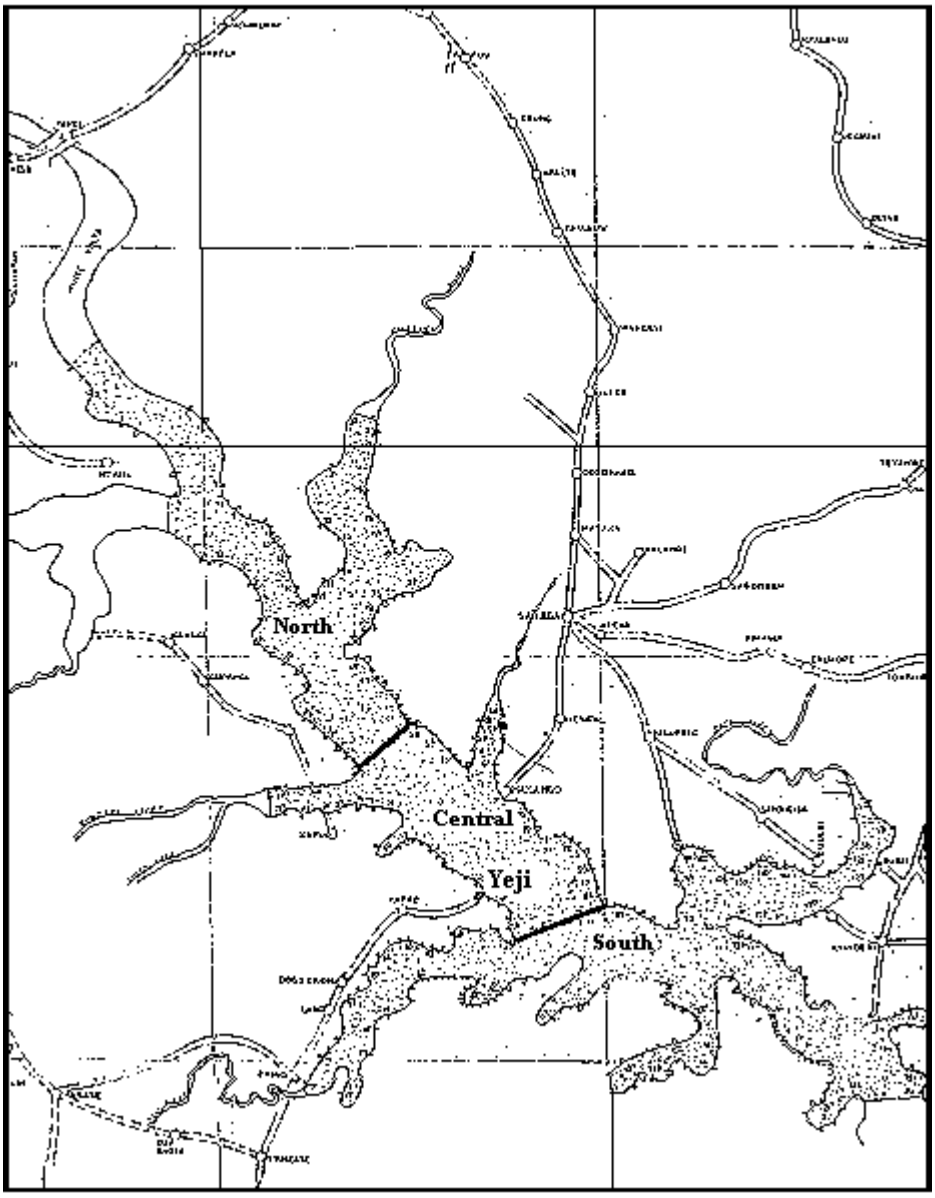


Table 3 presents the distribution of canoes and winchboats over the three geographical sub-strata.

Table 3: Distribution of canoes and winchboats and the average number of bundles of gillnets used per canoe in the Northern, Central and Southern sector of Stratum VII.

Sub-Stratum	*No. of Canoes*	*No. of Winchboats*	*Average no of bundles per Canoe*
North	2,805	176	2.34
Central	1,445	96	1,83
South	3,818	86	2.85

In the dry season gillnets were the major gears followed by traps. In the rainy season gillnets were the most important followed by castnets and beachseines. On the average 2.9 bundles of gillnets are used per canoe and a canoe is operated by 4 fishermen. On the average there was 1 canoe per household and 10-13 persons in the village were dependent on it.

Almost all interviewed fishermen (97%) said that the fish catches were declining. A major reason for the decline is an increased population, followed by a lower water level and the use of beach seines and winchboats.

About 4,500 ton of fresh fish is consumed annually by the total population around stratum VII of Lake Volta.

4. THE CATCH ASSESSMENT SURVEY.

4.1 Methods

4.1.1 Sampling and data collection

The Catch Assessment Survey started in March 1995 and became fully operational in October 1995. The Northern and Southern area were visited bi-monthly and within each sub-strata three different villages/landing sites were sampled during one day. The Central area around Yeji town was sampled one day per week. Table 4 presents the major characteristics of the different landing sites.

Table 4: Major characteristics of the sampled landing sites in Stratum VII of Lake Volta.

Name	*Sub-stratum*	*No. of canoes*	*Class*	*No of winchboats*
Gbevukpo	North	82	Large	4
Blackie kope	North	20	medium	5
Kejawu	North	120	large	8
Fanti town	Central	13	medium	7
Jaklai no 3	Central	37	medium	7
Salt Town	Central	10	small	3
Site area	Central	16	medium	0
Abodwese Akura	South	34	medium	0
Pedjai no. 1	South	9	small	0
Avorkope	South	120	large	17

At each landing site the following data was collected;

CANOES

- Total catch per canoe (by weighing of total catch)
- No of bundles of the sampled canoe, mesh size and type of gillnet (mono/multi filament).
- If not a gillnet then other gear characteristics were taken.
- Weight and number of the different species in the sampled canoes by means of a sub-sample.
- The number of fishermen per canoe.
- The number of days the fishermen went fishing in the previous month.
- The total number of canoes on the landing site.
- The total number of canoes that went fishing on the sample day.

WINCH BOATS

- The total catch of the winchboat was found by counting the number of headpans[3] landed.
- Mesh size of the gear.
- Species composition was obtained through experimental fishing.
- The number of winchboats at the landing site.

BEACH SEINES

- The number of beach seines operated.
- The total catch of the beach seines by weighing.
- The mesh size.

4.2 Statistics

From May 1995 till January 1997, 1,741 canoes and 283 winchboats were sampled at the different landing sites. The data were entered in a database program (MsACCESS) and statistical analysis was done by using SYSTAT.

Prior to analysis, the coefficient of variation (%) was calculated for the CPUE'S for all different types of stratification and methods of estimation. On the average the CV was 11% and in 4 cases exceeded 15%, the latter always in small sized villages. It was therefore concluded that the sample sizes were appropriate for a correct analysis.

[3] The average weight of a headpan is 40 kg of fish.

4.3 "Village size" *vs* "Geographical location" as stratification criteria

Analysis of variance of the catch per canoe and the catch per bundle indicates significant differences among the three type of landing sites (see Table 5).

Table 5: Mean catch per canoe and mean catch per bundle (± s.e.m[4]) among large, medium and small size villages. Different superscripts indicate a significant difference ($P \leq 0.005$).

Village size	*Catch/canoe/day (kg/day)*	*n*	*Catch/bundle/day (kg/day)*	*n*
Large	$16.77^{a} \pm 0.64$	375	$10.07^{a} \pm 0,5$	232
Medium	$12.91^{b} \pm 0.37$	1105	$8.36^{b} \pm 0.26$	876
Small	$11.73^{b} \pm 0.76$	261	$6.15^{c} \pm 0.52$	220

The picture changes if the catch per canoe or catch per bundle is analysed for the different individual landing sites (Tables 6 & 7).

Table 6: Mean daily catch per canoe (± s.e.m) at the different landing sites in Stratum VII of Lake Volta. . Different superscripts indicate a significant difference ($P \leq 0.005$).

Landing site	*CPUE-canoe (kg/canoe/day)*	*n*	*size*	*Location*
Abodwese	$17.7^{a} \pm 1.2$	90	medium	South
Avorkope	$22.8^{a} \pm 1.0$	135	large	South
Blackie	$18.4^{a} \pm 0.9$	151	medium	North
Fanti	$9.5^{b} \pm 0.7$	291	medium	Central
Gbevukpo	$12.7^{a} \pm 1.1$	123	large	North
Jaklai	$12.3^{b} \pm 0.8$	234	medium	Central
Kejawu	$13.4^{a} \pm 0.8$	240	large	North
Pedjai	$15.8^{a} \pm 1.7$	47	small	South
Salt	$10.8^{b} \pm 0.8$	214	small	Central
Site	$12.0^{b} \pm 0.8$	200	medium	Central

[4] s.e.m. is standard error of the mean

Table 7: Mean daily catch per bundle (± s.e.m) at the different landing sites in Stratum VII of Lake Volta. . Different superscripts indicate a significant difference (*P*≤0.005).

Landing site	*CPUE-bundle (kg/day)*	*n*	*size*	*Location*
Abodwese	$12.8^{a} \pm 0.9$	63	medium	South
Avorkope	$12.4^{a} \pm 0.8$	69	large	South
Blackie	$12.3^{a} \pm 0.7$	94	medium	North
Fanti	$7.6^{b} \pm 0.5$	240	medium	Central
Gbevukpo	$11.1^{a} \pm 0.7$	105	large	North
Jaklai	$7.3^{b} \pm 0.5$	234	medium	Central
Kejawu	$9.1^{a} \pm 0.6$	163	large	North
Pedjai	$14.2^{a} \pm 1.2$	47	small	South
Salt	$4.6^{b} \pm 0.5$	186	small	Central
Site	$5.1^{b} \pm 0.6$	167	medium	Central

The analysis indicates that the catches at the landing sites around Yeji in the central part of Stratum VII differ strongly from the others. The catches within the geographical locations do not differ among the different sizes of landing site. The overall difference between "Large", "Medium" and "Small" is artificial and is caused by the low catches for "Small" and "Medium" sized villages obtained in the Central area and the relative large number of samples obtained from this area.

Results of an ANOVA which uses the geographical location 'North", "Central" and "South" in relation to the obtained CPUE is presented in Table 7.

Table 8: Mean catch per canoe and mean catch per bundle (± s.e.m) in the Northern, Central and Southern sector of Stratum VII of Lake Volta. Different superscripts indicate a significant difference (*P*≤0.005).

Sector	*Catch/canoe/day (kg/day)*	*n*	*Catch/bundle/day (kg/day)*	*n*
North	$14.7^{a} \pm 0.52$	530	$10.5^{a} \pm 0.26$	362
Central	$11.0^{b} \pm 0.39$	939	$6.3^{b} \pm 0.38$	800
South	$19.9^{c} \pm 0.72$	272	$12.9^{c} \pm 0.57$	166

The results of the analysis clearly indicate differences in catches on basis of the geographical zonation, with the highest catch in the South and the lowest catches in the Central part. Coupled with the information that the CPUE in the Central part reduces the overall CPUE in the North and the South, it was been decided not to stratify for "Large, Medium or Small" but to use the geographical location of the landing sites as stratification criteria.

4.4 Estimation of the total annual catch of Stratum VII of Lake Volta.

Estimation of the total catch of Stratum VII was the major goal of the Catch Assessment Survey. Two different estimations were made. A total catch estimation without stratification and a total catch estimation with stratification as North, Central or South. The two methods were then compared afterwards.

Total catch estimates were made for 1996 which had a complete data set for the year only. The catches of canoes utilising gillnets and winchboats were considered only. The data available from the frame survey and catch assessment survey on beach seines, traps, hook and line, nifa-nifa, etc., was not sufficient to include them.

4.4.1 Non-stratified catch estimation.

4.4.1.1 Method used

In principle the total catch was estimated as;

Total catch = No. of canoes* annual catch/canoe + No. of Winch*annual catch/winchboat

The frame survey estimated the total number of canoes at 8068 and the total number of winchboats at 358. Estimation of the annual catch was made with the results of the catch assessment. It took into consideration the seasonal fluctuation in CPUE-canoe, the relative fishing effort i.e. the percentage of canoes that went fishing on a sampling day and the number of days fishermen went fishing in a week.

4.4.1.2 Canoes

CPUE-canoe

As indicated in Figures 4 & 5 the CPUE-canoe varies throughout the season with peak catches in July/August and low catches in January/February. Figure 3 indicate a significant outlier in February 1996, when a unusual high catch was observed during sampling in the South.

Figure 4: CPUE of canoes of all landing sites in Stratum VII combined

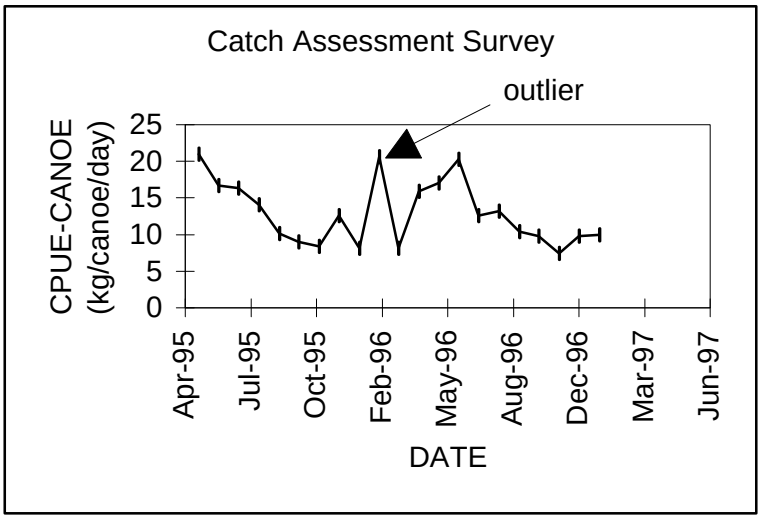
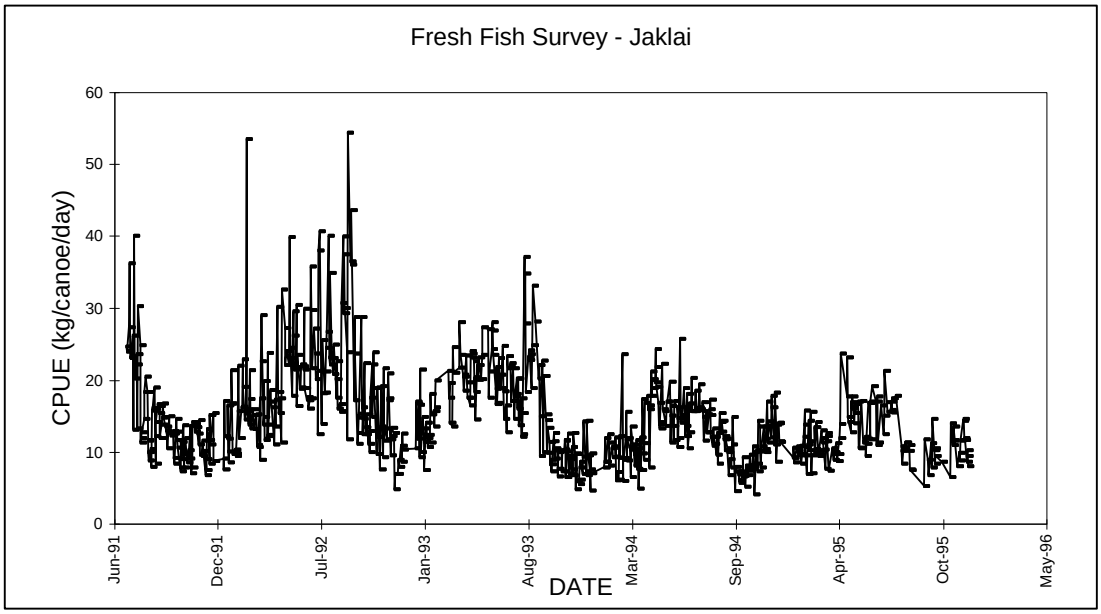


Figure 5: CPUE of the canoes as obtained in Jaklai in the central part of stratum VII.



Due to this seasonal fluctuation the CPUE-canoe was calculated monthly for the total catch estimate for 1996 (see Table 8)

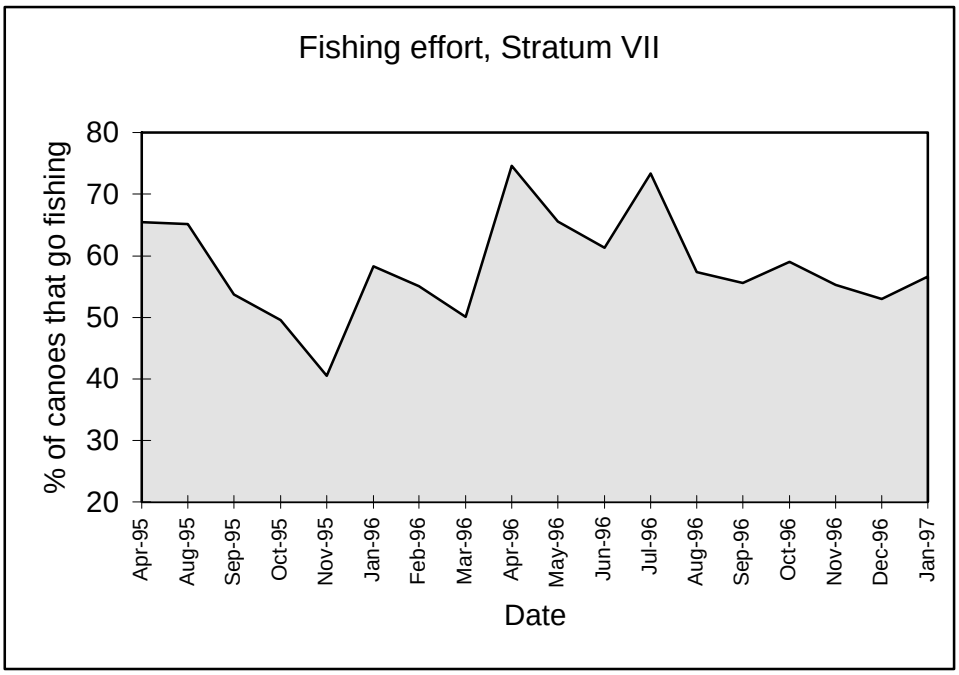
Fishing effort-canoes

During the frame survey it was indicated that in 12% of the villages fishing was not allowed a certain day of the week (Friday or Sunday). It is assumed that this is

uniformly covered the whole of Stratum VII and the fishing days are adjusted for this phenomenon and is expressed as primary fishing days (see Table 8)

The fishing effort is the number of canoes multiplied by the fraction of the canoes which went fishing and the monthly data as obtained from Stratum VII is presented in Figure 6.

Figure 6: The fishing effort in Stratum VII of Lake Volta.



It seems that the effort is following the same pattern as the CPUE-canoe. Approximately 40% of the canoes were observed to be fishing during November-January and this increased to about 60% in July-August. As for the CPUE-canoes the fraction of fishing canoes is calculated monthly for the estimation of the total catch in Stratum VII.

The number of canoe fishing days in a month for the whole of Stratum VII was calculated as follows:

Canoe days = {0.12*(day in the month-4)+0.88(day in the month)}*fraction of fishing canoes

Finally the monthly total catch was calculated by multiplying the total monthly canoe fishing days with the mean of the CPUE-canoe for that month and the results are presented in Table 9.

Table 9: Total catch estimate for canoes in Stratum VII of Lake Volta, without stratification.

MONTH	*CPUE (kg/canoe/day)*	*CANOES*	*MONTH DAYS*	*PRIM DAYS*	*EFFORT %*	*CANOE DAYS*	*MONTHLY CATCH (kg)*
Jan-96	8,16	8068	31	246235	0,584	143801	1172949
Feb-96	20,66	8068	28	222031	0,551	122339	2527622
Mar-96	8,10	8068	31	246235	0,501	123364	999722
Apr-96	15,93	8068	30	238167	0,746	177673	2831010
May-96	17,04	8068	31	246235	0,656	161530	2751677
Jun-96	20,24	8068	30	238167	0,613	145997	2954544
Jul-96	12,56	8068	31	246235	0,734	180737	2269196
Aug-96	13,20	8068	31	246235	0,574	141339	1865720
Sep-96	10,41	8068	30	238167	0,555	132183	1376580
Oct-96	9,83	8068	31	246235	0,59	145279	1427644
Nov-96	7,39	8068	30	238167	0,553	131707	973805
Dec-96	9,76	8068	31	246235	0,529	130259	1271789
TOTAL						**1736207**	**22422000**

4.4.1.3 Winchboats

In principle the method for the winchboats was similar to the one used for the canoes. For the winchboats it was assumed that they fish 6 days a week and make one trip a day or night[5] . The estimates for winchboats are presented in Table 10.

Table 10: Catch estimates of winchboats in Stratum VII of lake Volta during 1996, estimated without stratification.

MONTH	*CPUE (kg/trip)*	*NO OF WINCHBOATS*	*MONTH DAYS*	*WINCH DAYS*	*TRIPS per DAY*	*MONTHLY CATCH (kg)*
Jan-96	46	358	31	9666	1	447858
Feb-96	44	358	28	8592	1	376330
Mar-96	49	358	31	9666	1	470734
Apr-96	77	358	30	9308	1	717880
May-96	60	358	31	9666	1	575127
Jun-96	84	358	30	9308	1	778769
Jul-96	64	358	31	9666	1	616691
Aug-96	38	358	31	9666	1	365782
Sep-96	40	358	30	9308	1	375259
Oct-96	30	358	31	9666	1	293202
Nov-96	20	358	30	9308	1	188487
Dec-96	37	358	31	9666	1	353207
TOTAL				**113486**		**5559326**

[5] This aspect was not covered by the CAS and require verification**.**

4.4.1.4 Total catch and Confidence Limits

The total catch for the canoes and the winchboats has been calculated with the average monthly CPUE's. The maximum catch (95% confidence limit) can be calculated by replacing the CPUE's monthly with the 95% upper limit (average CPUE+1.96*standard error). For the minimum catch the monthly CPUE's are replaced with the lower limit (CPUE-1.96*standard error).

A summary of the results is presented in Table 11.

Table 11: Mean total catch (in kg/year) of Stratum VII of Lake Volta and its 95% upper and lower limit, estimated without stratification.

	Mean (kg/year)	*Max. (95%) (kg/year)*	*Min (95%) (kg/year)*
Total catch canoes (t/year)	22422	26065	18779
Total catch winch (t/year)	5559	7054	4064
Total catch Stratum VII (t/year)	**27981**	**33119**	**22843**

4.4.2 Estimates of total catch in Stratum with stratification "North, Central and South"

4.4.2.1 Key parameters

As discussed before significant differences are observed in the catches in the Northern, southern and Central area of stratum VII. The rather large impact of the sampling station in the central area with relatively low catches lead to an under estimate of the total catch when no stratification is used.

Key parameters used in the analysis are presented in Table 12.

Table 12: Key parameters of the Northern, Central and Southern area of Stratum VII of Lake Volta.

Area	*No. of Canoes*	*% canoes that do not fish one day in the week*	*No of Winchboats*
North	2805	3.8	176
Central	1445	5.3	96
South	3818	18.9	86

4.4.2.2 Total catch canoes.

In principle the estimation method was more or less similar to the one used for canoes in the case of no-stratification. The only difference was that in the Northern and Southern area the CPUE was determined bi-monthly. The results for the Northern, Central and Southern area are presented in Tables 13, 14 & 15.

Table 13: Catch estimates of canoes in the Northern area of Stratum VII of Lake Volta.

