rOCK ASSESSMENT OF THE FIVE MAJOR COMMERCIAL SH SPECIES IN YEJI AREA (STRATUM VII) OF THE VOLTA VKE

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hesis submitted to the University of Ghana, Legon, for the degree of Doctor of

ilosophy

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DEDICATION

Dedicated to my late father, Albert Kwame Danson and my mother, Felicia Akosua Dansoaah; and to my brothers, sisters, daughters and my dear wife, Comfort Ofori-Krah by whose efforts and support I have achieved a goal in life.

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DECLARATION

I hereby declare that this research work was carried out by me at the Department of Oceanography and Fisheries, University of Ghana, Legon, under the supervision of Professor C. J. Vanderpuye , and that it is my own work unless otherwise stated therein. I hereby affirm that this work has not already been accepted anywhere for any degree, neither has it been submitted concurrently for any other degree anywhere,

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SUMMARY

An assessment of the fishery of five major commercial species which together contribute more than 70% of the catches in stratum VII (near Yeji) of the Lake Volta has been made based on studies undertaken between March, 1995 and December, 1996. The species studied are: *Hemisynodontis membranaceus* (Geoffroy St. Hilaire, 1809), *Chrysichthys nigrodigitatus* (Lacepede, 1809), *Chrysichthys auratus* (Geoffroy St. Hilaire, 1809), *Oreochromis niloticus* (Linne, 1757), and *Schilbe intermedius* (Ruppell, 1832). The study aimed at contributing information to provide a basis for comprehensive developmental strategies, management and sustainable exploitation or conservation of the fisheries particularly in stratum VII of the lake.

Sixty-six fish species representing 39 genera and 19 families were encountered throughout the studies. Gill-net is the most important gear and the catches were dominated by the bagrids *Chrysichthys auratus, C. nigrodigitatus* and the cyprinid *Labeo spp.*

Data on gonadosomatic index and and gonad maturity stages of the major species indicate that *Chrysichthys nigrodigitatus* and C. *auratus-,* and the cichlid *Oreochromis niloticus* spawn throughout the year while the mochokid *Hemisynodontis membranaceus* shows two clear spawning seasons in February and July.

The mean annual catch-per-unit of effort (CPUE) of canoes utilizing gill-nets during the study period were estimated respectively as 10-18 kg canoe'[1] d'[1] and 7-15 kg canoe [1] d [1] for 1995 and 1996 which indicated declining catches over those years. The total annual canoe catch estimate in stratum VII alone during 1996 was about 25,000 metric tonnes.

Among the physico-chemical variables measured during the study, the mean monthly CPUE was found to be positively correlated with the ammonia concentration in the water; total dissolved solids (TDS), and conductivity. The relation with ammonia concentration (AMN) was best described by the equation:

$$Log_{m} CPUE = 0.6076 Log_{10} AMN + 1.3522 \qquad (r^{2} = 0.6992)$$

Growth parameters were estimated using length-based stock-assessment methods and the von Bertalanffy growth model for the major species are described as follows:

H. membranaceus: $L_t = 44.0 [1 - exp (- 0.55 (t + 0.26))]$

C. nigrodigitatus: $L_t = 44.5 [1 - exp (- 0.65 (t + 0.22))]$

C. auratus: $L_t = 31. Of 1 - exp (- 0.60 (t + 0.12))]$

O. niloticus : $L_t = 33.5 [1 - exp (-0.55 (t + 0.45))]$

S. intermedius: $L, = 30. Of 1 - exp (- 0.80 (t + 0.38))]$

The estimated longevity $(t_{max} - 3/K)$ for the major stocks were between 4 and 6 years indicating that they are short-lived. This was expected because tropical fish are known to be fast growing and short-lived. This increase in growth rate accompanied by a decrease in size appeared to be adaptation for survival by the species in the midst of increasing effort. The estimated ages at first capture of the major species based on the estimated length at first capture (L_{o50}) show that they are caught before reaching one year old which implies that there is growth over-fishing.

The length frequency analysis also showed that the fishery operated on three or four pseudo-cohorts of the major fish stocks. According to the the relative yield-per-recruit analysis, the present level of fishing ($E_{present}$) was greater than the maximum expected exploitation (E_{max}). Based on the E_{opt} = 0.5 optimization criterion, this implied that there was over-exploitation of the major stocks. This grave situation is aggravated by the progressive reduction in water level, brought about by poor rains. In order to forestall this situation, some options for management of the fisheries have been recommended. These include: a) limitation of entry into the fishery; b) enforcement of mesh size regulations; c) control over changing fishery technology; d) establishment of “lake reserves” through closure of fishing in selected areas; and e) adoption of a rights-based fisheries management system.

CHAPTER 1:

GENERAL INTRODUCTION

1.1 BACKGROUND AND JUSTIFICATION

Lake Volta was formed behind a dam erected on the Volta river at a narrow part of the river at Ajena near the township of Akosombo. The Ajena Gorge is approximately 97 kilometres north-east of Accra and about 162 kilometres from the river’s estuary at Ada in the Gulf of Guinea. The dam is a rock-fill type, with clay core and a height of about 74.4 metres above the downstream water-level (Anon, 1974). The closure of the dam at Akosombo occurred in 1964 and the water-level began to rise in September that year and reached the 61 metre contour in the first year (Lawson, 1963). Since then the dam has been a central feature of Ghana’s economy. The resulting reservoir, Lake Volta is estimated to have a surface area of about 8,700 km^ (about 3.6% of the land surface area of Ghana) and about 437 kilometres long. Lake Volta has a shoreline of 4,800km, a maximum depth of 70m and mean depth of 19m and about 81 kilometres wide at its widest point (Vanderpuye, 1982; Anon, 1974).