MONTH	*CPUE (kg/canoe/day)*	*CANOES*	*MONTH DAYS*	*PRIM DAYS*	*EFFORT %*	*CANOE DAYS*	*MONTHLY CATCH (kg)*
Jan-96	12,11	2805	31	86360	0,58	50089	606578
Feb-96	35,34	2805	28	77945	0,63	49222	1739512
Mar-96	35,34	2805	31	86360	0,63	54407	1922744
Apr-96	13,34	2805	30	83555	0,88	73529	981234
May-96	13,34	2805	31	86360	0,88	75997	1013801
Jun-96	18,42	2805	30	83555	0,63	52640	969639
Jul-96	18,42	2805	31	86360	0,63	54407	1002177
Aug-96	9,09	2805	31	86360	0,39	33681	306080
Sep-96	9,09	2805	30	83555	0,39	32587	296212
Oct-96	10,62	2805	31	86360	0,59	50953	541168
Nov-96	10,62	2805	30	83555	0,59	49298	523541
Dec-96	11,03	2805	31	86360	0,40	34544	380953
TOTAL						**2523527**	**10283639**

Table 14: Catch estimates of canoes in the Central area of Stratum VII of Lake Volta.

MONTH	*CPUE (kg/canoe/day)*	*CANOES*	*MONTH DAYS*	*PRIM DAYS*	*EFFORT %*	*CANOE DAYS*	*MONTHLY CATCH (kg)*
Jan-96	8,16	1445	31	44575	0,58	26014	212190
Feb-96	6,87	1445	28	40240	0,52	20933	143739
Mar-96	8,10	1445	31	44575	0,51	22644	183506
Apr-96	14,29	1445	30	43130	0,70	30252	432340
May-96	17,04	1445	31	44575	0,66	29237	498053
Jun-96	13,00	1445	30	43130	0,58	25016	325203
Jul-96	12,56	1445	31	44575	0,73	32540	408548
Aug-96	8,35	1445	31	44575	0,65	28974	241978
Sep-96	10,41	1445	30	43130	0,55	23722	247043
Oct-96	8,82	1445	31	44575	0,58	25854	228137
Nov-96	7,39	1445	30	43130	0,55	23722	175392
Dec-96	7,35	1445	31	44575	0,61	27057	198786
TOTAL						**315964**	**3294916**

Table 15: Catch estimates of canoes in the Southern area of Stratum VII of Lake Volta.

MONTH	*CPUE (kg/canoe/day)*	*CANOES*	*MONTH DAYS*	*PRIM DAYS*	*EFFORT %*	*CANOE DAYS*	*MONTHLY CATCH (kg)*
Jan-96	15,37	3818	31	115472	0,44	50692	779136
Feb-96	15,55	3818	28	104018	0,44	45664	709863
Mar-96	15,55	3818	31	115472	0,65	75057	1167129
Apr-96	23,66	3818	30	111654	0,65	72575	1717067
May-96	23,66	3818	31	115472	0,59	68013	1609182
Jun-96	23,55	3818	30	111654	0,59	65764	1549056
Jul-96	23,55	3818	31	115472	0,65	75057	1767581
Aug-96	21,77	3818	31	115472	0,65	75057	1633640
Sep-96	21,77	3818	30	111654	0,59	65585	1427792
Oct-96	8,65	3818	31	115472	0,59	67828	586577
Nov-96	8,65	3818	30	111654	0,53	59176	511876
Dec-96	12,22	3818	31	115472	0,53	61200	747931
TOTAL						**781667**	**14206831**

The total canoe catch in 1996 in respectively the Northern, Central and Southern areas was 10,283 tonnes, 3,294 tonnes and 14,266 tonnes, with a total canoe catch of 27,785 tonnes.

4.4.2.3 The winchboats.

As with the canoes in the Northern and Southern area the CAS was executed bi-monthly and results were used for the calculation of two months. In a number of months no winchboats were sampled at all and in this case the average CPUE for that month was taken from the non-stratified data set. The results for the Northern, Central and Southern area are presented in Tables 16, 17 and 18.

Table 16: Catch estimates of winchboats in the Northern area of Stratum VII of Lake Volta.

MONTH	*CPUE (kg/trip)*	*WINCHBOATS*	*MONTH DAYS*	*WINCH DAYS*	*TRIPS per DAY*	*MONTHLY CATCH (kg)*
Jan-96	57,17	176	31	4752	1	271656
Feb-96	46,67	176	28	4224	1	197120
Mar-96	46,67	176	31	4752	1	221760
Apr-96	67,88	176	30	4576	1	310596
May-96	67,88	176	31	4752	1	322542
Jun-96	96,88	176	30	4576	1	443300
Jul-96	96,88	176	31	4752	1	460350
Aug-96	33,00	176	31	4752	1	156816
Sep-96	33,00	176	30	4576	1	151008
Oct-96	52,86	176	31	4752	1	251177
Nov-96	52,86	176	30	4576	1	241874
Dec-96	61,67	176	31	4752	1	293040
TOTAL						**3321239**

Table 17: Catch estimates of winchboats in the Central area of Stratum VII of Lake Volta.

MONTH	*CPUE (kg/trip)*	*WINCHBOATS*	*MONTH DAYS*	*WINCH DAYS*	*TRIPS per DAY*	*MONTHLY CATCH (kg)*
Jan-96	46,33	96	31	2592	1	120096
Feb-96	39,50	96	28	2304	1	91008
Mar-96	48,70	96	31	2592	1	126230
Apr-96	48,80	96	30	2496	1	121805
May-96	59,50	96	31	2592	1	154224
Jun-96	70,00	96	30	2496	1	174720
Jul-96	63,80	96	31	2592	1	165370
Aug-96	38,41	96	31	2592	1	99563
Sep-96	40,32	96	30	2496	1	100628
Oct-96	25,00	96	31	2592	1	64800
Nov-96	20,25	96	30	2496	1	50544
Dec-96	28,23	96	31	2592	1	73165
TOTAL						**1342153**

Table 18: Catch estimates of winchboats in the Southern area of Stratum VII of Lake Volta.

MONTH	*CPUE (kg/trip)*	*WINCHBOATS*	*MONTH DAYS*	*WINCH DAYS*	*TRIPS per DAY*	*MONTHLY CATCH (kg)*
Jan-96	46,33	86	31	2322	1	107586
Feb-96	43,80	86	28	2064	1	90403
Mar-96	48,70	86	31	2322	1	113081
Apr-96	136,67	86	30	2236	1	305587
May-96	59,50	86	31	2322	1	138159
Jun-96	60,00	86	30	2236	1	134160
Jul-96	63,80	86	31	2322	1	148144
Aug-96	37,84	86	31	2322	1	87869
Sep-96	40,32	86	30	2236	1	90146
Oct-96	13,33	86	31	2322	1	30960
Nov-96	20,25	86	30	2236	1	45279
Dec-96	22,13	86	31	2322	1	51394
TOTAL						**1342768**

The total catch of winchboats in respectively the Northern, Central and Southern area was 3,321 tonnes, 1,342 tonnes and 1,342 tonnes, with a **total of 4,359 tonnes**.

4.4.2.4 Total catch and Confidence Limits

The total catch for the canoes and the winchboats has been calculated with the average monthly CPUE's. The maximum catch (95% confidence limit) can be calculated by replacing the CPUE's monthly with the 95% upper limit (average CPUE+1.96*standard error). For the minimum catch the monthly CPUE's are replaced with the lower limit (CPUE-1.96*standard error).

A summary of the results is presented in Table 19**.**

Table 19: Mean total catch of Stratum VII of Lake Volta and its 95% upper and lower limit, estimated without stratification.

	Mean (tonnes)	*Max. (95%)*	*Min (95%) (kg)*
Total catch canoes North	10283	12321	8077
Total catch canoes Central	3294	3847	2743
Total catch canoes South	14266	17888	10178
Total catch winch North	3321	3558	3070
Total catch winch Central	1342	1457	1226
Total catch winch South	1342	1496	1449
Total catch Stratum VII (t/year)	**33848**	**40567**	**26743**

It shows that Stratum VII of Lake Volta on the average produced **33,800 tonnes in 1996** if stratification is used for the estimate. The lowest estimate for 1996 is 26,700 tonnes.

4.4.3 Comparison of catch estimates.

A summary of the results of estimation without stratification and with stratification is presented in Table 20.

Table 20: Comparison of the total catch in Stratum VII estimated without and with stratification.

	Non stratified (t/year)	*Stratified (t/year)*
Average gillnets	22422	27843
Max. gillnets	26065	34056
Min gillnets	18779	20988
Average winch	5559	6005
Max. winch	7054	6511
Min winch	4064	5745
Average all	**27981**	**33848**
Max. all	33119	40567
Min all	22843	26743

Stratum VII of Volta produced between 27.900 and 33,800 tonnes in 1996 depending on the method used for the estimation. Due to the impact of the lower catches in the Central area it was concluded that stratification is indeed necessary and **33,800 tonnes is the final total catch estimate for Stratum VII of Lake Volta for 1996**.

4.4.4 An analysis of catch trends and extrapolation for the whole of Lake Volta

In this chapter an analysis of catches is given. It is mainly given as an illustration of how catch and effort data can be used and why long term monitoring programmes and regular updating of the frame survey is an absolute necessity for proper fisheries analysis. The available data does not allow at present to make a complete analysis for the whole of Stratum VII.

Since 1991 the catch in Jaklai is monitored weekly by the “fresh fish survey” and it is observed that the CPUE decreased significantly over the years (Table 21)

Table 21: Fisheries data of Jaklai in the central area of Stratum VII of Lake Volta during 1991-1996.

Year	*No of Canoes*	*CPUE ± std*[6] *(kg/canoe/day)*	*Significance (P)*
1991/1992	6,500	16.4±6.1	-
1992	?	18.9±8.5	0.001
1993	?	16.2±6.5	0.001
1994	?	12.5±4.2	0.0001
1995	8,060	12.1±3.5	.
1996	8,060 (?)	12.2±11.3	.

With the surplus production model of Schaefer it can be seen if overfishing takes place by using catch and effort data such as the ones presented in Table 21. The objective of the Schaefer model is to determine the optimum level of effort (no. of canoes); the effort that produces the maximum yield (total catch) that can be sustained without affecting the long-term productivity of the stock, the so-called Maximum Sustainable Yield (MSY). In the Schaefer model the effort is plotted against the Catch per Unit of effort after which the regression line is calculated following:

$$\mathbf{Y(i)/f(i) = a + b*f(i)}$$

The slope and the intercept of the regression line is further used for the calculation of the annual yields;

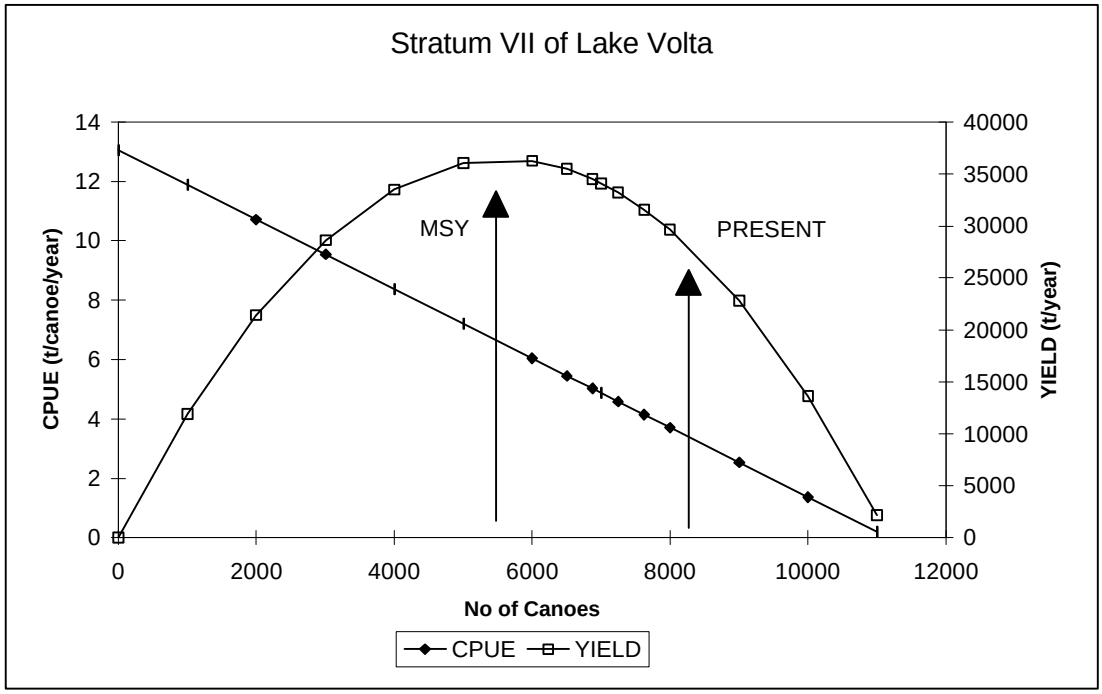
$$\mathbf{Y(i) = a*f(i) + b* f(i)*f(i)}$$

The MSY is calculated with **MSY =- 0.25*a*a/b** and the corresponding Fmsy with **Fmsy = -0.5*a/b.**

The Schaefer-curve of Stratum VII of Lake Volta is presented in Figure 7.

[6] std is standard deviation

Figure 7: A Schaefer curve for canoes in Stratum VII of Lake Volta.



The curve indicates that a maximum sustainable yield of **36500 t/year** can be obtained from stratum VII at a fishing effort of **5500 canoes** and a **CPUE of 6.6 t/canoe/year.** Such an analysis would indicate that at present stratum VII is over-exploited due to the activities of **8060** canoes.

It should however be realised that the curve has been made with two valid data points only, which is statistically not correct. The analysis stresses the importance of regular updating of the frame survey.

Assuming that the trends as observed in stratum VII are representative for the whole of Lake Volta we can estimate the total production of Lake Volta (Table 22).

Table 22: Extrapolated production figures for the different strata of Lake Volta.

Stratum	*No. Canoes in 1978*	*% of total no. of canoes*	*Fopt-1996 (No. of Canoes)*	*MSY (t/year)*
1	3092	21	8596	57000
2	1894	13	5265	35000
3	2614	18	7267	48000
4	2645	18	7353	49000
5	908	6	2524	17000
6	588	4	1635	10000
7	1978	13	5500	36500
8	1027	7	2855	19000
Total	**14746**	**100**	**41000**	**271500**

A maximum fishing effort of 41,000 canoes and a MSY of 271,000 t/year for the whole of Lake Volta is certainly an **overestimation.** Most likely the fishermen are moving to the most productive strata and that the distribution of the canoes over the different strata has changed over the years. **A new full frame survey for the whole of Lake Volta would clarify this and is an essential exercise**.

It is however certain that the previous used production figure of 44,000 t/year for Lake Volta is an under-estimation, as the actual total catch of Stratum VII is already 33.800 t/year.

The total production of Lake Volta most likely will be around 150,000 - 200,000 t/year (180-240 kg/ha) with a total annual value of 30 million USD This is a substantial quantity, if compared with the annual marine catches of 300,000-400,000 t/year, and it justifies that serious action is taken in order to protect the productivity of this natural resource.

A production of 180-240 kg/ha/year is high but not un-common for African lakes as can be seen from the examples below.

Lake Albert (Uganda)	***182 kg/ha/year***
Lake George (Uganda)	***108 kg/ha/year***
Lake Nakawali (Uganda)	***236 kg/ha/year***
Lake Kainji (Nigeria)	***100 kg/ha/year***

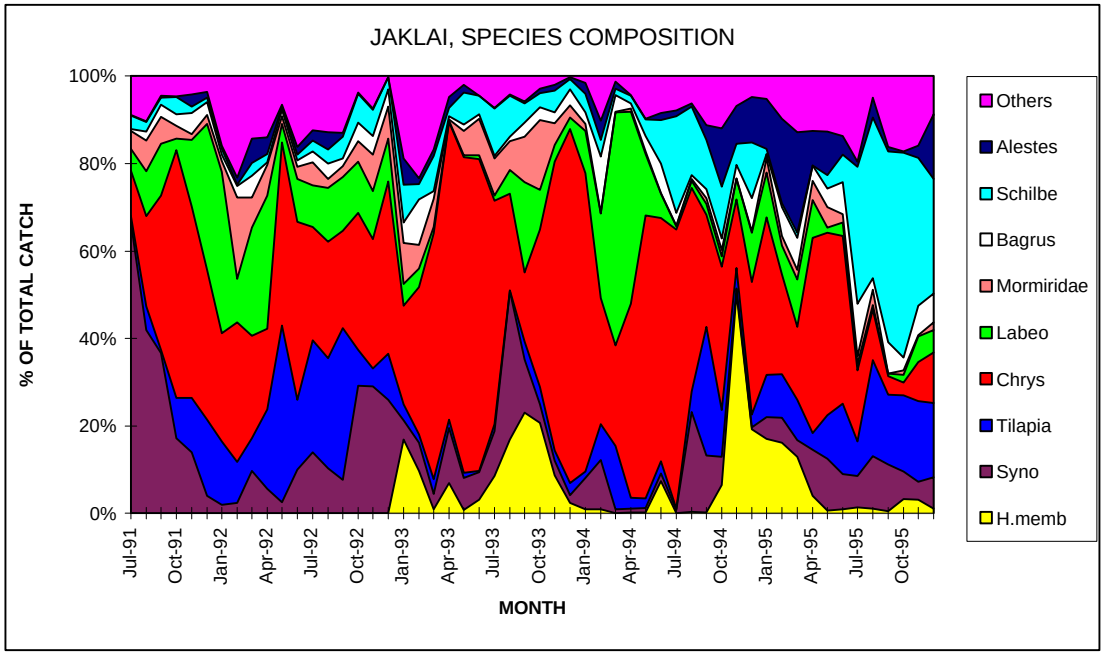
4.5 Species composition of the catch in Stratum VII

4.5.1 Gillnets

4.5.1.1 Long-term trends

Results of the fresh fish survey in Jaklai are used to analyse long-term trends in species composition. The results are presented in Figure 8. It should be remarked that during 1991 *H. membraceus* and *S. schall* were grouped as Synodontis**.**

Figure 8: The species composition of gillnets In Stratum VII of Lake Volta.



No regular seasonal pattern could be detected. It seems, however that a distinct shift in species composition took place in 94/95 whereby *Chrysichthys* has been replaced by *Schilbe*. It could not be verified if this trend continued in 1996 as the data were at the Legon University for entering in Dbase. A further analysis will be carried out in the near future.

4.5.1.2 Geographical differences

There is a distinct difference in species composition of the gillnets in the North or the South as can be seen in Figure 9 & 10. In the North a large part of the catch consists of *O. niloticus*, *L. coubie* and *S. galileus*. While in the South the two tilapia species are almost absent and the bulk of the catch consists of *C. auratus*, *C. nigrodigitatus* and *H. membraceus*. This difference again stresses the importance of

stratification in North, Central and South. The reason for the difference will be further studied.

Figure 9: Species composition of gillnets in the northern area of Stratum VII of Lake Volta.

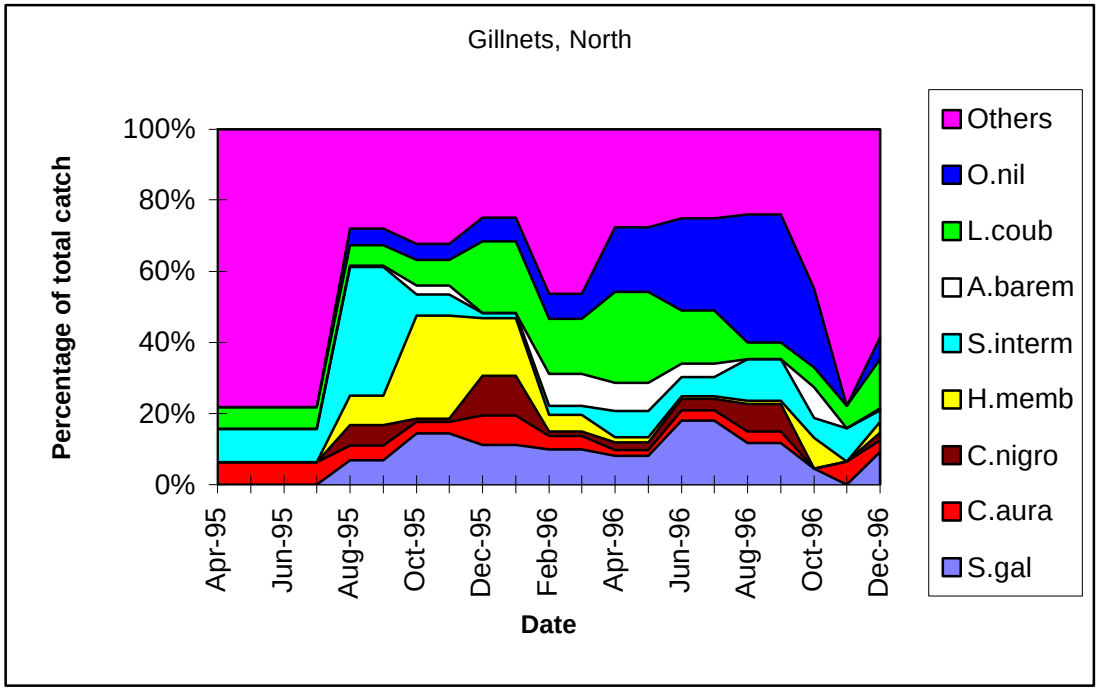
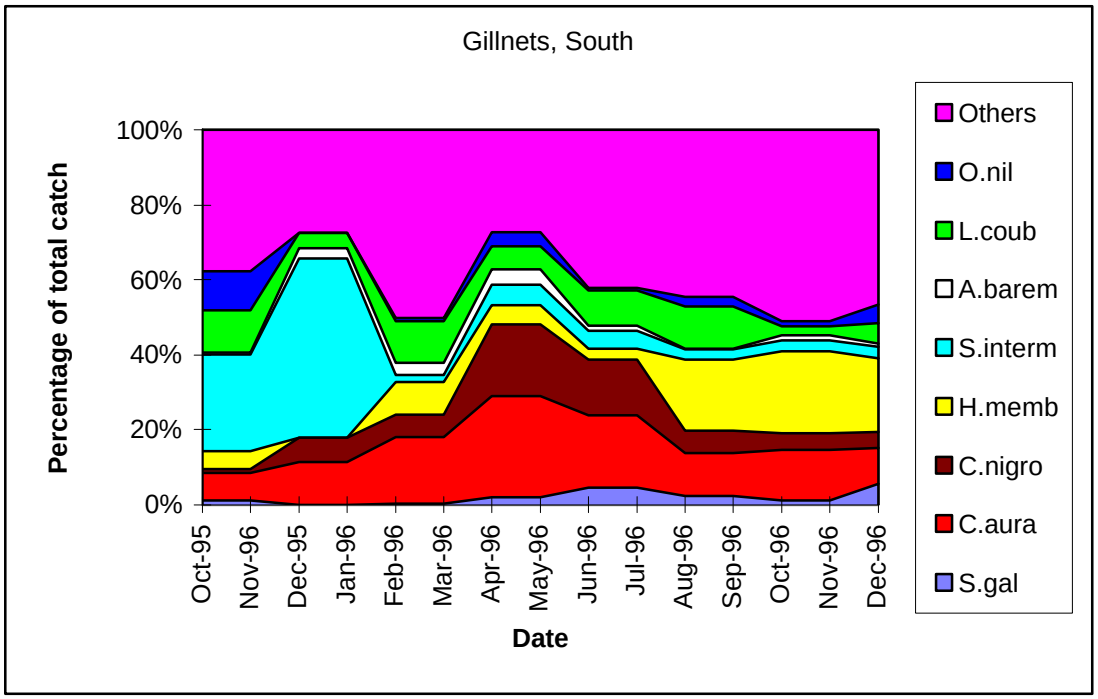


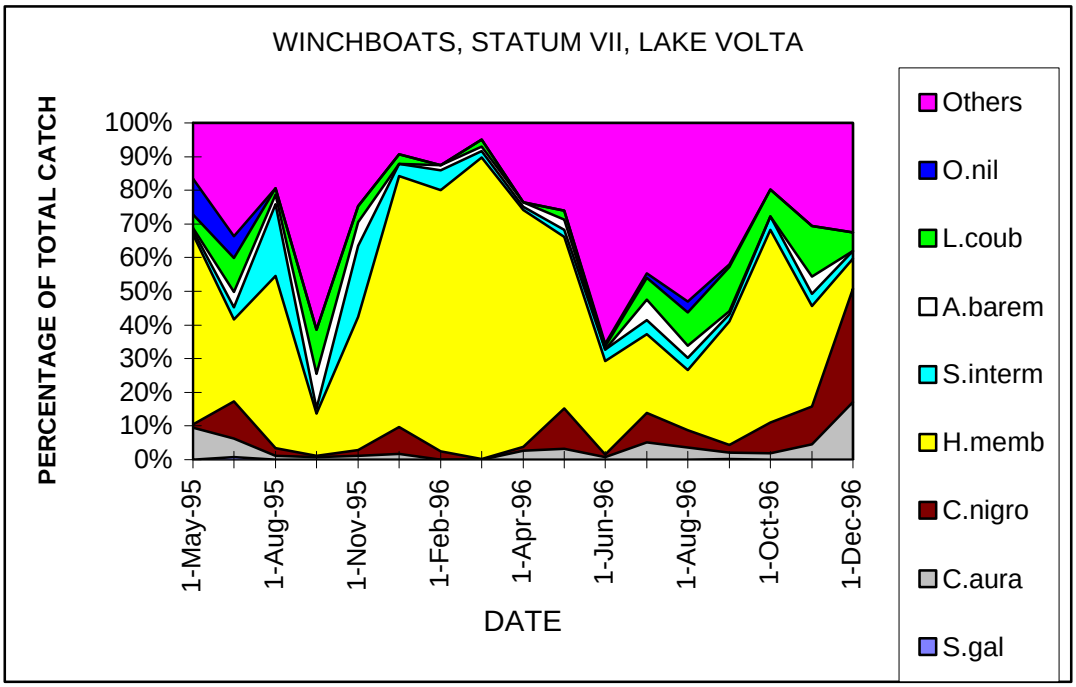
Figure 10: Species composition of gillnets in the Southern area of Stratum VII of Lake Volta.



4.5.2 Winchboats

The obtained data for winchboats did not allow for a differentiation for species composition in North or South. The overall picture for Stratum VII is however clear that the majority of the catch consists of *H. Membraceus* (see Figure 11).

Figure 11: Species composition of winchboats in Stratum VII of Lake Volta.



4.5.3 A Comparison with the results of the Market Survey

4.5.3.1 Total Fish Production

The results of the market survey for 1996 are presented in Table 23.

Table 23: The quantity of smoked, dried or processed fish and its equivalent in fresh fish which passed through the Yeji market in 1996.

Species	*Smoked (t/year)*	*%*	*dried (t/year)*	*%*	*processed (t/year)*	*%*	*Fresh Weight Equivalent (t/year)*
Alestes	63	3.9	27	1.2	90	2.4	201
Bagrus/Aucheno	28	1.7	9	0.4	38	1.0	85
Chrysichthys	787	48.0	178	8.2	965	25.3	2210
Citharinus	5	0.4	1	0.1	6	0.2	15
Clarias	55	3.4	5	0.3	61	1.6	143
Cynothrissa	32	2.0	3	0.1	35	0.9	82
Distichodus	9	0.6	4	0.2	13	0.4	30
Gymnarchus	3	0.2	2	0.1	6	0.2	13
Heterotis	3	0.2	67	3.1	71	1.9	130
Hydrocynus	5	0.3	17	0.8	22	0.6	43
Labeo	201	12.3	52	2.4	253	6.7	578
Lates	2	0.2	11	0.5	13	0.4	26
Mormyridae	18	1.1	60	2.8	78	2.1	152
Schilbeidae	45	2.8	13	0.6	59	1.6	134
Synodontis	302	18.4	65	3.0	367	9.6	842
Tilapia	73	4.5	1656	76.1	1730	45.3	3158
TOTAL	**1639**		**2176**		**3816**		**7852**

The market survey indicated that 7852 tonnes (in fresh fish equivalents) passed through Yeji market in 1996. This is rather low in comparison with a total catch of 33,700 as obtained from the Catch Assessment Survey. The major reasons are;

* 44% of all villages in Stratum VII are using Yeji as their only market.

* The fresh weight equivalent was calculated with conversion factors of 1.5 -2. Preliminary results of the fish processing research programme indicated that the conversion factor should be in the order of 2 -3, which would increase the fresh weight equivalent to about 15,000 t/year.

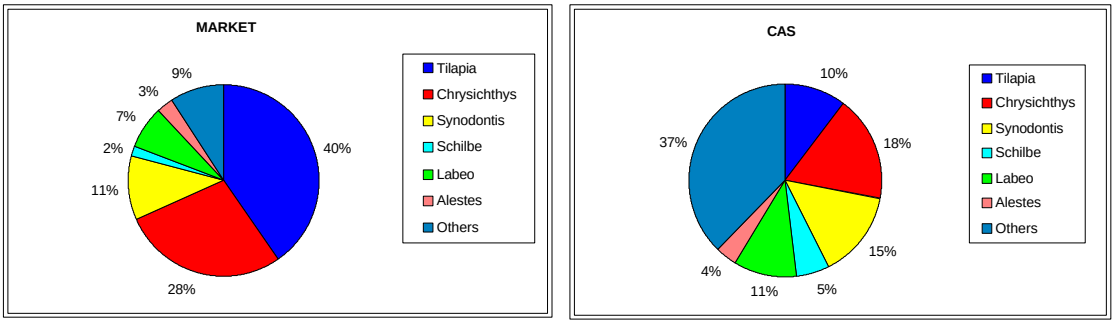
* Home consumption of fish in Stratum VII was estimated at 4,500 t/year and is not accounted for in the market survey.

In general it can be concluded that the market survey confirms the results of the catch assessment survey and in the future more attention should be given to the used conversion factors and other outlet channels in Stratum VII.

4.5.3.2 Species composition

A comparison of the species composition as obtained through the market survey and the catch assessment survey is presented in Figure 12.

Figure 12: Species composition as obtained with the market and catch assessment survey.



Both surveys indicate that *Tilapia spp*, *Chrysichthys spp*. and *Hemisynodontis/Synodontis spp.* are the major species. There are however large differences between the two estimates. In the market survey the mentioned species are covering 79%, while in the catch assessment survey they cover only 43%. In the market survey *Tilapia spp*. are the most important while *"Other species"* are the most important in the catch assessment survey. The differences are most likely caused by;

- The catch assessment survey covers mainly gillnets and winchboats. Traps and Nifa nifa are not covered. These gears are however very site specific and are mainly catching *Tilapia spp.* It indicates that in the catch assessment survey more stratification types have to be used.

- *Tilapia spp* are the highest priced species and are most likely only sold while the less valuable species are used for home consumption. A small survey could verify this phenomena.

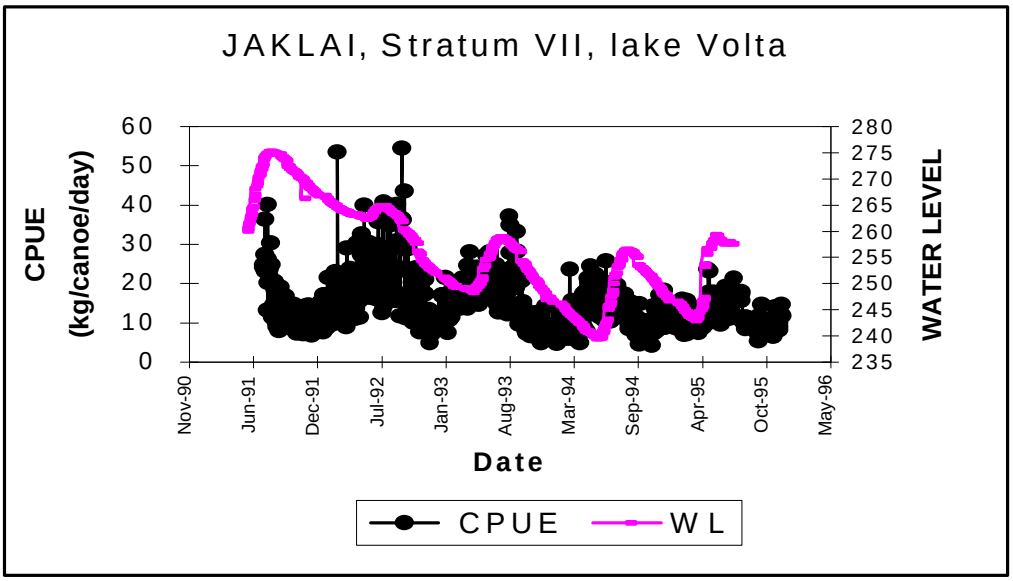
4.6 Biological and technical interactions

4.6.1 The impact of waterlevel

A particular phenomena of Lake Volta the seasonal fluctuation of the waterlevel. Therefore it can be expected that typical "floodplain" characteristics in fisheries such as the *"floodpulse concept"*, *"seasonal growth"*, *"seasonal reproduction related to water level"*, etc are also valid in Lake Volta.

In a large number of floodplains the fish catch depends[7] on the floodlevel. It could be reasoned that the decline in the CPUE is caused also by a decline in the floodlevels as observed the last years in Lake Volta.
Waterlevels as measured at Akosombo were obtained from the Volta River Authority (VRA) and modified for a time lag in Stratum VII by using a similar set measured in the Pru river in Stratum VII. The water levels and the CPUE of the canoes are presented in Figure 13

Figure 13: CPUE of Stratum VII in relation to waterlevels.



The results seems to indicate the existence of a relation between the water level and the fish catch.

Therefore it could be concluded that the decline of the CPUE is caused by an increased number of canoes and a reduced waterlevel. A multi linear regression analysis of both factors on the CPUE indicated that both partial coefficients are significant ($P < 0.05$) and the relation could be described with;

$$CPUE = -0.00275 * No.\ of\ canoes + 0{,}0958 * Waterlevel + 10{,}0327$$

This analysis stresses again the importance of long term data series as the picture could become more clear if we have observation during a period of high water levels.

Other factors could also be a source of the seasonal fluctuation in CPUE:

- The fishermen start to use larger mesh sizes as the “milky water” arrives and they do so because they know that they catch more fish with the larger mesh

[7] and of course on the fishing effort

sizes This could be true but it could also be an effect of a better catchability due to the higher turbidity. In order to clarify this, monthly a fixed traject (inshore and offshore) should be measured with the echo-sounder in order to determine if their are seasonal changes in abundancy**.**

4.6.2 Differences within Stratum VII

If there are differences in the CPUE among zones within Stratum VII one of the first questions is ***"why this difference ?"***

In general it can be stated that CPUE is related to factors such as: mesh size, the season, the number of bundles used per canoe, the fishing effort or number of fishermen per canoe, fishing effort as the number of days the gear is in the water, mono or multi-filament nets, fishing skill of the fishermen, habitat, inshore or offshore fishing, water depth, turbidity or *"milky water"*, soil type, etc.

The impact of a number of the mentioned factors, which were monitored during the CAS, on the catch per canoe or the catch per bundle is analysed with a multi-linear regression analysis (Stepwise) and the Sum of squares was used as a measure of the relative weight each factor has in explaining the total variation.

The relation between the CPUE-canoe and mesh size, number of bundles used, no. of days the gear is set and the number of assistants can be described with:

CPUE-canoe = -0.678*Mesh +3.108*Bundles + 2.028*Days + 2.606*Assistents+0.000*Month
(*P*=0.000)

Table 24: Relative contribution of each factor to the CPUE-canoe and the significance of the partial regression coefficients.

Factor	*df*	*% Sum of Squares*	*F-value*	*Significance*
Mesh	1	2.5	4.37	0.037
Bundles	1	51.9	89.28	0.000
Days	1	7.2	12.40	0.000
Assistants	1	37.5	64.49	0.000
Month	1	0.7	1.19	0.276

The analysis indicated that 57% of the variation can be explained by the indicated parameters. It further indicates that the CPUE-canoe is largely influenced by the number of bundles used and the number of assistants per canoes. This is logical because more gears and more fishermen are giving a higher catch. The influence of

mesh size, days the gear is set and season[8] is outnumbered by the above mentioned factors.

Therefore a better insight in the catch will be obtained by analysing the Catch per bundle (CPUE-bundles)

The relation between the CPUE-bundles and mesh size, number of days the gear is set, the number of assistants and the month can be described with:

CPUE-canoe = -0.624*Mesh + 1.43*Days + 1.23*Assistents +0.000*Month
($P \leq 0.000$)

Table 24: Relative contribution of each factor to the CPUE-bundle and the significance of the partial regression coefficients.

Factor	*df*	*% Sum of Squares*	*F-value*	*Significance*
Mesh	1	7.12	8.92	0.003
Days	1	11,28	14.38	0.000
Assistants	1	26.8	34.15	0.000
Month	1	54.75	69.69	0.000

55% of the total variation of the CPUE-bundles can be explained by the used indicators. Furthermore it becomes clear that a major factor influencing the CPUE-bundle is the season followed by the number of days the gear is set.

The question remains whether differences in the number of bundles used, the number of days the gear is set or the number of assistants per canoe in the three geographical sub-strata could explain the difference in the catches per canoe.

Differences of the major factors influencing the CPUE-canoe in the three geographical sub-strata are analysed again with an ANOVA and the results are presented in Table 25.

Table 25: Mean values of the average mesh size, the number of bundles, the number of days the gears are set and the number of assistants per canoe in the northern, central and southern area of Stratum VII of Lake Volta. (different superscripts indicate significant difference).

Stratum	*Mesh size*	*No of bundles*	*Days set*	*No. of Assistants*
North	$2.14^{a}\pm0.05$	$1.56^{a}\pm0.05$	$1.03^{a}\pm0.03$	$2.02^{a}\pm0.04$
Central	$2.71^{b}\pm0.05$	$1.91^{b}\pm0.04$	$1.34^{b}\pm0.02$	$1.79^{c}\pm0.03$
South	$2.60^{b}\pm0.07$	$1.62^{b}\pm0.08$	$1.73^{c}\pm0.52$	$2.52^{c}\pm0.06$

[8] Month in the model is entered in the international computer code for days which means that 1-Jan-96 is coded as a number: 30400, this could also limited the impact of seasonality. This point will be checked in the near future.

Significant differences are found for the different areas of Stratum VII but they cannot yet directly explain the different in catches and it is recommended to carry out an in-depth analysis in the near future (World Bank project).

5. LENGTH BASED STOCK ASSESSMENT PROGRAMME.

In addition to the traditional catch and effort data collection a length-based stock-assessment programme was carried out in Stratum VII of Lake Volta. It was the first time that such a programme was used for the fish stocks of Lake Volta. Therefore within this chapter the methods used and the results are discussed and where necessary details are explained.

5.1 Species and gears

60-70 % of the catch in Stratum VII is comprised of *O. niloticus, S. galileus, H. membraceus, C. nigrodigitatus, C. auratus, S. intermedius* and *L. coubie*. Therefore it was decided to concentrate on those species only. The major gears used in Stratum VII are gillnets and the winchboats and they were the only gear sampled for the length-based programme.

5.2 Sampling programme

The length-based sampling programme started in June 1995 and was continued till December 1996. Sampling was carried out monthly in the Central part and bi-monthly in the Northern and Southern part of stratum VII.

Commercial winchboats could not be sampled as the fishermen/fish processors did not allow that the fish were measured. Obtaining samples by buying the fish was also not possible. Therefore the project decided to purchase a winchboat with a purse seine (mesh 2 inch, stretched) and all samples were obtained from experimental fishing. It is assumed that the catches are representative for the commercial winchboats.

Gillnets could be sampled by project staff members as long as not all species within one catch was measured. The latter was acceptable since it would take too much time and the women want to have their fish so they could start the processing.

The standard length of the individual fishes was measured with an accuracy of 0.5 cm and from at least 200 fishes the individual weight was recorded in order to determine the length-weight relationship.

5.3 Analysis of data

A preliminary analysis indicated that there were no direct differences for the Northern, Central and Southern part of stratum VII. Therefore it was decided to group[9] all data and carry out one analysis for the whole of Stratum VII. Only a complete analysis for 1996 could be made, this as the sampling programme did not cover two complete years.

The used analytical methods are well described by Sparre and Venema (1992[10]) and are therefore only summarised in this chapter. For the Yield per Recruit Analysis the project designed a spreadsheet model in MsExcel and all further analysis was carried out by using the computer program FISAT[11].

5.3.1 Growth parameters

Growth parameters (k, and $L\infty$) for the von Bertalanffy seasonal growth model were fitted with ELEFAN to grouped length frequency data (gillnets and winchboats combined).While t_0 was calculated from the formula;

$$\mathbf{Log_{10}(-t_0) = -0.392-0.275Log_{10}(L\infty) -1.038Log_{10}(k)}$$

The growth performance indice φ (phi prime) was calculated from;

$$\mathbf{\varphi = Log_{10}(k) + 2Log_{10}(L\infty)}$$

5.3.2 Mortalities

Total mortality rate (Z) was estimated using the using the linearized length converted catch curve method, using the growth parameters from the von Bertalanffy

---

9 This increased the sample size and improved the final results of the analysis.

10 Sparre P. & Venema S.C. (1992) Introduction to tropical fish stock-assessment. Part 1-manual. FAO Fisheries Technical Paper 306/1 Rev. 1, 337 pp.

11 FAO ICLARM STOCK ASSESSMENT TOOLS

plot as input data. Natural mortality (M) was estimated with Pauly's empirical relation ship:

$$\mathbf{Ln\ (M) = -0.4851 - 0.0824Ln\ (L\infty) + 0.6543Ln(k)+0.463Ln(T)}$$

An average water temperature of 29.8 ^{o}C was used for the estimate of M.

5.3.3 Yield per Recruit Analysis

Yield per Recruit was calculated in two different ways;

- Relative Yield per Recruit model which uses the selection ogives as obtained from the length converted catch curve and the parameters L∞, M and k. This method is a basic option of FISAT and details are described in the FISAT manual.

- A length-based Beverton and Holt model which considers the length of first rcruitment into the system[12] (Lr) and Length of first capture (Lc) and calculates the Yield per recruit as follows:

$$\mathbf{Y/R = F*A*W\infty*[1/Z - 3U/(Z+K) + 3U^2/(Z+2K) - U^3/(Z+3K)]}$$

Whereby;

$$\mathbf{A = [\ L\infty\text{-}Lc/L\infty\text{-}Lr]^{M/K}}$$

Lc or $L_{50\%}$ is length at which 50% of the fish is caught by the gear
Lr is Length at first recruitment into the system

$$\mathbf{U = 1 - (Lc/L\infty)}$$

5.3.4 Estimation of fishing mortality from Cohort Analysis

A length cohort analysis or Virtual Population Analysis (VPA) was used to estimate the stock size and fishing mortality. The input parameters were: terminal exploitation rate (F/Z), M, k, L∞ and a and b in the length weight relationship. The terminal exploitation rate was chosen so that the exploitation rate of the last 4-5 length groups became approximately equal as they are fully exploited.

5.3.5 Predictive Analysis

[12] for all species kept at 1 cm

Catch and stock biomass are predicted for various levels of fishing effort , using the length-based Thompson and Bell models. Whereby the results of the VPA were used as input parameters

In the next chapter for each species the results will be presented and discussed in a summary.

5.4 Hemisynodontis membraceus

5.4.1 Growth parameters

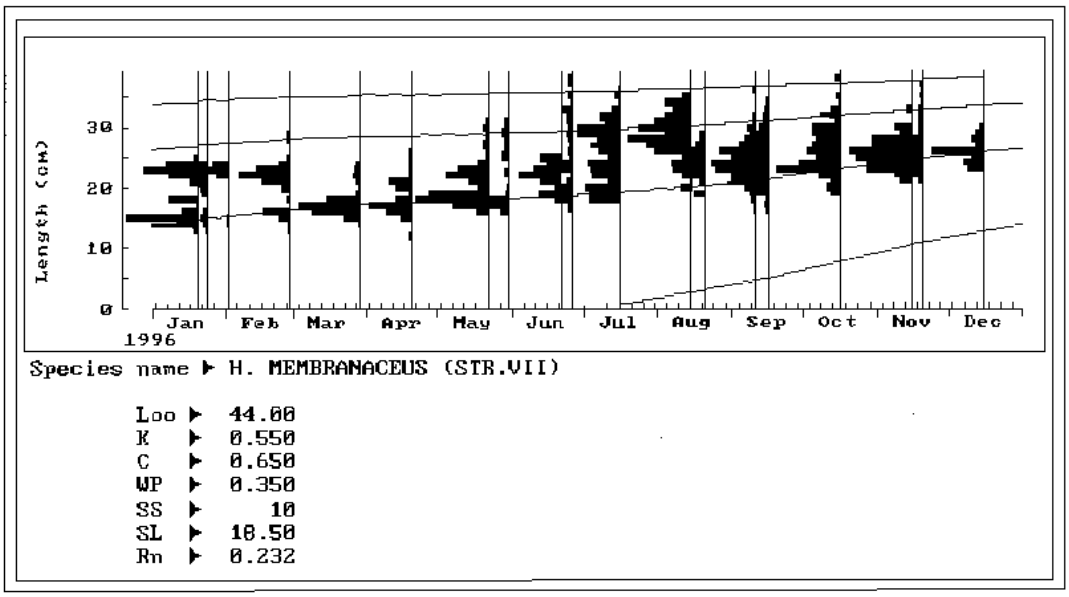
The growth parameters of *H. membraceus* for 1996 are presented in Table 26.

Table 26: Growth parameters as estimated with ELEFAN for *H. membraceus* for Stratum VII of Lake Volta.

Parameter	
$L\infty$	44 cm
K	0.55 $year^{-1}$
C	0.65
Wp	0.35 year
t_0	0.26 year
Rn	0.232
φ	3.0273

Figure 14 shows the growth curves superimposed on the length frequency data.

Figure 14: Length frequency data and estimated growth curves of *H. membraceus* in Stratum VII of Lake Volta.



The results indicates that at least 4 cohorts are found in the fisheries.

The length weight relation ship could be described with:

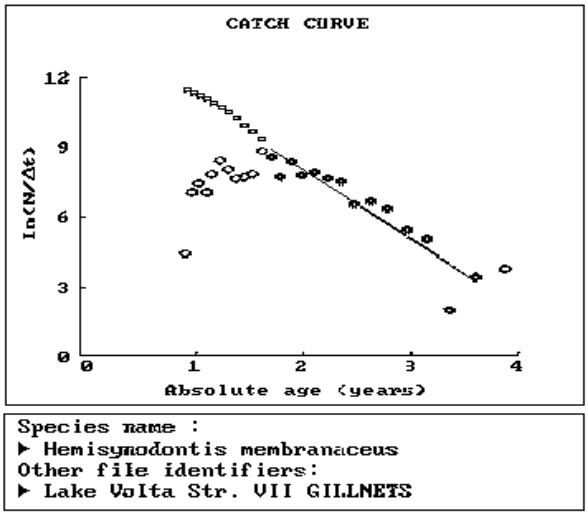
$$W = 0.0157\ L^{3.23}$$

5.4.2 Gillnets

5.4.2.1 Mortality rates

The linearised catch curve of *H. membraceus* for gillnets is presented in Figure 15.

Figure 15: The length converted catch curve of *H. membraceus* for gillnets in stratum VII of Lake Volta.



Parameter estimates as obtained from the catch curve are presented in Table 27.

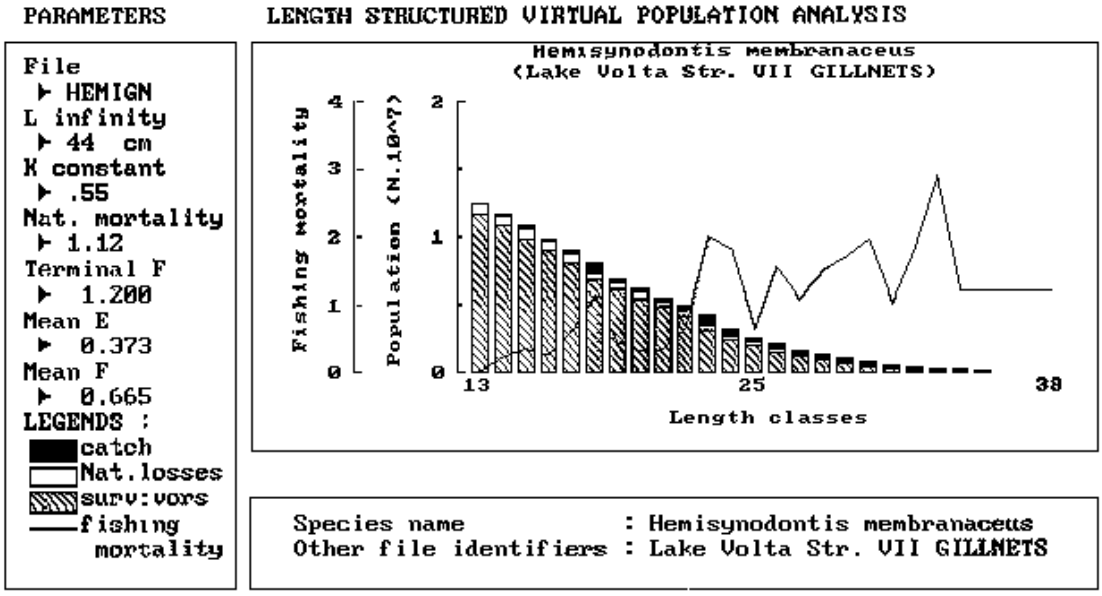
Table 27: Parameter estimates as obtained from a length converted catch curve for *H. membraceus* caught by gillnets in Stratum VII of Lake Volta.

Parameter	
Total mortality (Z, year^{-1})	3.94
Natural mortality (M, year^{-1})	1.12
Fishing mortality (F, year^{-1})	2.82
Exploitation rate (E)	0.72
Cut-off length (L', cm)	23.5
Mean length (from L', cm)	27.6
L25 (cm)	21.7
L50 (cm)	22.6
L75 (cm)	23.54

5.4.2.2 Virtual Population Analysis

The fishing mortality (F) of gillnets per length group as obtained from a VPA is presented in Figure 16.

Figure 16: Fishing mortality from gillnets for *H. membraceus* in stratum VII of Lake Volta.

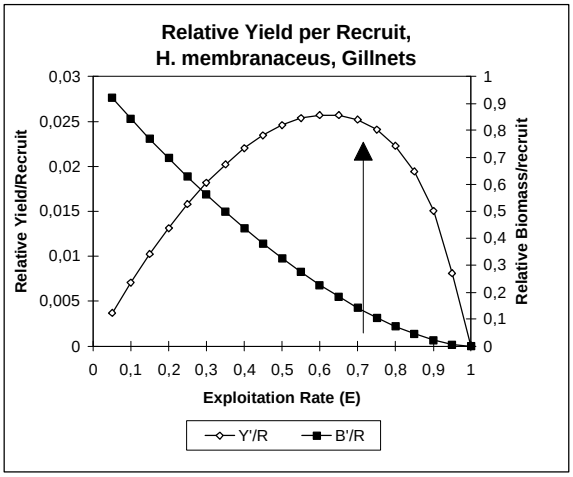


There are two visible peaks in fishing mortality; one small peak at 17 cm and a relative wide peak at 22-30 cm. The difference could be caused by the different mesh sizes or by the different habitats where the gill nets were used. The total catch of *H. membraceus* by gillnets in 1996 was 1927 tonnes.

5.4.2.3 Yield per Recruit Analysis

The results of the Relative Yield per Recruit Analysis is presented in Figure 17.

Figure 17: Relative Yield per Recruit of *H. membraceus* caught by gill nets.



The present Exploitation rate was estimated at 0.72 (see table 27) and is indicated by a arrow. The analysis indicated a maximum exploitation rate of 0.62, a $E_{0.1}$ =0.59 and a $E_{0,5\ of\ B/R}$ = 0,35. If all data are representative it would mean that the exploitation rate of the gillnets is too high.

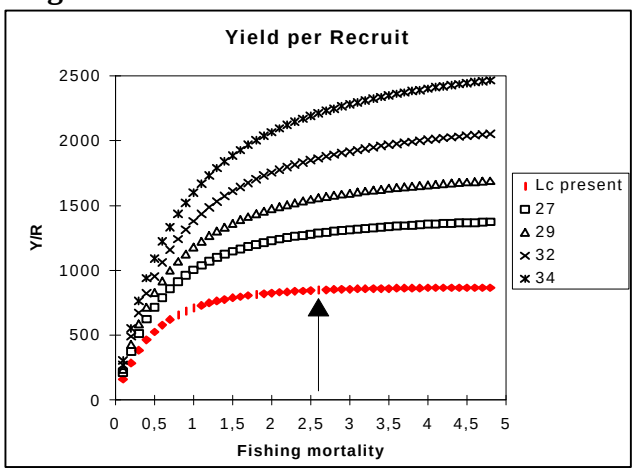
The input data used in the Yield per Recruit analysis following the length-based Beverton and Holt model are presented in Table 28.

Table 28: Input parameters Y/R analysis for *H. membraceus*

SPECIES	*Hemisynodontis Membraceus*			
GEARTYPE	Gill nets			
L∞	44	cm	k	0,55
Lr	1	cm	M	1,12
Lc present	22,60	cm	F	2,82
Lc/L∞	0,51		a	0,0157
F present	2,82	year	b	3,23

The Yield per Recruit curve obtained with those input parameters is presented in Figure 18.

Figure 18: Yield per Recruits of *H. membraceus* for gill nets in stratum VII of Lake Volta.



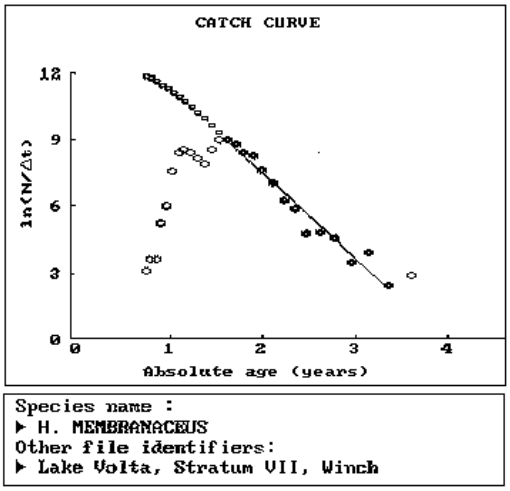
The present Fishing mortality of gillnets for *H. membraceus* was estimated before at 2.82 (indicated by the arrow) which is larger as the F_{MSY} = 2. Again it would mean over exploitation[13], especially *"growth overfishing"*, the fish are caught too early and the growth potential is not used optimally. Increasing the length at first capture would increase the Yield per Recruit.

5.4.3 Winchboats

5.4.3.1 Mortality rates

The linearised catch curve of *H. membraceus* for winchboats is presented in Figure 19.

Figure 19: The length converted catch curve of *H. membraceus* for winchboats in stratum VII of Lake Volta.



Parameter estimates as obtained from the catch curve are presented in Table 29.

[13] If the data are representative

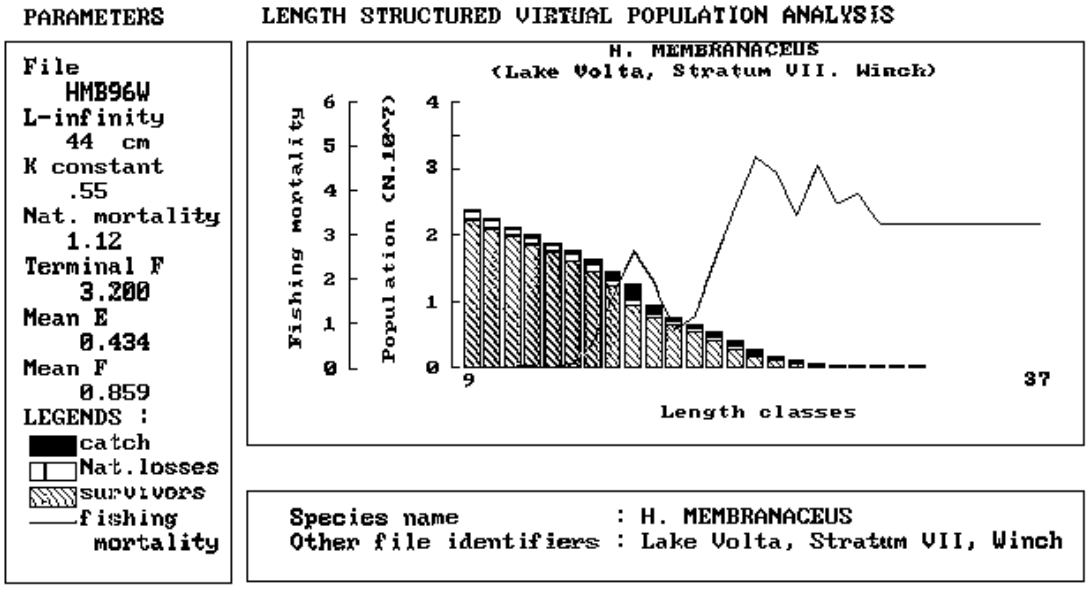
Table 29: Parameter estimates as obtained from a length converted catch curve for *H. membraceus* caught by winchboats in Stratum VII of Lake Volta.

Parameter	
Total mortality (Z, year^{-1})	4.03
Natural mortality (M, year^{-1})	1.12
Fishing mortality (F, year^{-1})	2.91
Exploitation rate (E)	0.72
Cut-off length (L', cm)	22.5
Mean length (from L', cm)	25.1
L25 (cm)	20.3
L50 (cm)	21.3
L75 (cm)	22.2

5.4.3.2 Virtual Population Analysis

The fishing mortality (F) of winchboats per length group as obtained from a VPA is presented in Figure 20.

Figure 20: Fishing mortality from winchboats for *H. membraceus* in stratum VII of Lake Volta.



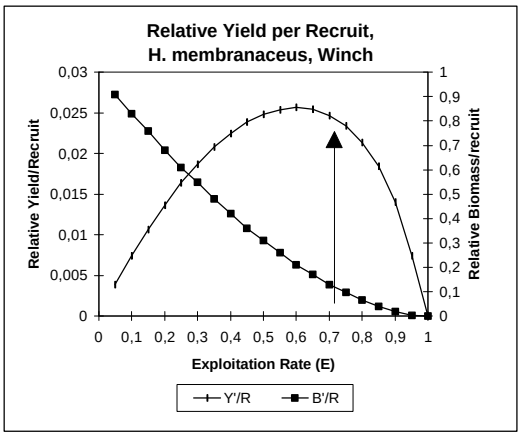
There are two visible peaks in fishing mortality; one small peak at 17 cm and a second peak which starts at 23 cm. It seems that the winchboats, which are operating in the main channel/open water are not catching *H. membraceus* with a length of 19-21 cm. This could be an artefact, but this phenomena was also observed in 1995.

Therefore it is most likely related to behaviour of the fish. At present it is assumed that this length group migrate to the inshore waters/waters with tree stumps in order to reproduce. This should be checked in the future, as this hypothesis is not coherent with the Length at first recruitment of 28.5 cm currently used. The total catch of *H. membraceus* by winchboats in 1996 was 2647 tonnes.

5.4.3.3 Yield per Recruit Analysis

The results of the Relative Yield per Recruit Analysis is presented in Figure 21.

Figure 21: Relative Yield per Recruit of *H. membraceus* caught by winchboats.



The present Exploitation rate was estimated at 0.72 (see table 29) and is indicated by a arrow. The analysis indicated a maximum exploitation rate of 0.59, a $E_{0.1}$ =0.57 and a $E_{0,5 \text{ of } B/R}$ = 0,31. If all data are representative it would mean that the exploitation rate of the winchboats is too high.

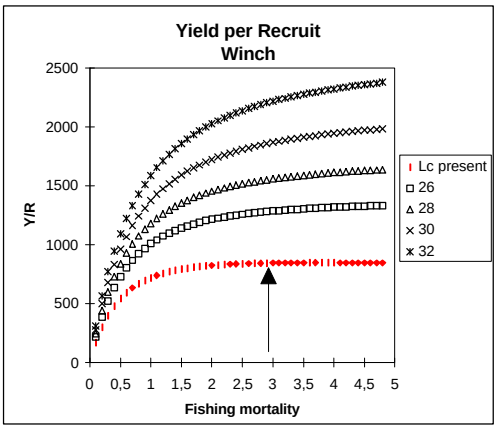
The input data used in the Yield per Recruit analysis following the length-based Beverton and Holt model are presented in Table 30.

Table 30: Input parameters Y/R analysis for *H. membraceus*.

SPECIES	*Hemisynodontis Membraceus*			
GEARTYPE	Winch			
L∞	44	cm	k	0,55
Lr	1	cm	M	1,12
Lc present	21.3	cm	F	2,91
Lc/L∞	0,51		a	0,0157
F present	2,91	year	b	3,23

The Yield per Recruit curve obtained with those input parameters is presented in Figure 22.

Figure 22: Yield per Recruits of *H. membraceus* for winchboats in stratum VII of Lake Volta.

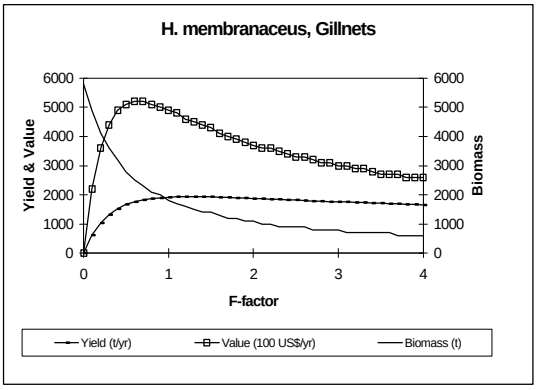


The present Fishing mortality of winchboats for *H. membraceus* was estimated before at 2.91 (indicated by the arrow) which is larger as the F_{MSY} = 2. Again it would mean over exploitation[14], especially "*growth overfishing*", the fish are caught too early and the growth potential is not used optimally. Increasing the length at first capture would increase the Yield per Recruit.

5.4.4 Thompson and Bell prediction for *H. membraceus*

The results of the VPA analysis were used for prediction of catch and value with a Thompson and Bell model. The results for gillnets, winchboats and the cumulative values are presented in Figures 23, 24 & 25.

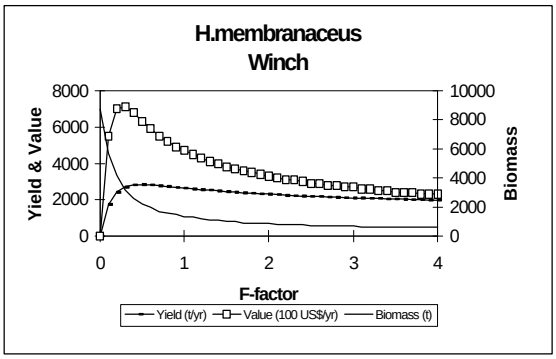
Figure 23: Thompson and Bell analysis for *H. membraceus* caught by gillnets.



At the present fishing effort (F_{factor}=1) the annual catch of gillnets is estimated 1927 tonnes with a value of 490.000 USD/yr.
The optimal fishing effort considering yield is F_{factor}=1.1 (Yield=1941 t/yr). The optimal economic fishing effort is F_{factor} =0.6 (Value=520,000 USD/yr).

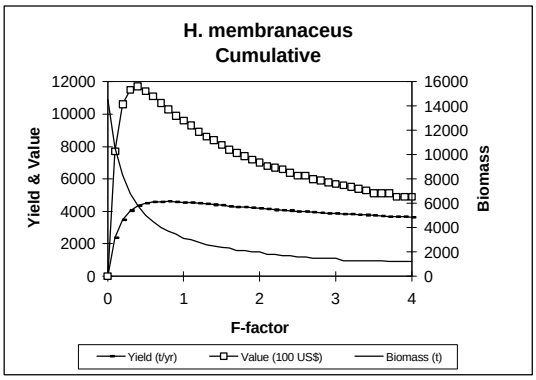
[14] If the data are representative

Figure 24: Thompson and Bell analysis for *H. membraceus* caught by winchboats.



At the present fishing effort (F_{factor}=1) the annual catch of winchboats is estimated 2647 tonnes with a value of 475.000 USD/yr.
The optimal fishing effort considering yield is F_{factor} =0.5 (Yield=2832 t/yr). The optimal economic fishing effort is F_{factor} =0.2 (Value=712,000 USD/yr).

Figure 25: Cumulative Thompson and Bell analysis for *H. membraceus*.



At the present fishing effort (F_{factor} =1) the annual cumulative catch is estimated 4574 tonnes with a value of 969.000 USD/yr.
The optimal fishing effort considering yield is F_{factor} =0.8 (Yield=4601 t/yr). The optimal economic fishing effort is F_{factor} =0.4 (Value=1.15 million USD/yr).

5.5 Chrysichthys nigrodigitatus

5.5.1 Growth parameters

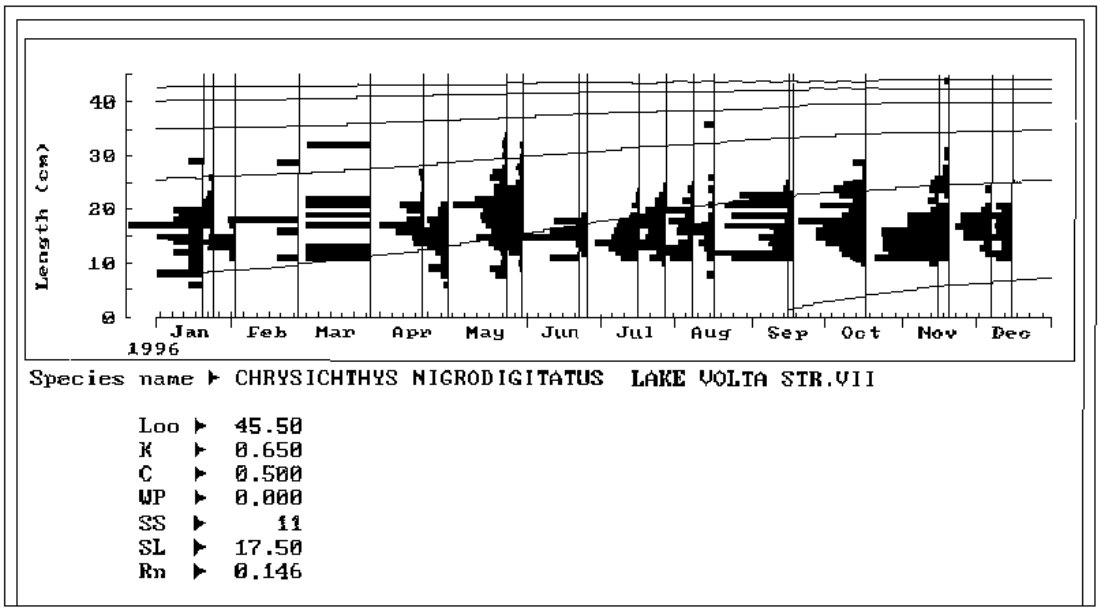
The growth parameters of *C. nigrodigitatus* for 1996 are presented in Table 31.

Table 31: Growth parameters as estimated with ELEFAN for *C. nigrodigitatus* for Stratum VII of Lake Volta.

Parameter	
$L\infty$	44.5 cm
K	0.65 $year^{-1}$
C	0.5
Wp	0.00 year
t_0	0.222 year
Rn	0.146
φ	3.129

Figure 26 shows the growth curves superimposed on the length frequency data.

Figure 26: Length frequency data and estimated growth curves of *C. nigrodigitatus* in Stratum VII of Lake Volta.



The results indicates that at 4-5 cohorts are found in the fisheries. A major problem of the fitted curve are the low sample sizes in February, March and September

The length weight relationship could be described with:

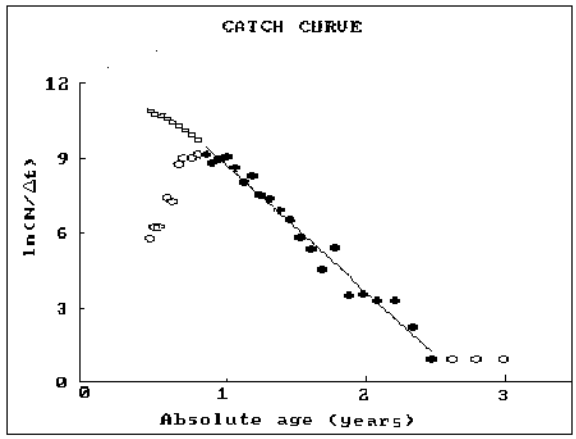
$$W = 0.0336\ L^{2.81}$$

5.5.2 Gillnets

5.5.2.1 Mortality rates

The linearised catch curve of *C. nigrodigitatus* for gillnets is presented in Figure 27.

Figure 27: The length converted catch curve of *C. nigrodigitatus* for gillnets in stratum VII of Lake Volta.



Parameter estimates as obtained from the catch curve are presented in Table 32.

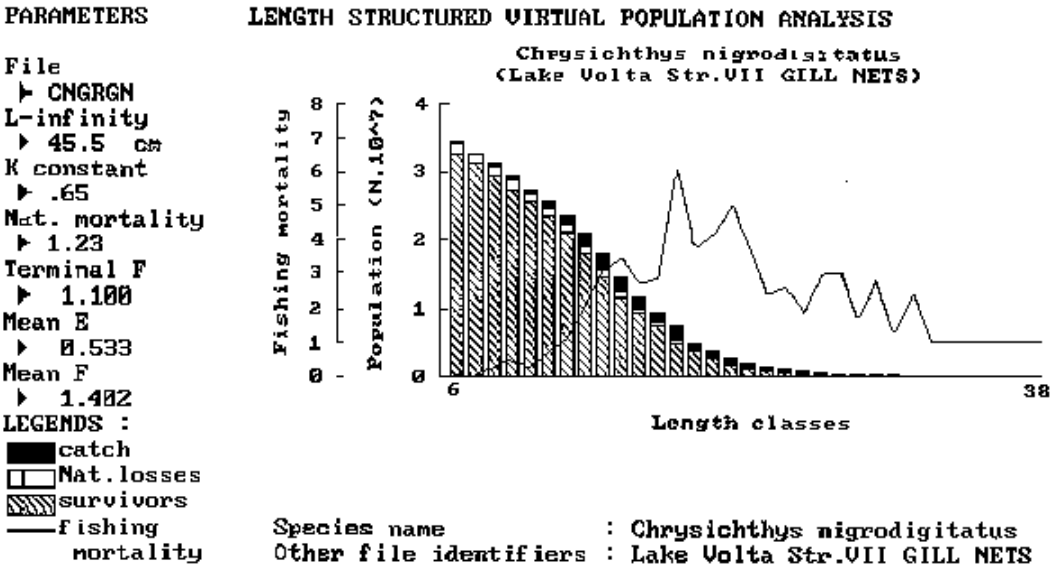
Table 32: Parameter estimates as obtained from a length converted catch curve for *C. nigrodigitatus* caught by gillnets in Stratum VII of Lake Volta.

Parameter	
Total mortality (Z, year^{-1})	4.09
Natural mortality (M, year^{-1})	1.23
Fishing mortality (F, year^{-1})	2.86
Exploitation rate (E)	0.70
Cut-off length (L', cm)	14.5
Mean length (from L', cm)	18.6
L25 (cm)	11.4
L50 (cm)	13.3
L75 (cm)	14.5

5.5.2.2 Virtual Population Analysis

The fishing mortality (F) of gillnets per length group as obtained from a VPA is presented in Figure 28.

Figure 28: Fishing mortality from gillnets for *C. nigrodigitatus* in stratum VII of Lake Volta.

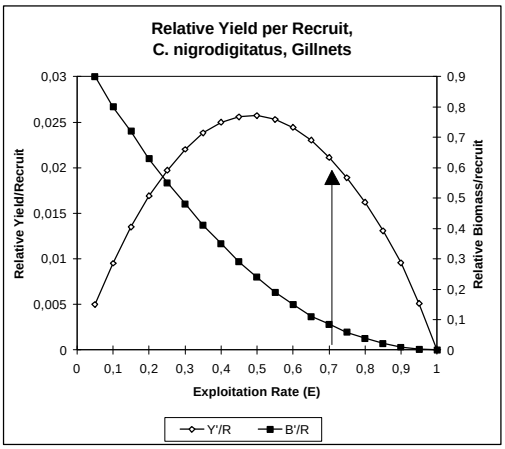


The fishing mortality starts at a length class of 6 cm and gradually increases to a maximum of 6 at a length class of 18 cm. The total catch of *C. nigrodigitatus* by gillnets in 1996 was 1661 tonnes.

5.5.2.3 Yield per Recruit Analysis

The results of the Relative Yield per Recruit Analysis is presented in Figure 29.

Figure 29: Relative Yield per Recruit of *C. nigrodigitatus* caught by gill nets.



The present Exploitation rate was estimated at 0.70 (see table 32) and is indicated by a arrow. The analysis indicated a maximum exploitation rate of 0.48, a $E_{0.1}$ =0.32 and a $E_{0,5\ of\ B/R}$ = 0,37. If all data are representative it would mean that the exploitation rate of the gillnets is too high.

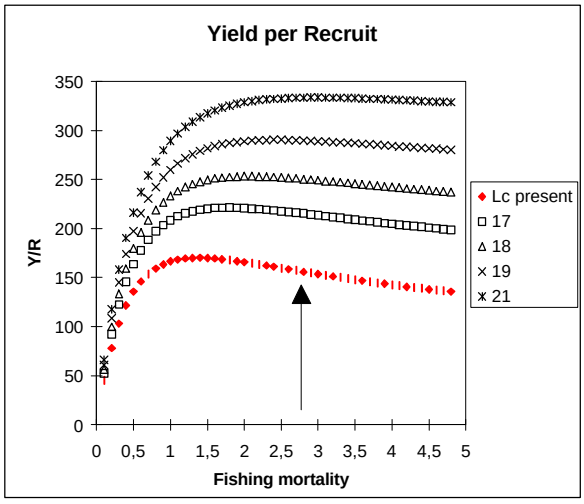
The input data used in the Yield per Recruit analysis following the length-based Beverton and Holt model are presented in Table 33.

Table 33: Input data Y/R analysis for *C. nigrodigitatus*.

SPECIES	*C. nigrodigitatus*			
GEARTYPE	Gill nets			
L∞	45.5	cm	k	0,65
Lr	1	cm	M	1,23
Lc present	13.8	cm	F	2,86
Lc/L∞	0,51		a	0,0366
F present	2,86	year	b	2.81

The Yield per Recruit curve obtained with those input parameters is presented in Figure 30.

Figure 30: Yield per Recruits of *C. nigrodigitatus* for gill nets in stratum VII of Lake Volta.



The present Fishing mortality of gillnets for *C. nigrodigitatus* was estimated before at 2.86 (indicated by the arrow) which is larger as the F_{MSY} = 1. Again it would mean overexploitation[15], especially *"growth overfishing"*, the fish are caught too early and the growth potential is not used optimally. Increasing the length at first capture would increase the Yield per Recruit.

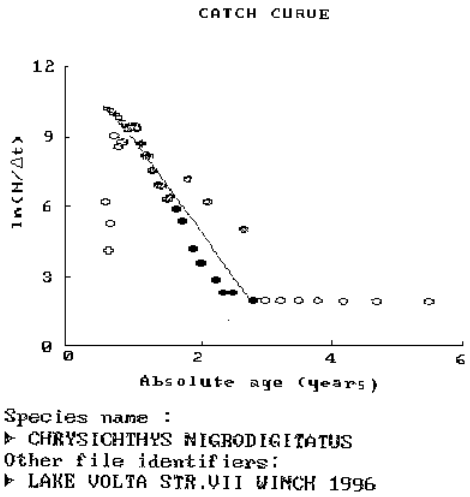
5.5.3 Winchboats

5.5.3.1 Mortality rates

The linearised catch curve of *C. nigrodigitatus* for winchboats is presented in Figure 31.

[15] If the data are representative

Figure 31: The length converted catch curve of *C. nigrodigitatus* for winchboats in stratum VII of Lake Volta.



Parameter estimates as obtained from the catch curve are presented in Table 34.

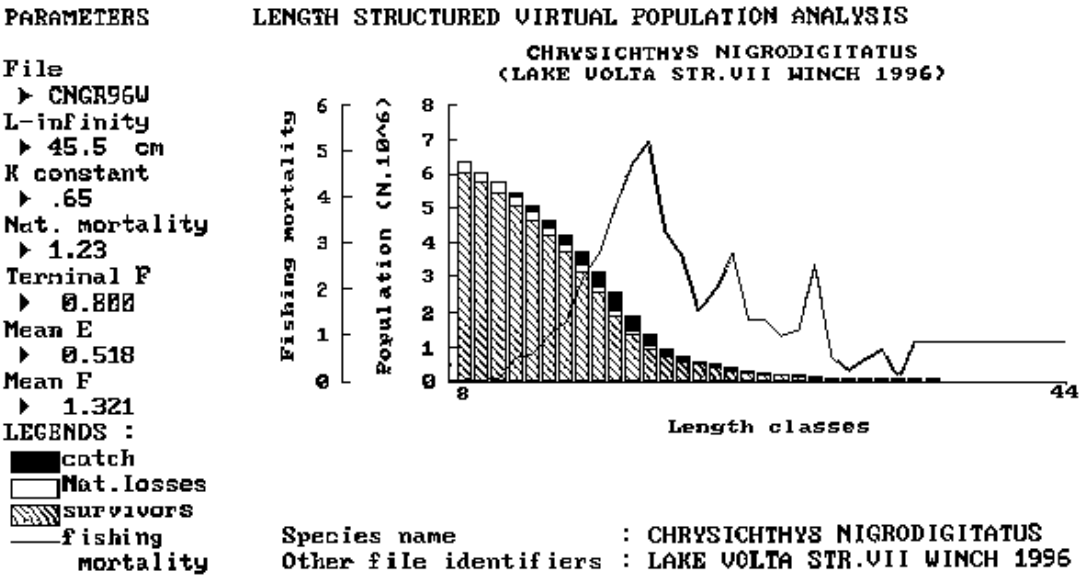
Table 34: Parameter estimates as obtained from a length converted catch curve for *C. nigrodigitatus* caught by winchboats in Stratum VII of Lake Volta.

Parameter	
Total mortality (Z, year^{-1})	3.45
Natural mortality (M, year^{-1})	1.23
Fishing mortality (F, year^{-1})	2.22
Exploitation rate (E)	0.64
Cut-off length (L', cm)	15.5
Mean length (from L', cm)	19.4
L25 (cm)	10.9
L50 (cm)	13.3
L75 (cm)	14.5

5.5.3.2 Virtual Population Analysis

The fishing mortality (F) of winchboats per length group as obtained from a VPA is presented in Figure 32.

Figure 32: Fishing mortality from winchboats for *C. nigrodigitatus* in stratum VII of Lake Volta.

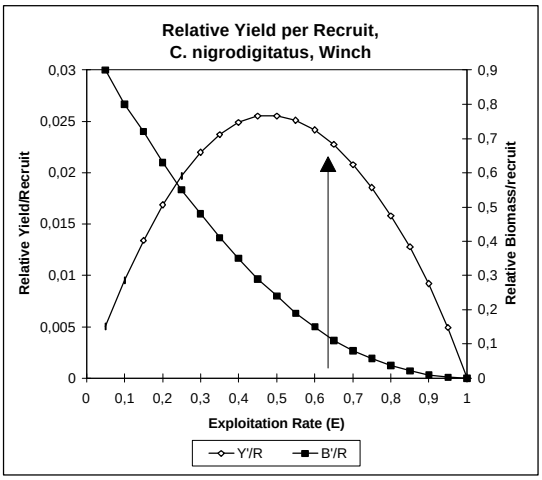


The major fishing mortality of *C. nigrodigitatus* takes place at a length of 17-20 cm. The total catch of *C. nigrodigitatus* by winchboats in 1996 was 366 tonnes.

5.5.3.3 Yield per Recruit Analysis

The results of the Relative Yield per Recruit Analysis is presented in Figure 33.

Figure 33: Relative Yield per Recruit of *C. nigrodigitatus* caught by winchboats.



The present Exploitation rate was estimated at 0.64 (see table 34) and is indicated by a arrow. The analysis indicated a maximum exploitation rate of 0.45, a $E_{0.1}$ =0.37 and a $E_{0,5 \text{ of } B/R}$ = 0,31. If all data are representative it would again mean that the exploitation rate of the winchboats is too high.

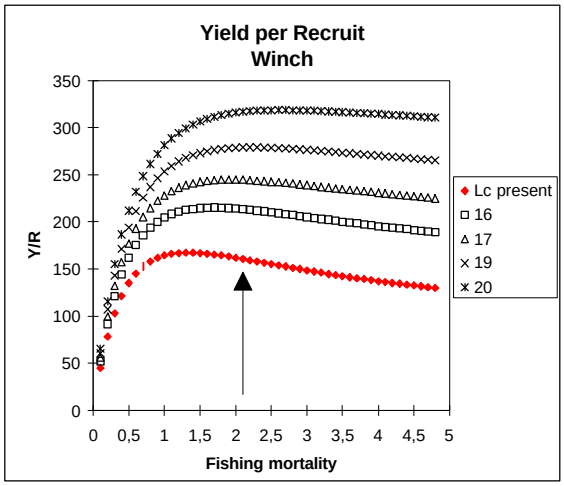
The input data used in the Yield per Recruit analysis following the length-based Beverton and Holt model for C. nigrodigitatus are presented in Table 35.

Table 35: Input parameters Y/R analysis *C. nigrodigitatus*.

SPECIES	*C. nigrodigitatus*			
GEARTYPE	Winch			
L∞	45.5	cm	k	0,65
Lr	1	cm	M	1,23
Lc present	13.3	cm	F	2,22
Lc/L∞	0,3		a	0,0366
F present	2.22	year	b	2.81

The Yield per Recruit curve obtained with those input parameters is presented in Figure 33.

Figure 33: Yield per Recruits of *C. nigrodigitatus* for winchboats in stratum VII of Lake Volta.

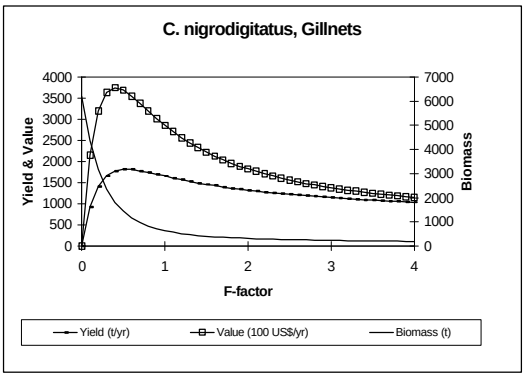


The present Fishing mortality of winchboats for *C. nigrodigitatus* was estimated before at 2.22 (indicated by the arrow) which is larger as the F_{MSY} = 1.3. Again it would mean overexploitation[16], especially *"growth overfishing"*, the fish are caught too early and the growth potential is not used optimally. Increasing the length at first capture would increase the Yield per Recruit.

5.5.4 Thompson and Bell prediction for *C. nigrodigitatus*

The results of the VPA analysis were used for prediction of catch and value with a Thompson and Bell model. The results for gillnets, winchboats and the cumulative values are presented in Figures 34, 35 & 36.

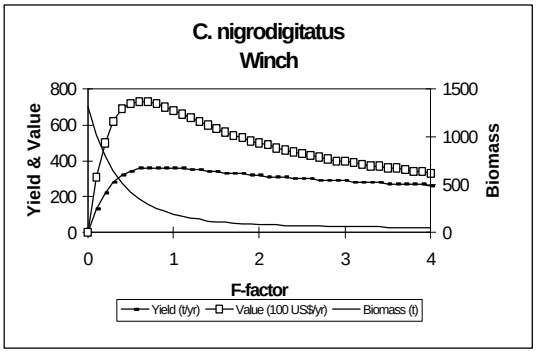
Figure 34: Thompson and Bell analysis for *C. nigrodigitatus* caught by gillnets.



At the present fishing effort (F_{factor} =1) the annual catch of gillnets is estimated at 1660 tonnes with a value of 286.000 USD/yr.
The optimal fishing effort considering yield is F_{factor} =0.4 (Yield=1820 t/yr). The optimal economic fishing effort is F_{factor} =0.3 (Value=375,000 USD/yr).

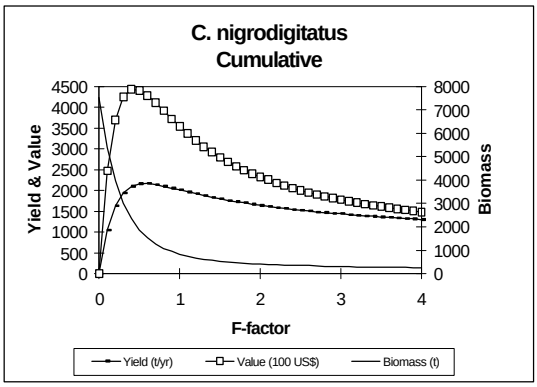
16 If the data are representative

Figure 35: Thompson and Bell analysis for *C. nigrodigitatus* caught by winchboats.



At the present fishing effort (F_{factor} =1) the annual catch of winchboats is estimated 360 tonnes with a value of 68.000 USD/yr.
The optimal fishing effort considering yield is F_{factor} =0.8 (Yield=370 t/yr). The optimal economic fishing effort is F_{factor} =0.6 (Value=73,000 USD/yr).

Figure 36: Cumulative Thompson and Bell analysis for *C. nigrodigitatus.*



At the present fishing effort (F_{factor} =1) the annual cumulative catch is estimated 2027 tonnes with a value of 354.000 USD/yr.
The optimal fishing effort considering yield is F_{factor} =0.6 (Yield=2155 t/yr). The optimal economic fishing effort is F_{factor} =0.4 (Value=442.000 USD/yr). The optimal fishing effort considering the biomass is F_{factor} =0.3.

5.6 Chrysichthys auratus

5.6.1 Growth parameters

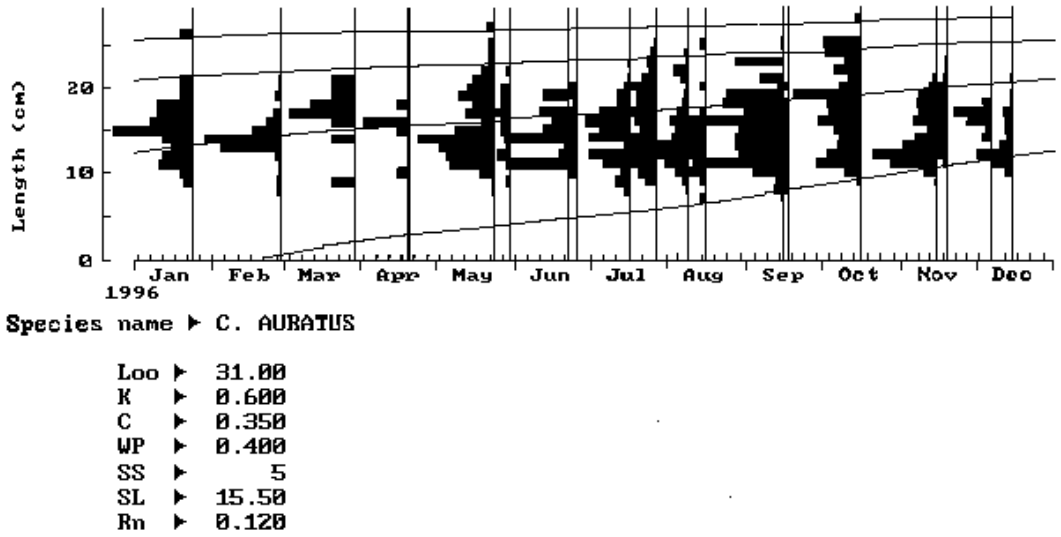
The growth parameters of *C. auratus* for 1996 are presented in Table 36.

Table 36: Growth parameters as estimated with ELEFAN for *C. auratus* for Stratum VII of Lake Volta.

Parameter	
$L\infty$	31 cm
K	0.6 $year^{-1}$
C	0.35
Wp	0.4 year
t_0	0.153 year
Rn	0.120
φ	2.760

Figure 37 shows the growth curves superimposed on the length frequency data.

Figure 37: Length frequency data and estimated growth curves of *C. auratus* in Stratum VII of Lake Volta.



The results indicates that at 4 cohorts are found in the fisheries.

The length weight relationship could be described with:

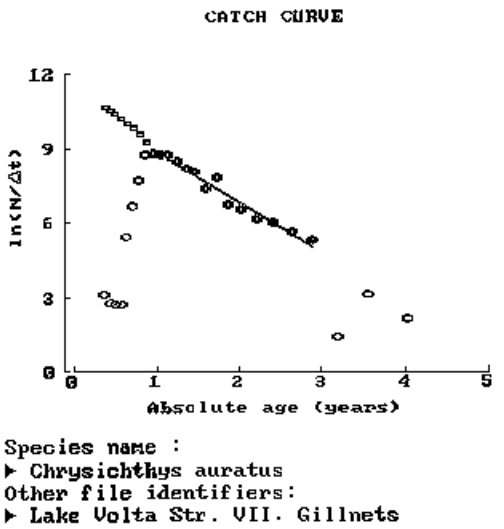
$$W = 0.023\ L^{2.97}$$

5.6.2 Gillnets

5.6.2.1 Mortality rates

The linearised catch curve of *C. auratus* for gillnets is presented in Figure 38.

Figure 38: The length converted catch curve of *C. auratus* for gillnets in Stratum VII of Lake Volta



Parameter estimates as obtained from the catch curve are presented in Table 37.

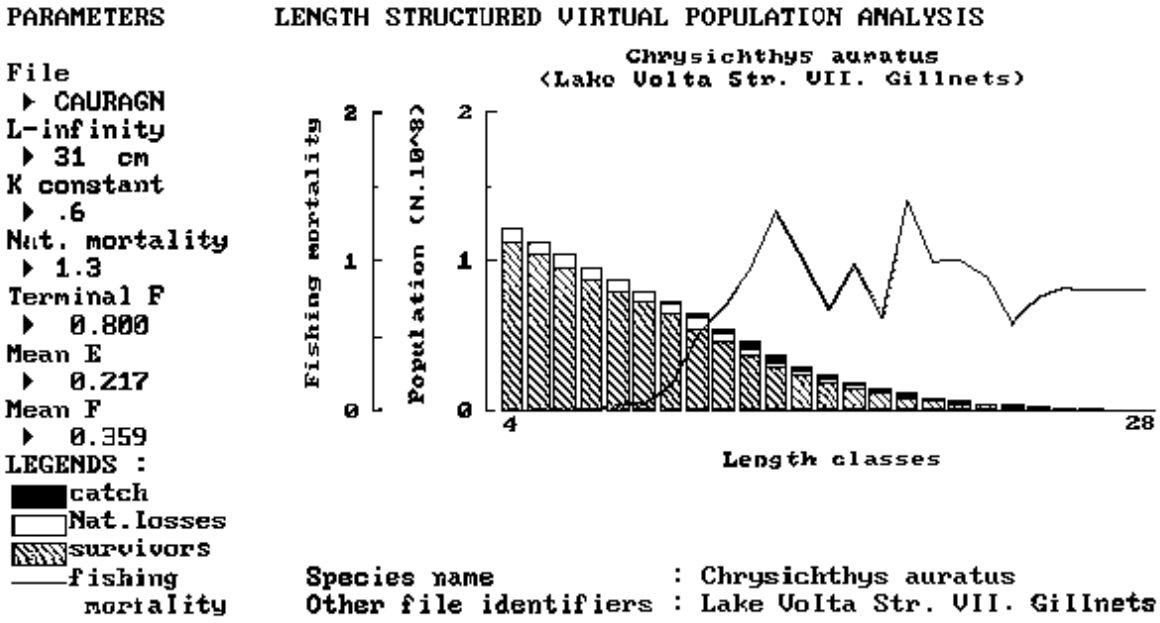
Table 37: Parameter estimates as obtained from a length converted catch curve for *C. auratus* caught by gillnets in Stratum VII of Lake Volta.

Parameter	
Total mortality (Z, year^{-1})	3.30
Natural mortality (M, year^{-1})	1.30
Fishing mortality (F, year^{-1})	2.00
Exploitation rate (E)	0.61
Cut-off length (L', cm)	11.5
Mean length (from L', cm)	15.8
L25 (cm)	9.9
L50 (cm)	10.7
L75 (cm)	11.6

5.6.2.2 Virtual Population Analysis

The fishing mortality (F) of gillnets per length group as obtained from a VPA is presented in Figure 39.

Figure 39: Fishing mortality from gillnets for *C. auratus* in stratum VII of Lake Volta.

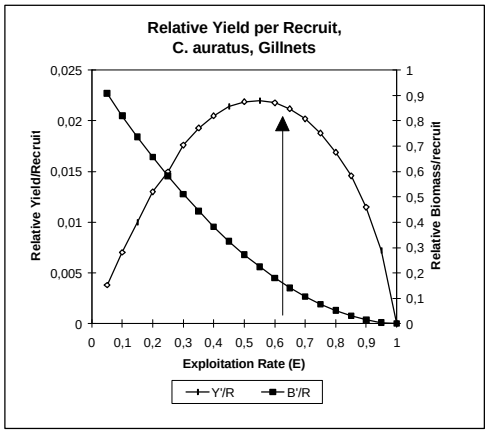


The fishing mortality starts at a length class of 8 cm and gradually increases to two peaks at respectively 13 and 18 cm. The two peaks could be a result of different mesh sizes or fishing habitats. However they could also be the result of the low sample sizes in the length frequency data and the lack of data in the CAS, which are needed to raise the data for a VPA. The total catch of *C. auratus* by gillnets in 1996 was 2153 tonnes.

5.6.2.3 Yield per Recruit Analysis

The results of the Relative Yield per Recruit Analysis is presented in Figure 40.

Figure 40: Relative Yield per Recruit of *C. auratus* caught by gill nets.



The present Exploitation rate was estimated at 0.61 (see table 37) and is indicated by a arrow. The analysis indicated a maximum exploitation rate of 0.54, a $E_{0.1}$ =0.50 and a $E_{0,5\ of\ B/R}$ = 0,31. If all data are representative it would mean that the exploitation rate of the gillnets is too high.

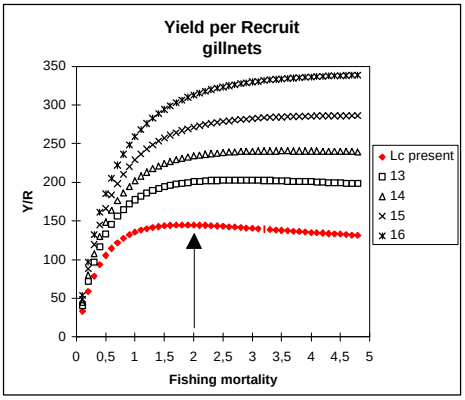
The input data used in the Yield per Recruit analysis following the length-based Beverton and Holt model for *C. auratus* are presented in Table 38.

Table 38: Input parameters Y/R analysis *C. auratus*.

SPECIES	*C. auratus*			
GEARTYPE	Gill nets			
L∞	31	cm	k	0,60
Lr	1	cm	M	1,30
Lc present	10.7	cm	F	2,00
Lc/L∞	0,51		a	0,023
F present	2,0	year	b	2.967

The Yield per Recruit curve obtained with those input parameters is presented in Figure 41.

Figure 41: Yield per Recruits of *C. auratus* for gill nets in stratum VII of Lake Volta.



The present Fishing mortality of gillnets for *C. auratus* was estimated before at 2.00 (indicated by the arrow) which is larger as the F_{MSY} = 1.5 Again it would mean overexploitation[17], especially *"growth overfishing"*, the fish are caught too early and the growth potential is not used optimally. Increasing the length at first capture would increase the Yield per Recruit.

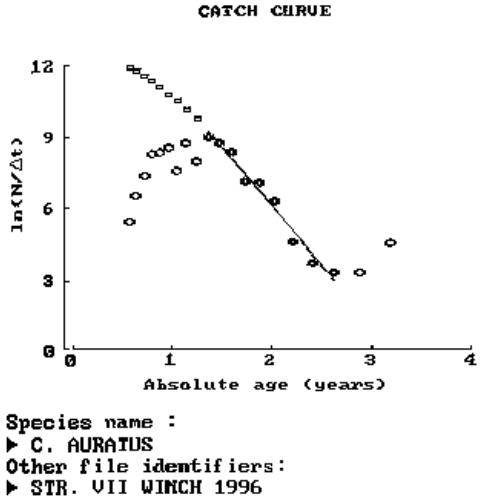
[17] If the data are representative

5.6.3 Winchboats

5.6.3.1 Mortality rates

The linearised catch curve of *C. auratus* for winchboats is presented in Figure 42.

Figure 42: The length converted catch curve of *C. auratus* for winchboats in stratum VII of Lake Volta.



Parameter estimates as obtained from the catch curve are presented in Table 39.

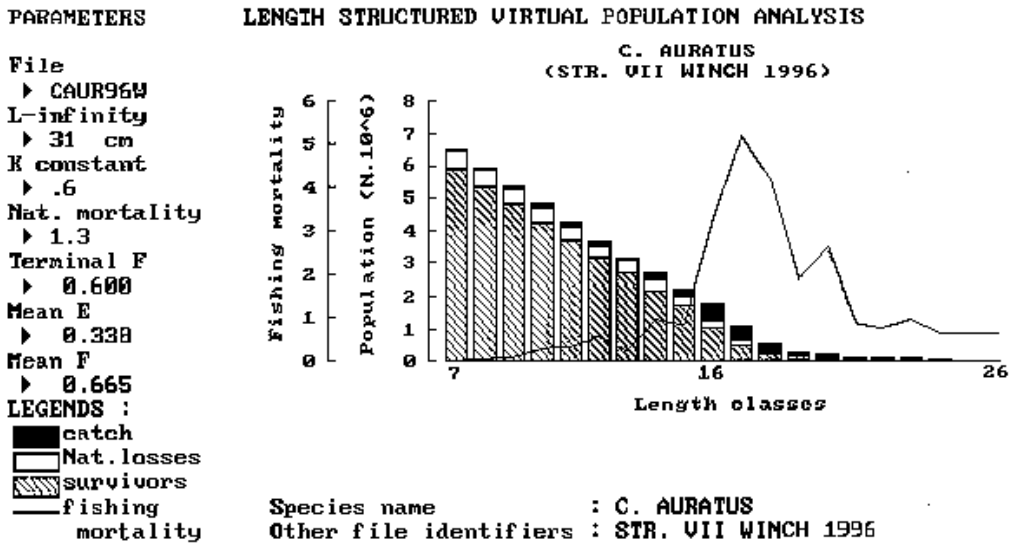
Table 39: Parameter estimates as obtained from a length converted catch curve for *C. auratus* caught by winchboats in Stratum VII of Lake Volta.

Parameter	
Total mortality (Z, year^{-1})	4.04
Natural mortality (M, year^{-1})	1.30
Fishing mortality (F, year^{-1})	2.74
Exploitation rate (E)	0.68
Cut-off length (L', cm)	15.5
Mean length (from L', cm)	17.5
L25 (cm)	14.3
L50 (cm)	15.1
L75 (cm)	16.1

5.6.3.2 Virtual Population Analysis

The fishing mortality (F) of winchboats per length group as obtained from a VPA is presented in Figure 43.

Figure 43: Fishing mortality from winchboats for *C. auratus* in stratum VII of Lake Volta.

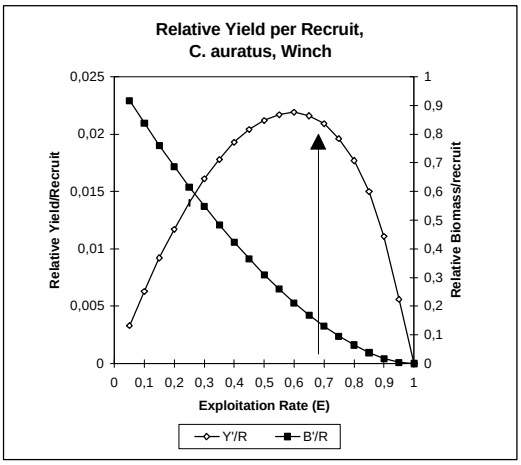


The major fishing mortality of *C. auratus* takes place at a length of 16-20 cm. The total catch of *C. auratus* by winchboats in 1996 was 175 tonnes.

5.6.3.3 Yield per Recruit Analysis

The results of the Relative Yield per Recruit Analysis is presented in Figure 44.

Figure 44: Relative Yield per Recruit of *C. auratus* caught by winchboats.



The present Exploitation rate was estimated at 0.68 (see table 39) and is indicated by a arrow. The analysis indicated a maximum exploitation rate of 0.59, a $E_{0.1}$ =0.56 and a $E_{0,5\ of\ B/R}$ = 0,33. If all data are representative it would again mean that the exploitation rate of the winchboats is too high.

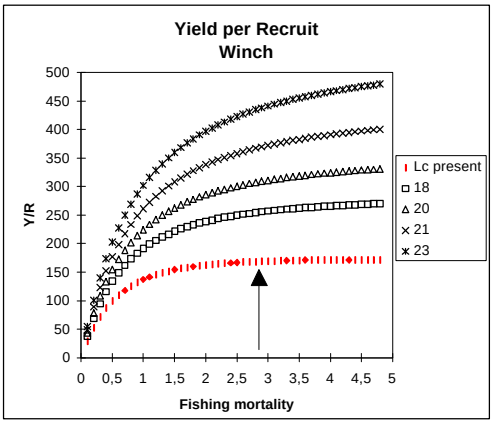
The input data used in the Yield per Recruit analysis following the length-based Beverton and Holt model for *C. auratus* are presented in Table 40.

Table 40: Input parameters Y/R analysis *C. auratus*.

SPECIES	*C. auratus*			
GEARTYPE	Winch			
L∞	31	cm	k	0,60
Lr	1	cm	M	1,30
Lc present	15.1	cm	F	2,74
Lc/L∞	0,3		a	0,023
F present	2.74	year	b	2.967

The Yield per Recruit curve obtained with those input parameters is presented in Figure 45.

Figure 45: Yield per Recruits of *C. auratus* for winchboats in stratum VII of Lake Volta.



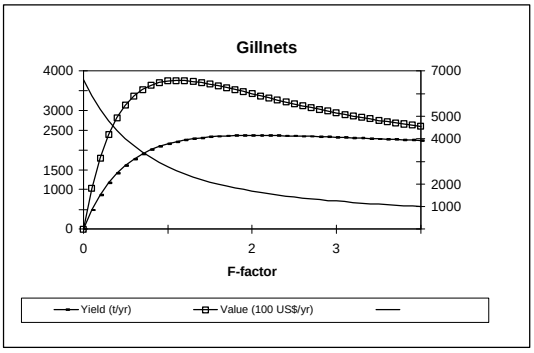
The present Fishing mortality of winchboats for *C. auratus* was estimated before at 2.74 (indicated by the arrow) which is larger as the F_{MSY} = 1.6. Again it would mean overexpoitation[18], especially *"growth overfishing"*, the fish are caught too early and the growth potential is not used optimally. Increasing the length at first capture would increase the Yield per Recruit.

[18] If the data are representative

5.6.4 Thompson and Bell prediction for *C. auratus*

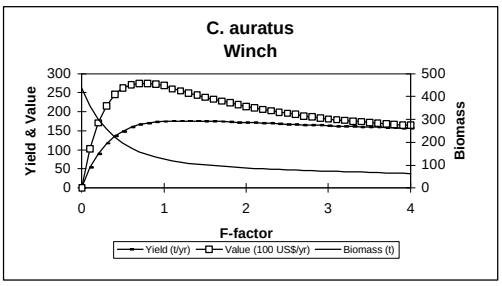
The results of the VPA analysis were used for prediction of catch and value with a Thompson and Bell model. The results for gillnets, winchboats and the cumulative values are presented in Figures 45, 46 & 47.

Figure 45: Thompson and Bell analysis for *C. auratus* caught by gillnets.



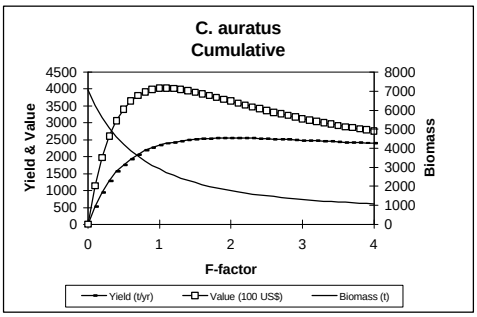
At the present fishing effort (F_{factor} =1) the annual catch of gillnets is estimated at 2160 tonnes with a value of 375.000 USD/yr.
The optimal fishing effort considering yield is almost reached and is F_{factor} =1.6 (Yield=2370 t/yr). The optimal economic fishing effort is reached at F_{factor} =1 (Value=375,000 USD/yr).

Figure 46: Thompson and Bell analysis for *C. auratus* caught by winchboats.



At the present fishing effort (F_{factor} =1) the annual catch of winchboats is estimated 174 tonnes with a value of 27.000 USD/yr.
The optimal fishing effort considering yield is F_{factor} =1.1 (Yield=176 t/yr). The optimal economic fishing effort is F_{factor} =0.6 (Value=27.500 USD/yr).

Figure 47: Cumulative Thompson and Bell analysis for *C. auratus*.



At the present fishing effort (F_{factor} =1) the annual cumulative catch is estimated 2336 tonnes with a value of 402.000 USD/yr.
The optimal fishing effort considering yield is F_{factor} =2 (Yield=2549 t/yr). The optimal economic fishing effort is F_{factor}=1.1 (Value=402.000 USD/yr). The optimal fishing effort considering the biomass is F_{factor} =0.8

5.7

Growth parameters

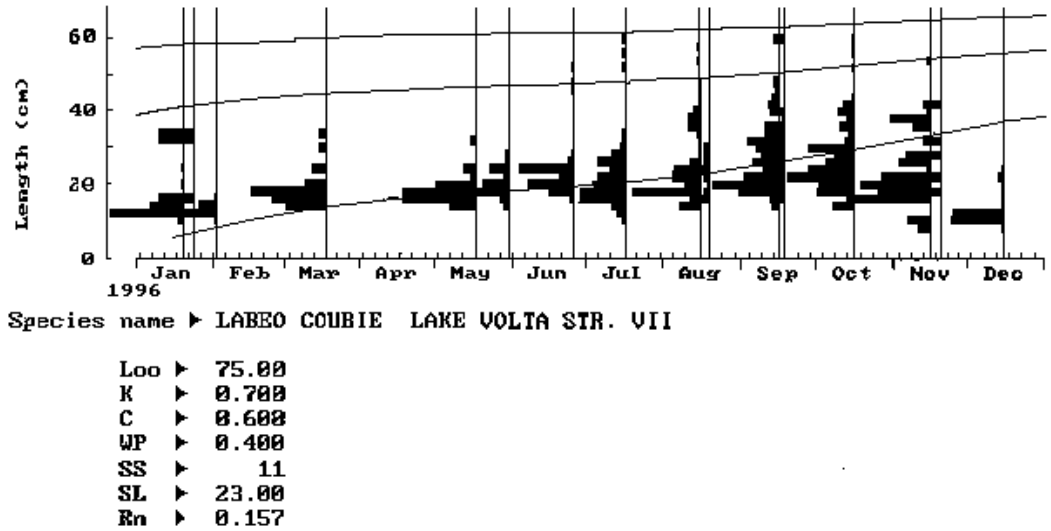
The growth parameters of *L. coubie* 996 are presented in Table 41.

Table 41: Growth parameters as estimated with ELEFAN for *L. coubie* Stratum VII of Lake Volta.

Parameter	
L∞	75 cm
	0.7 year [1]
	0.6
Wp	
t	0.178 year
Rn	
φ	3.595

Figure 48 shows the growth curve

Length frequency data and estimated growth curves of in Stratum VII of Lake Volta.



The results indicate that at 3 cohorts are found in the fisheries.

The length weight relationship could be described with:

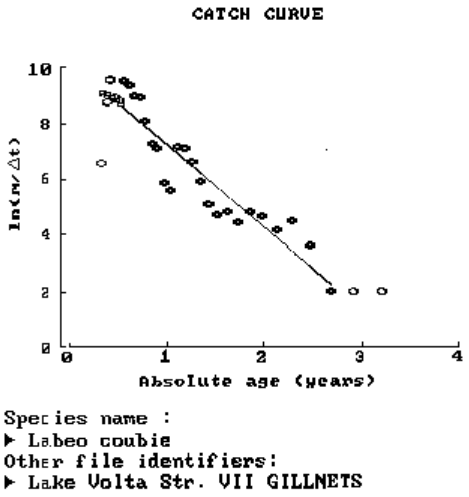
$$W = 0.02\ L^{3.137}$$

5.7.2 Gillnets

5.7.2.1 Mortality rates

The linearised catch curve of *L. coubie* for gillnets is presented in Figure 49.

Figure 49: The length converted catch curve of *L. coubie* for gillnets in stratum VII of Lake Volta.



Parameter estimates as obtained from the catch curve are presented in Table 42.

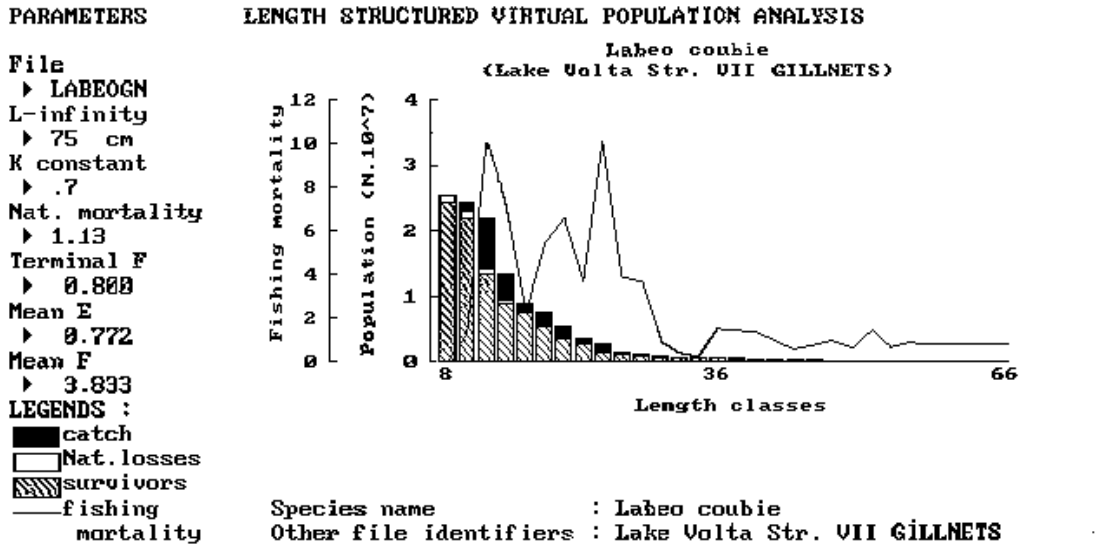
Table 42: Parameter estimates as obtained from a length converted catch curve for *L. coubie* caught by gillnets in Stratum VII of Lake Volta.

Parameter	
Total mortality (Z, year^{-1})	2.34
Natural mortality (M, year^{-1})	1.13
Fishing mortality (F, year^{-1})	1.21
Exploitation rate (E)	0.52
Cut-off length (L', cm)	17.0
Mean length (from L', cm)	24.4
L25 (cm)	7.6
L50 (cm)	9.3
L75 (cm)	10.8

5.7.2.2 Virtual Population Analysis

The fishing mortality (F) of gillnets per length group as obtained from a VPA is presented in Figure 50.

Figure 50: Fishing mortality from gillnets for *L. coubie* in stratum VII of Lake Volta.

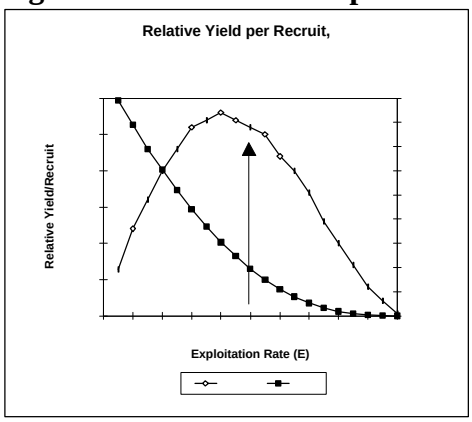


Two distinct peaks in fishing mortality, at respectively a length of 11 cm and 23 cm, are visible. The two peaks are most likely the result of different mesh sizes as during the CAS it was observed that a large number of small *L. coubie* were caught with the smaller mesh sizes. The total catch of *L. coubie* by gillnets in 1996 was 3452 tonnes.

5.7.2.3 Yield per Recruit Analysis

The results of the Relative Yield per Recruit Analysis is presented in Figure 51.

Figure 51: Relative Yield per Recruit of *L. coubie* caught by gill nets.



The present Exploitation rate was estimated at 0.52 (see table 42) and is indicated by a arrow. The analysis indicated a maximum exploitation rate of 0.41, a $E_{0.1}$ =0.35 and a $E_{0,5 \text{ of B/R}}$ = 0,26. If all data are representative it would mean that the exploitation rate of the gillnets is too high.

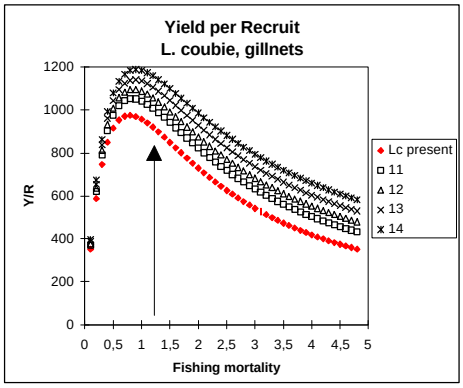
The input data used in the Yield per Recruit analysis following the length-based Beverton and Holt model for *L. coubie* are presented in Table 43.

Table 43: Input parameters Y/R analysis *L.coubie*.

SPECIES	*L. coubie*			
GEARTYPE	Gill nets			
L∞	75	Cm	k	0,70
Lr	1	Cm	M	1.13
Lc present	9.3	Cm	F	1.21
Lc/L∞	0.12		a	0,02
F present	1.21	year	b	3.137

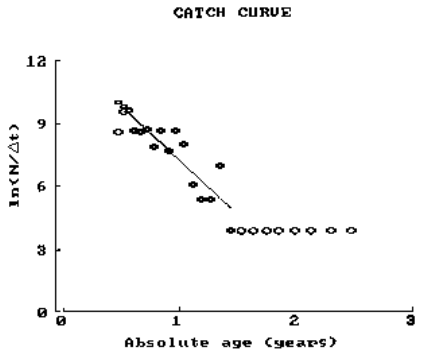
The Yield per Recruit curve obtained with those input parameters is presented in Figure 52.

Figure 52: Yield per Recruits of *L. coubie* for gill nets in stratum VII of Lake Volta.



The present Fishing mortality of gillnets for *L. coubie* was estimated before at 1.21 (indicated by the arrow) which is larger as the F_{MSY} = 0.8 Again it would mean overexpoitation[19], especially *"growth overfishing"*, the fish are caught too early and the growth potential is not used optimally. Increasing the length at first capture would increase the Yield per Recruit.

[19] If the data are representative

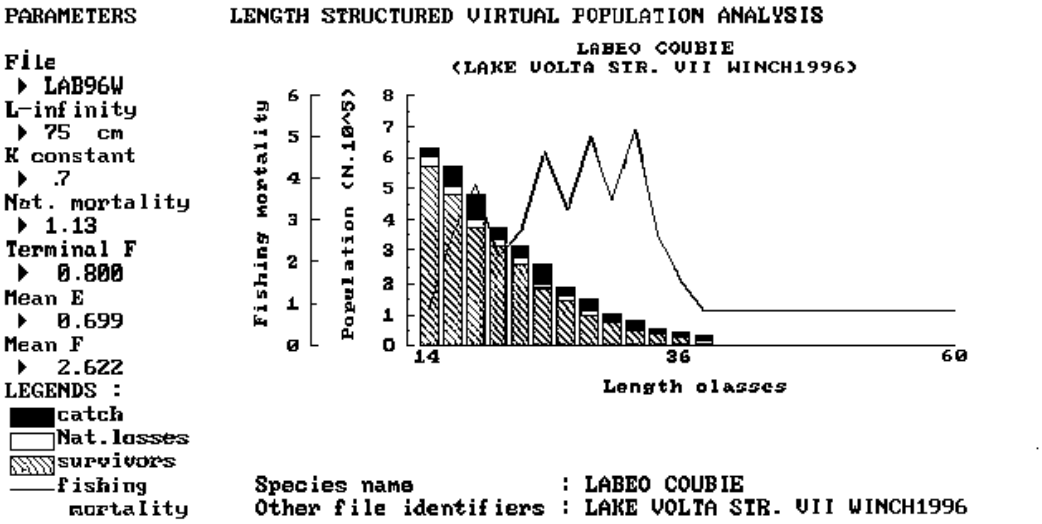


Species name :
▶ LABEO COUBIE
Other file identifiers:
▶ LAKE VOLTA STR. VII WINCH1996

5.7.3.2 Virtual Population Analysis

presented in Figure 54.

Figure 54: Fishing mortality from winchboats for *L. coubie* in st

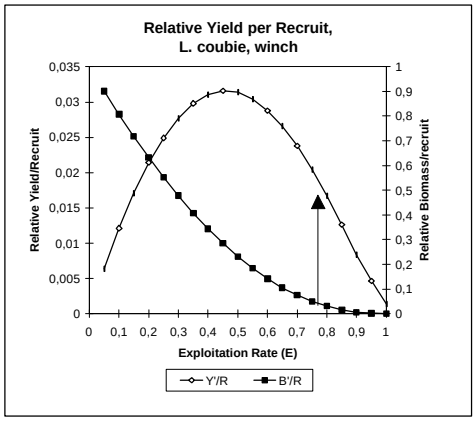


There are two peaks in the fishing mortality at respectively 18 cm and at 21- cm. The first peak is most likely artificial and caused by low sample sizes and raising of the length frequency data to annual caught numbers. *L. coubie* by

5.7.3.3

The results of the Relative Yield per Recruit Analysis is presented in Figure 55.

Figure 55: Relative Yield per Recruit of *L. coubie* caught by winchboats.



The present Exploitation rate was estimated at 0.77 (see table 44) and is indicated by a arrow.

rate of 0.46, a $E_{0.1}$ $_{0,5\ of\ B/R}$ = 0,28.

in

mean that the exploitation rate of the

-based

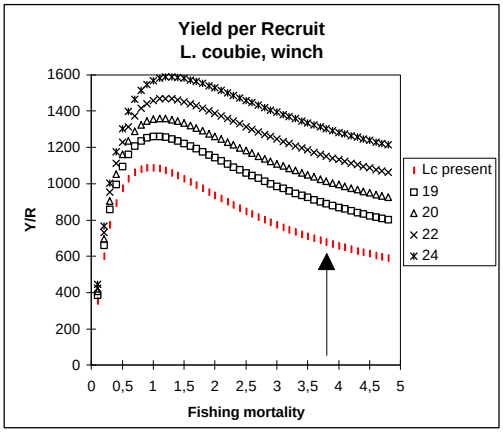
L. coubie are presented in Table 45.

Table 45: Input parameters Y/R analysis .

SPECIES				
	Winch			
L∞	70		k	0,70
	1	cm		1,13
Lc present		cm	F	
Lc/L	0,12		a	0,02
	3.87	year		3.137

The Yield per Recruit curve obtained with those input parameters is presente in Figure 56.

Figure 56: Yield per Recruits of *L. coubie* for winchboats in stratum VII of Lake Volta.

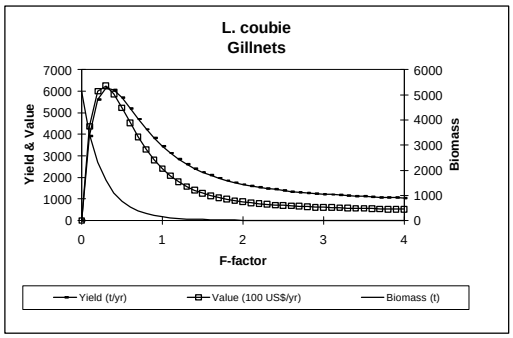


The present Fishing mortality of winchboats for *L. coubie* was estimated before at 3.87 (indicated by the arrow) which is larger as the F_{MSY} = 1. Again it would mean overexpoitation[20], especially *"growth overfishing"*, the fish are caught too early and the growth potential is not used optimally. Increasing the length at first capture would increase the Yield per Recruit.

5.7.4 Thompson and Bell prediction for *L. coubie*

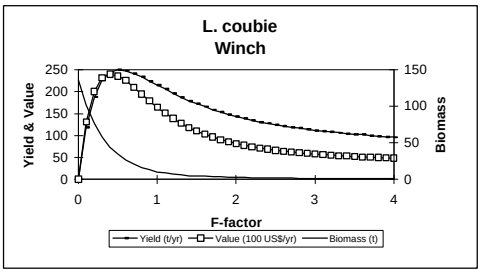
The results of the VPA analysis were used for prediction of catch and value with a Thompson and Bell model. The results for gillnets, winchboats and the cumulative values are presented in Figures 57, 58 & 59.

Figure 57: Thompson and Bell analysis for *L. coubie* caught by gillnets.



At the present fishing effort (F_{factor} =1) the annual catch of gillnets is estimated at 3452 tonnes with a value of 240.000 USD/yr.
The optimal fishing effort considering yield is almost reached and is F_{factor}=0.3 (Yield=6059 t/yr). The optimal economic fishing effort is reached at F_{factor}=0.2 (Value=625,000 USD/yr).

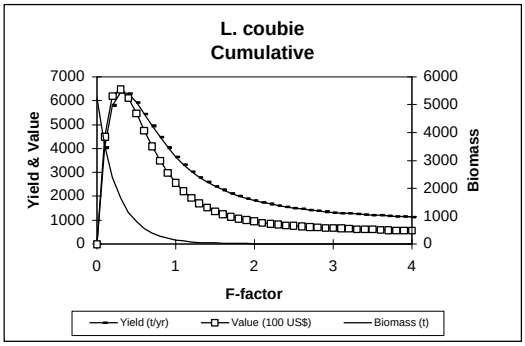
Figure 58: Thompson and Bell analysis for *L. coubie* caught by winchboats.



At the present fishing effort (F_{factor}=1) the annual catch of winchboats is estimated 215 tonnes with a value of 16.000 USD/yr.
The optimal fishing effort considering yield is F_{factor}=0.4 (Yield=250 t/yr). The optimal economic fishing effort is F_{factor}=0.4 (Value=24.000 USD/yr).

[20] If the data are representative

Figure 59: Cumulative Thompson and Bell analysis for *L. coubie*.



At the present fishing effort (F_{factor}=1) the annual cumulative catch is estimated 3667 tonnes with a value of 257.000 USD/yr.
The optimal fishing effort considering yield is F_{factor}=0.3 (Yield=6304 t/yr). The optimal economic fishing effort is F_{factor}=0.3 (Value=611.000 USD/yr). The optimal fishing effort considering the biomass is F_{factor} =0.2

5.8 Schilbe intermedius

5.8.1 Growth parameters

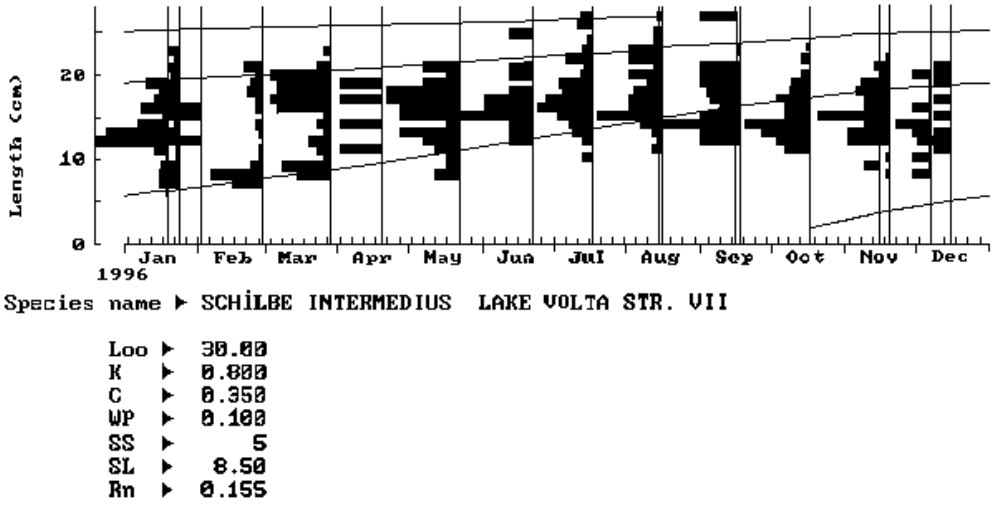
The growth parameters of *S. intermedius* for 1996 are presented in Table 46.

Table 46: Growth parameters as estimated with ELEFAN for *S. intermedius* for Stratum VII of Lake Volta.

Parameter	
$L\infty$	30 cm
K	0.8 $year^{-1}$
C	0.35
Wp	0.1 year
t_0	0.337 year
Rn	0.155
φ	2.857

Figure 60 shows the growth curves superimposed on the length frequency data.

Figure 60: Length frequency data and estimated growth curves of *S. intermedius* in Stratum VII of Lake Volta.



The results indicate that at 3 cohorts are found in the fisheries.

The length weight relationship could be described with:

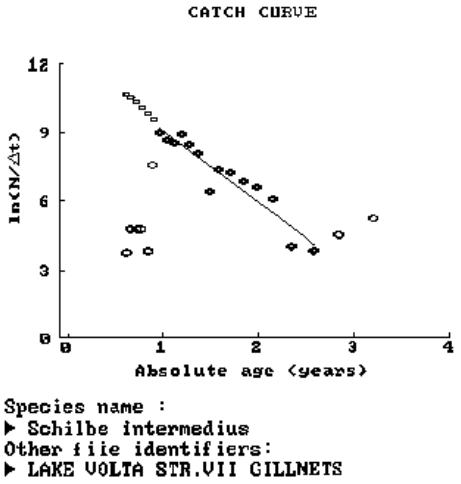
$$W = 0.006\ L^{3.23}$$

5.8.2 Gillnets

5.8.2.1 Mortality rates

The linearised catch curve of *S. intermedius* for gillnets is presented in Figure 61.

Figure 61: The length converted catch curve of *S. intermedius* for gillnets in stratum VII of Lake Volta.



Parameter estimates as obtained from the catch curve are presented in Table 47.

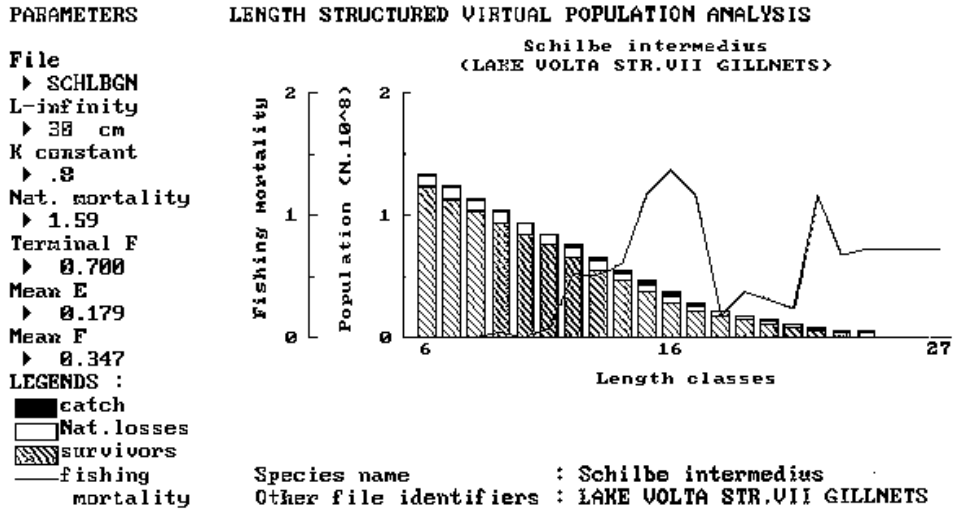
Table 47: Parameter estimates as obtained from a length converted catch curve for *S. intermedius* caught by gillnets in Stratum VII of Lake Volta.

Parameter	
Total mortality (Z, year^{-1})	4.49
Natural mortality (M, year^{-1})	1.59
Fishing mortality (F, year^{-1})	2.90
Exploitation rate (E)	0.65
Cut-off length (L', cm)	11.5
Mean length (from L', cm)	15.9
L25 (cm)	10.6
L50 (cm)	11.4
L75 (cm)	12.1

5.8.2.2 Virtual Population Analysis

The fishing mortality (F) of gillnets per length group as obtained from a VPA is presented in Figure 62.

Figure 62: Fishing mortality from gillnets for *S. intermedius* in stratum VII of Lake Volta.

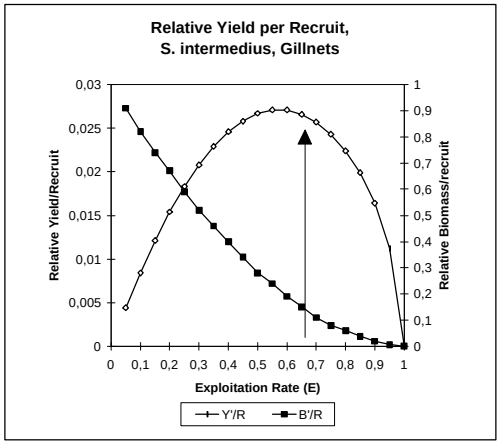


The fishing mortality starts at a length of 11 cm and reaches it peak at a length of 16 cm. The total catch of *S. intermedius* by gillnets in 1996 was 1307 tonnes.

5.8.2.3 Yield per Recruit Analysis

The results of the Relative Yield per Recruit Analysis is presented in Figure 63.

Figure 63: Relative Yield per Recruit of *S. intermedius* caught by gill nets.



The present Exploitation rate was estimated at 0.65 (see table 47) and is indicated by a arrow. The analysis indicated a maximum exploitation rate of 0.57, a $E_{0.1}$ =0.50 and a $E_{0,5 \text{ of } B/R}$ = 0,32. If all data are representative it would mean that the exploitation rate of the gillnets is too high.

The input data used in the Yield per Recruit analysis following the length-based Beverton and Holt model for *S. intermedius* are presented in Table 48.

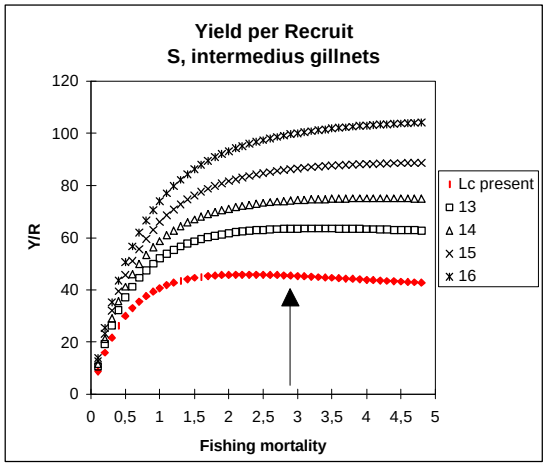
Table 48: Input parameters Y/R analysis *S. intermedius*..

.

SPECIES	*S. intermedius*			
GEARTYPE	Gill nets			
L∞	30	cm	k	0.80
Lr	1	cm	M	1.59
Lc present	10.6	cm	F	2.90
Lc/L∞	0.35		a	0.006
F present	2.90	year	b	3.23

The Yield per Recruit curve obtained with those input parameters is presented in Figure 64.

Figure 64: Yield per Recruits of *S. intermedius* for gill nets in stratum VII of Lake Volta.



The present Fishing mortality of gillnets for *S. intermedius* was estimated before at 2.90 (indicated by the arrow) which is larger as the F_{MSY} = 1.4 Again it would mean overexpoitation[21], especially *"growth overfishing"*, the fish are caught too early and the growth potential is not used optimally. Increasing the length at first capture would increase the Yield per Recruit.

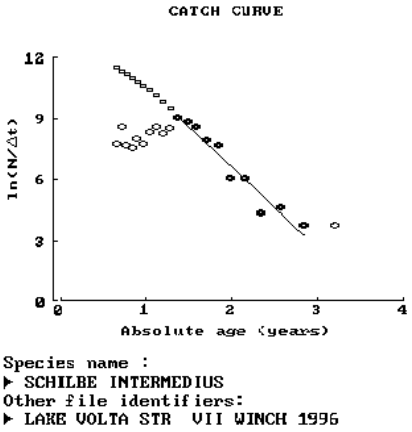
5.8.3 Winchboats

5.8.3.1 Mortality rates

The linearised catch curve of *S. intermedius* for winchboats is presented in Figure 65.

[21] If the data are representative

Figure 65: The length converted catch curve of *S. intermedius* for winchboats in stratum VII of Lake Volta.



Parameter estimates as obtained from the catch curve are presented in Table 49.

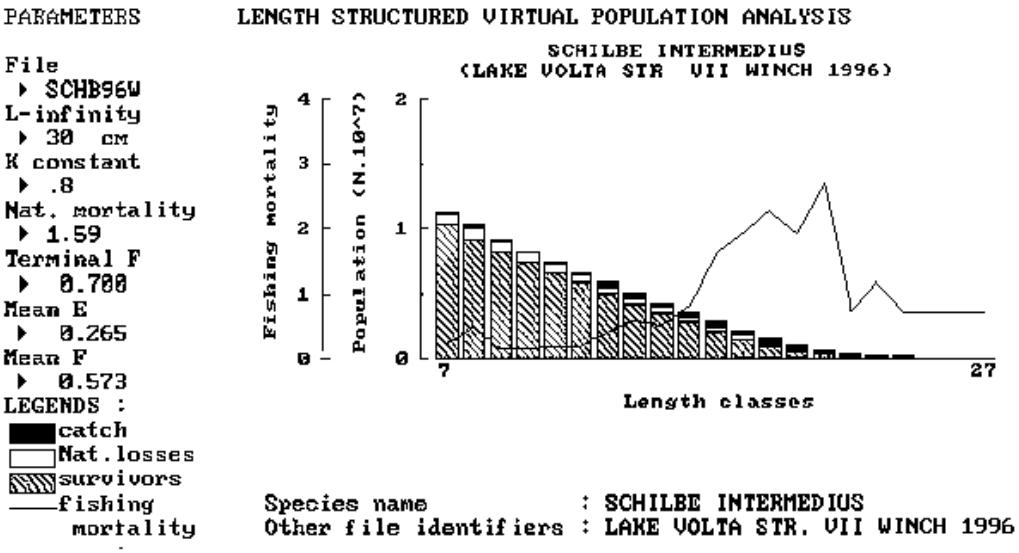
Table 49: Parameter estimates as obtained from a length converted catch curve for *S. intermedius* caught by winchboats in Stratum VII of Lake Volta.

Parameter	
Total mortality (Z, year^{-1})	3.23
Natural mortality (M, year^{-1})	1.59
Fishing mortality (F, year^{-1})	1.64
Exploitation rate (E)	0.51
Cut-off length (L', cm)	16.5
Mean length (from L', cm)	18.8
L25 (cm)	14.7
L50 (cm)	15.8
L75 (cm)	16.8

5.8.3.2 Virtual Population Analysis

The fishing mortality (F) of winchboats per length group as obtained from a VPA is presented in Figure 65.

Figure 65: Fishing mortality from winchboats for *S. intermedius* in stratum VII of Lake Volta.

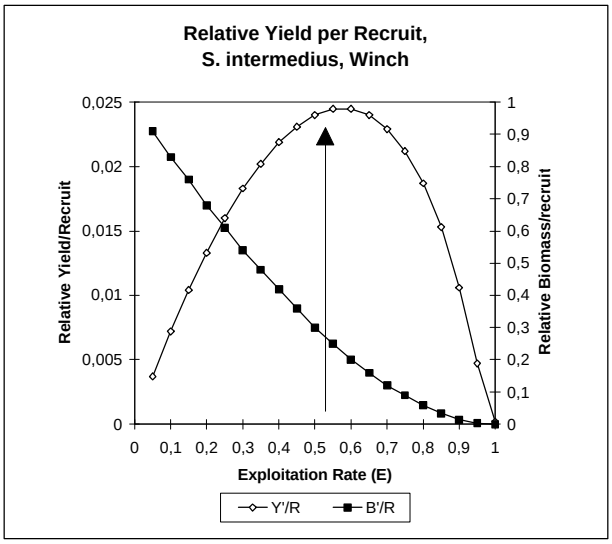


The fishing mortality starts at a length of 15 cm and reaches it peak at a length of 20 cm. The total catch of *S. intermedius* by gillnets in 1996 was 155 tonnes.

5.8.3.3 Yield per Recruit Analysis

The results of the Relative Yield per Recruit Analysis is presented in Figure 66.

Figure 66: Relative Yield per Recruit of *S. intermedius* caught by winchboats.



The present Exploitation rate was estimated at 0.51 (see table 49) and is indicated by a arrow. The analysis indicated a maximum exploitation rate of 0.57, a $E_{0.1}$ =0.55 and a $E_{0,5\ of\ B/R}$ = 0,33. It would mean that the present exploitation rate almost reached its maximum.

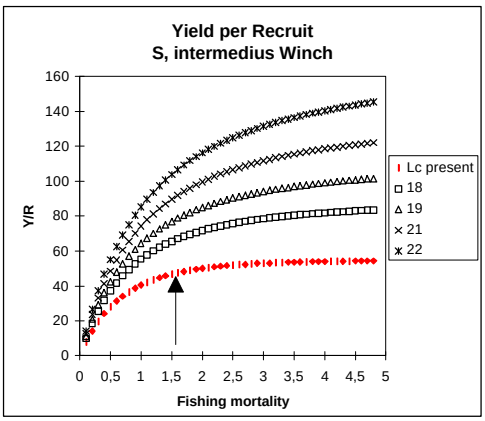
The input data used in the Yield per Recruit analysis following the length-based Beverton and Holt model for *S. intermedius* are presented in Table 50.

Table 50: Input parameters Y/R analysis *S. intermedius*.

SPECIES	*S. intermedius*			
GEARTYPE	Winch			
L∞	30	cm	k	0.80
Lr	1	cm	M	1.59
Lc present	14.8	cm	F	1.64
Lc/L∞	0.49		a	0,006
F present	1.64	year	b	3.23

The Yield per Recruit curve obtained with those input parameters is presented in Figure 67.

Figure 67: Yield per Recruits of *S. intermedius* for winchboats in stratum VII of Lake Volta.

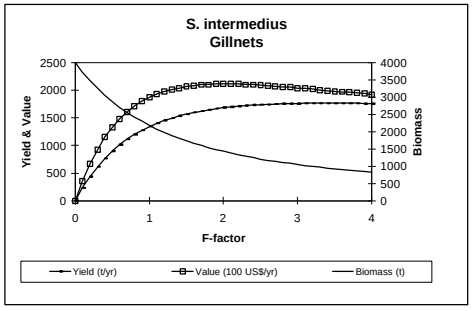


The present Fishing mortality of winchboats for *S. intermedius* was estimated before at 1.64 (indicated by the arrow). The analysis indicated that the present fishing mortality almost reached the Fmsy=2

5.8.4 Thompson and Bell prediction for *S. intermedius*

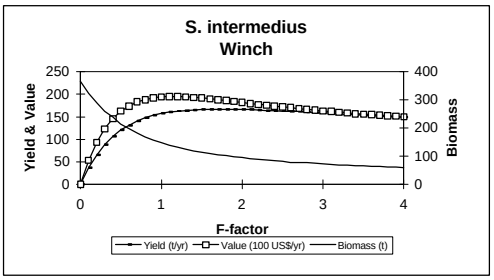
The results of the VPA analysis were used for prediction of catch and value with a Thompson and Bell model. The results for gillnets, winchboats and the cumulative values are presented in Figure 68, 69 & 70.

Figure 68: Thompson and Bell analysis for *S. intermedius* caught by gillnets



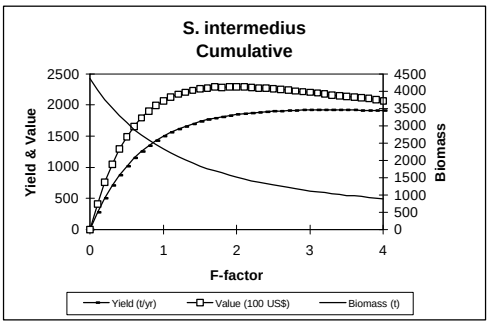
At the present fishing effort (F_{factor} =1) the annual catch of gillnets is estimated at 1307 tonnes with a value of 187.000 USD/yr.
The optimal fishing effort considering yield is not yet reached and is F_{factor}=2 (Yield=1683 t/yr). The optimal economic fishing effort is reached at F_{factor}=1.7 (Value=210,000 USD/yr).

Figure 69: Thompson and Bell analysis for *S. intermedius* caught by winchboats.



At the present fishing effort (F_{factor}=1) the annual catch of winchboats is estimated 155 tonnes with a value of 19.000 USD/yr.
The optimal fishing effort considering yield is F_{factor}=1.4 (Yield=165 t/yr). The optimal economic fishing effort is F_{factor}=1.1 (Value=19.500 USD/yr).

Figure 70: Cumulative Thompson and Bell analysis for *S. intermedius*.



At the present fishing effort (F_{factor}=1) the annual cumulative catch is estimated 1462 tonnes with a value of 206.000 USD/yr.
The optimal fishing effort considering yield is F_{factor}=3.3 (Yield=1920 t/yr). The optimal economic fishing effort is F_{factor}=1.9 (Value=229.000 USD/yr). The optimal fishing effort considering the biomass is F_{factor} =1.2.

5.9 Sarotherodon galileus

5.9.1 Growth parameters

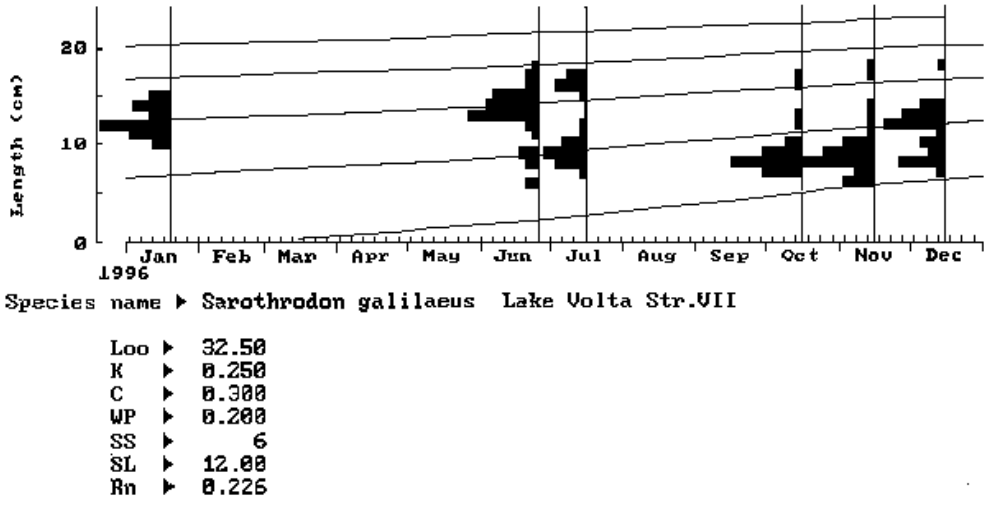
The growth parameters of *S. galileus* for 1996 are presented in Table 51.

Table 51: Growth parameters as estimated with ELEFAN for *S. galileus* for Stratum VII of Lake Volta.

Parameter	
$L\infty$	32.5 cm
K	0.25 $year^{-1}$
C	0.30
Wp	0.2 year
t_0	0.656 year
Rn	0.226
φ	2.42

Figure 71 shows the growth curves superimposed on the length frequency data.

Figure 71: Length frequency data and estimated growth curves of S. galileus in Stratum VII of Lake Volta.



The results indicated that at 4 cohorts are found in the fisheries.

The length weight relationship could be described with:

$$W = 0.0125\ L^{3.01}$$

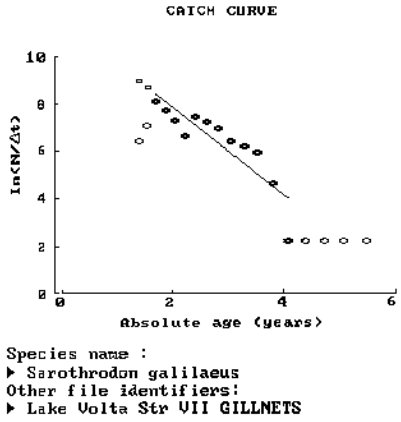
5.9.2 Gillnets

S. galileus was not caught by the winchboats. Therefore the stock-assessments analysis the results of gillnets only

5.9.2.1 Mortality rates

The linearised catch curve of *S. galileus* for gillnets is presented in Figure 72.

Figure 72: The length converted catch curve of *S. galileus* for gillnets in stratum VII of Lake Volta.



Parameter estimates as obtained from the catch curve are presented in Table 52.

Table 52: Parameter estimates as obtained from a length converted catch curve for *S. galileus* caught by gillnets in Stratum VII of Lake Volta.

Parameter	
Total mortality (Z, year^{-1})	1.84
Natural mortality (M, year^{-1})	0.73
Fishing mortality (F, year^{-1})	1.84
Exploitation rate (E)	0.60
Cut-off length (L', cm)	7.5
Mean length (from L', cm)	11.3
L25 (cm)	6.6
L50 (cm)	7.5
L75 (cm)	8.42

5.9.2.2 Virtual Population Analysis

The fishing mortality (F) of gillnets per length group as obtained from a VPA is presented in Figure 73.

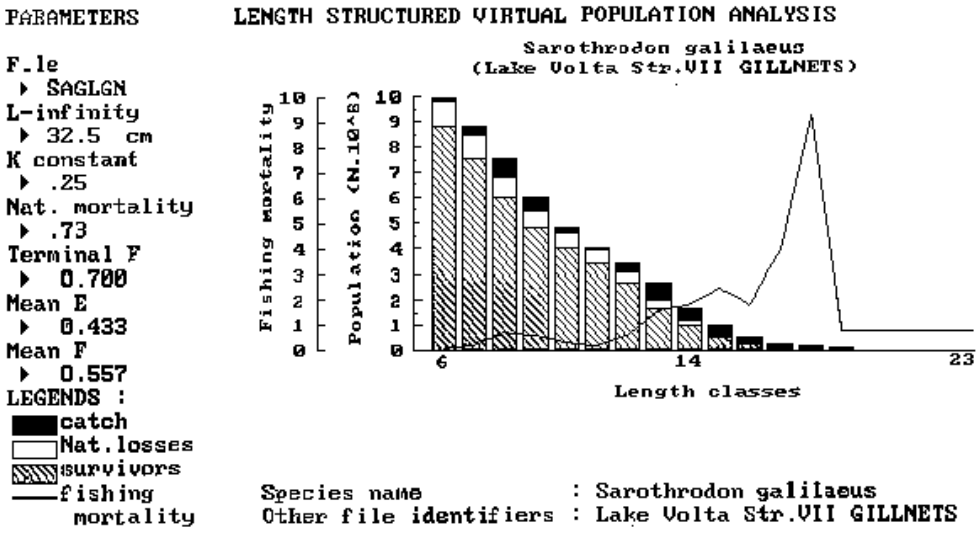


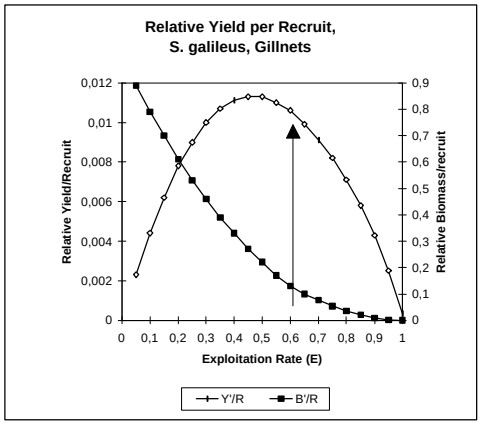
Figure 73: Fishing mortality from gillnets for *S. galileus* in stratum VII of Lake Volta.

The fishing mortality starts at a length of 6 cm and reaches it peak at a length of 19 cm. The total catch of *S. galileus* by gillnets in 1996 was 998 tonnes.

5.9.2.3 Yield per Recruit Analysis

The results of the Relative Yield per Recruit Analysis is presented in Figure 74.

Figure 74: Relative Yield per Recruit of *S. galileus* caught by gill nets.



The present Exploitation rate was estimated at 0.60 (see table 52) and is indicated by a arrow. The analysis indicated a maximum exploitation rate of 0.46, a $E_{0.1}$ =0.41 and a $E_{0,5 \text{ of } B/R}$ = 0,27. If all data are representative it would mean that the exploitation rate of the gillnets is too high.

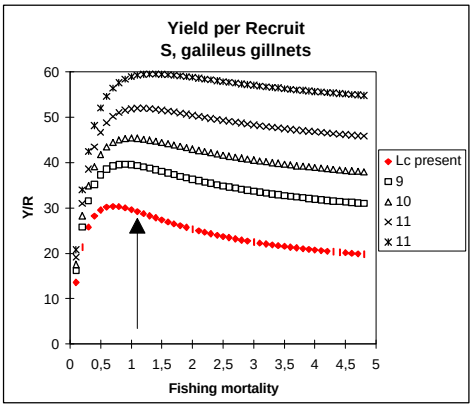
The input data used in the Yield per Recruit analysis following the length-based Beverton and Holt model for *S. galileus* are presented in Table 53.

Table 53: Input parameters Y/R analysis *S. galileus*.

SPECIES	*S. galileus*			
GEARTYPE	Gill nets			
L∞	32.5	cm	k	0.25
Lr	1	cm	M	0.73
Lc present	7.5	cm	F	1.11
Lc/L∞	0.23		a	0.0125
F present	1.11	year	b	3.01

The Yield per Recruit curve obtained with those input parameters is presented in Figure 75.

Figure 75: Yield per Recruits of *S. galileus* for gill nets in stratum VII of Lake Volta.



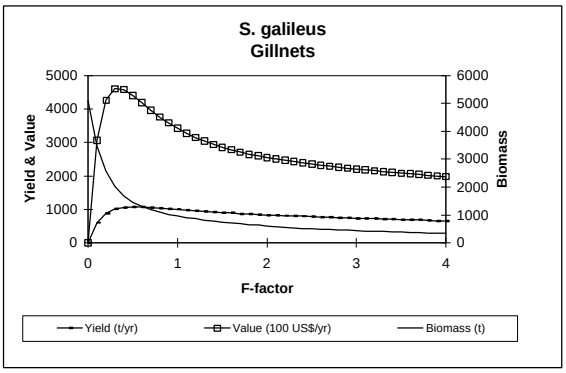
The present Fishing mortality of gillnets for *S. galileus* was estimated before at 1.11 (indicated by the arrow) which is larger as the F_{MSY} = 0.9 Again it would mean overexpoitation[22], especially *"growth overfishing"*, the fish are caught too early and the growth potential is not used optimally. Increasing the length at first capture would increase the Yield per Recruit.

5.9.3 Thompson and Bell prediction for *S. galileus*

The results of the VPA analysis were used for prediction of catch and value with a Thompson and Bell model. The results for gillnets, winchboats and the cumulative values are presented in Figure 76.

[22] If the data are representative

Figure 76: Thompson and Bell analysis for *S. galileus* caught by gillnets



At the present fishing effort (F_{factor} =1) the annual catch of gillnets is estimated at 998 tonnes with a value of 343.000 USD/yr.

The optimal fishing effort considering yield reached and is F_{factor}=0.4 (Yield=1074 t/yr). The optimal economic fishing effort is reached at F_{factor}=0.2 (Value=461,000 USD/yr).

5.10 Oreochromis niloticus

5.10.1 Growth parameters

The data set for *O. niloticus* did not give a reliable fit (Rn = 0.070) when a class interval of 1 cm was used. The results improved when the data set was regrouped using a class interval of 2 cm. Within the analysis this class interval was further used

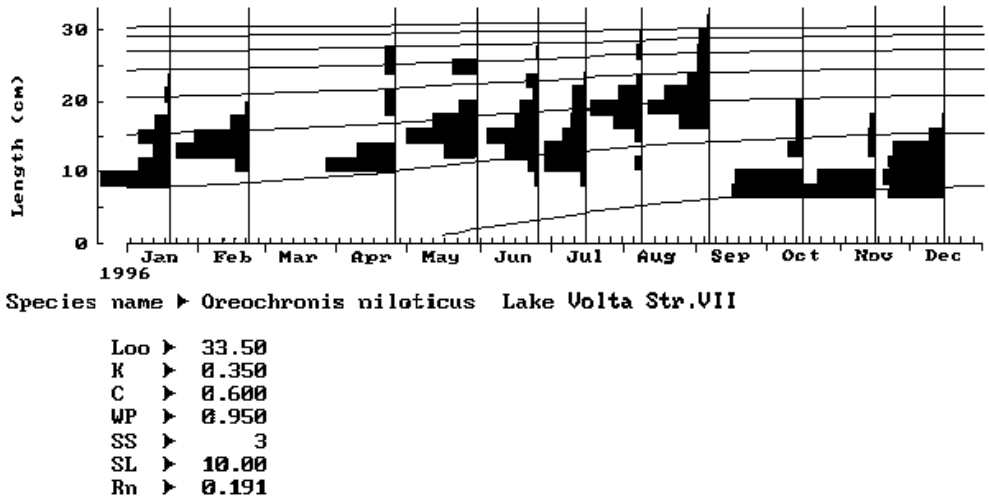
The growth parameters of *O. niloticus* for 1996 are presented in Table 54.

Table 54: Growth parameters as estimated with ELEFAN for *O. niloticus* for Stratum VII of Lake Volta.

Parameter	
$L\infty$	33.5 cm
K	0.35 $year^{-1}$
C	0.6
Wp	0.95 year
t_0	0.45 year
Rn	0.191
φ	2.59

Figure 77. shows the growth curves superimposed on the length frequency data.

Figure 77: Length frequency data and estimated growth curves of *O. niloticus* in Stratum VII of Lake Volta.



The results indicated that at 5-6 cohorts are found in the fisheries.

The length weight relationship could be described with:

$$W = 0.081\ L^{2.777}$$

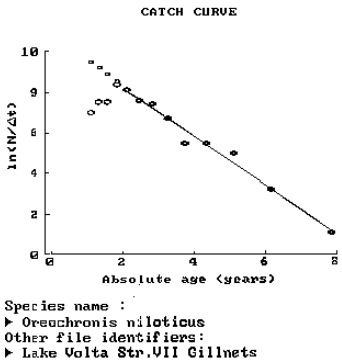
5.10.2 Gillnets

O. niloticus was not caught by the winchboats. Therefore the stock-assessments analysis the results of gillnets only

5.10.2.1 Mortality rates

The linearised catch curve of *O. niloticus* for gillnets is presented in Figure 78.

Figure 78: The length converted catch curve of *O. niloticus* for gillnets in stratum VII of Lake Volta.



Parameter estimates as obtained from the catch curve are presented in Table 55.

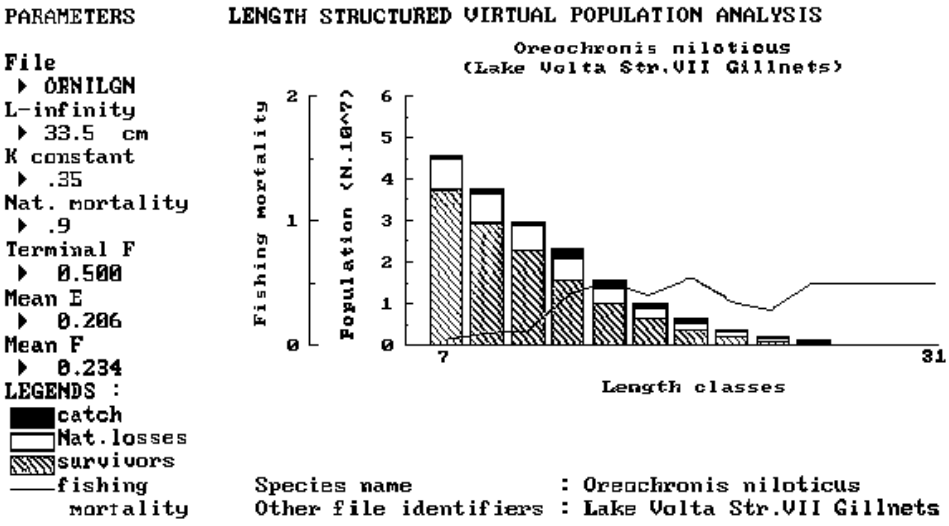
Table 55: Parameter estimates as obtained from a length converted catch curve for *O. niloticus* caught by gillnets in Stratum VII of Lake Volta.

Parameter	
Total mortality (Z, year^{-1})	1.28
Natural mortality (M, year^{-1})	0.90
Fishing mortality (F, year^{-1})	0.38
Exploitation rate (E)	0.3
Cut-off length (L', cm)	14.0
Mean length (from L', cm)	18.4
L25 (cm)	9.6
L50 (cm)	11.4
L75 (cm)	13.3

5.10.2.2 Virtual Population Analysis

The fishing mortality (F) of gillnets per length group as obtained from a VPA is presented in Figure 79.

Figure 79: Fishing mortality from gillnets for *O. niloticus* in stratum VII of Lake Volta.

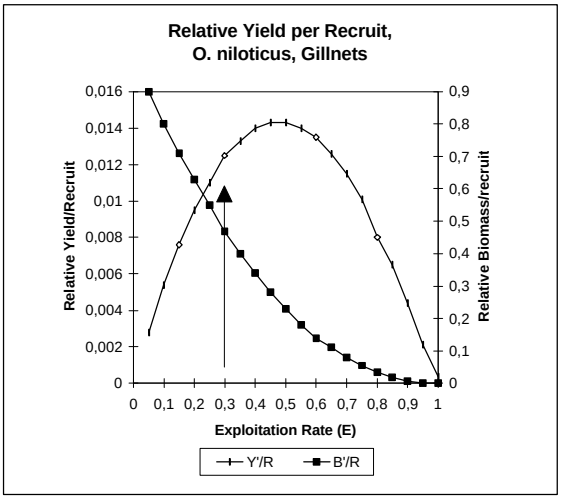


The fishing mortality starts at a length of 7 cm and remains more or less constant in all length classes. The total catch of *O. niloticus* by gillnets in 1996 was 1675 tonnes.

5.10.2.3 Yield per Recruit Analysis

The results of the Relative Yield per Recruit Analysis is presented in Figure 80.

Figure 80: Relative Yield per Recruit of *O. niloticus* caught by gill nets.



The present Exploitation rate was estimated at 0.3 (see table 55) and is indicated by a arrow. The analysis indicated a maximum exploitation rate of 0.47, a $E_{0.1}$ =0.45 and a $E_{0,5 \text{ of } B/R}$ = 0,32. If all data are representative it would mean that the gillnets are under-exploiting the stocks of *O. niloticus*.

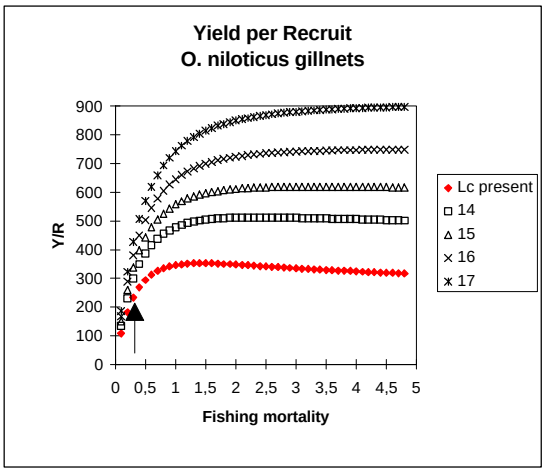
The input data used in the Yield per Recruit analysis following the length-based Beverton and Holt model for *O. niloticus* are presented in Table 56.

Table 56: Input parameters Y/R analysis *O. niloticus*.

SPECIES	*O. niloticus*			
GEARTYPE	Gill nets			
L∞	33.5	cm	k	0.35
Lr	1	cm	M	0.90
Lc present	11.5	cm	F	0.38
Lc/L∞	0.34		a	0.081
F present	0.38	year	b	2.777

The Yield per Recruit curve obtained with those input parameters is presented in Figure 81.

Figure 81: Yield per Recruits of *S. galileus* for gill nets in stratum VII of Lake Volta.

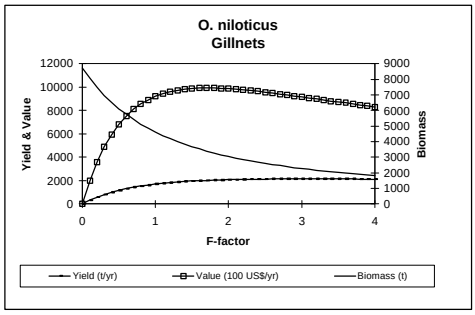


The present Fishing mortality of gillnets for *O. niloticus* was estimated before at 0.38 (indicated by the arrow) which is lower as the F_{MSY} = 1.2 It would mean again that the stocks of *O. niloticus* are under exploited by the gillnets. Increasing the length at first capture would increase the Yield per Recruit.

5.10.3 Thompson and Bell prediction for *O. niloticus*

The results of the VPA analysis were used for prediction of catch and value with a Thompson and Bell model. The results for gillnets, winchboats and the cumulative values are presented in Figure 82.

Figure 82: Thompson and Bell analysis for *O. niloticus* caught by gillnets



At the present fishing effort (F_{factor} =1) the annual catch of gillnets is estimated at 1675 tonnes with a value of 921.000 USD/yr.
The optimal fishing effort considering yield is not yet reached and is F_{factor}=3.1 (Yield=2150 t/yr). The optimal economic fishing effort is reached at F_{factor}=1.7 (Value=992,000 USD/yr).

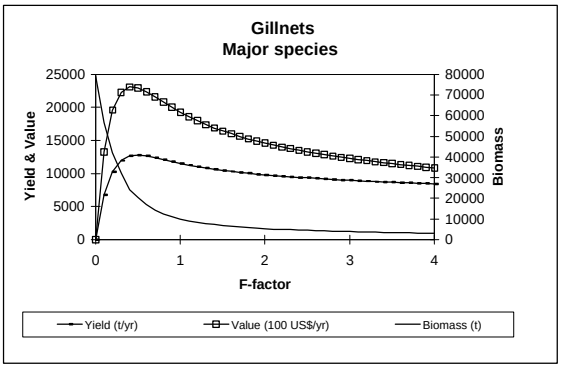
5.10.4 Remarks

It seems that the analysis indicates that the stocks of *O. niloticus* are under exploited by the gillnets. It should however be realized that the original data set (the length frequencies) only gave a reasonable growth-fit after "massage" of the data. The quality of length-based stock-assessment depends always on the quality of the used data and ***"rubbish in is rubbish out".*** **Statements on the status of the stocks of *O. niloticus* can only be made if more data are available.**

5.11 Multi species & multi gear Thompson and Bell analysis

FISAT allows[23] a multi species multi gear analysis and the results of such an analysis are presented in Figures 83, 84 & 85

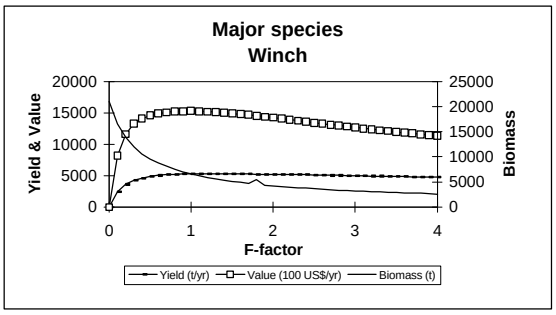
Figure 83: Thompson and Bell analysis for the major species caught by gillnets.



At the present fishing effort (F_{factor} =1) the annual catch of gillnets is estimated at 11,545 tonnes with a value of 1,920.000 USD/yr.
The optimal fishing effort considering yield is reached and is F_{factor}=0.4 (Yield=12,700 t/yr). The optimal economic fishing effort is reached at F_{factor}=0.3 (Value=2,300,000 USD/yr).

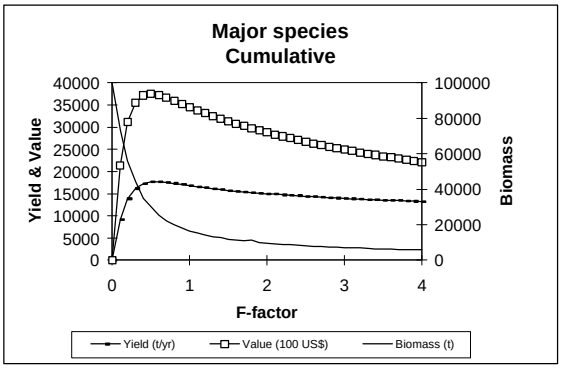
23 FISAT allows a multi-species and multi gear analysis. It is however our experience that the software still has some bugs, especially in this module. The program often "crashed" using this module.

Figure 84: Thompson and Bell analysis for the major species caught by winchboats.



At the present fishing effort (F_{factor}=1) the annual catch of winchboats is estimated 5,271 tonnes with a value of 1,520,000 USD/yr.
The optimal fishing effort considering yield is F_{factor}=1.1 (Yield=5,290 t/yr). The optimal economic fishing effort is F_{factor}=1.0 (Value=1,520,000 USD/yr).

Figure 85: Cumulative Thompson and Bell analysis for the major species.



At the present fishing effort (F_{factor}=1) the annual cumulative catch (for the major species) is estimated 16,816 tonnes with a value of 3.440.000 USD/yr.
The optimal fishing effort considering yield is F_{factor}=0.6 (Yield=17,500 t/yr). The optimal economic fishing effort is F_{factor}=0.5 (Value=3.750.000 USD/yr). The optimal fishing effort considering the biomass is F_{factor} =0.3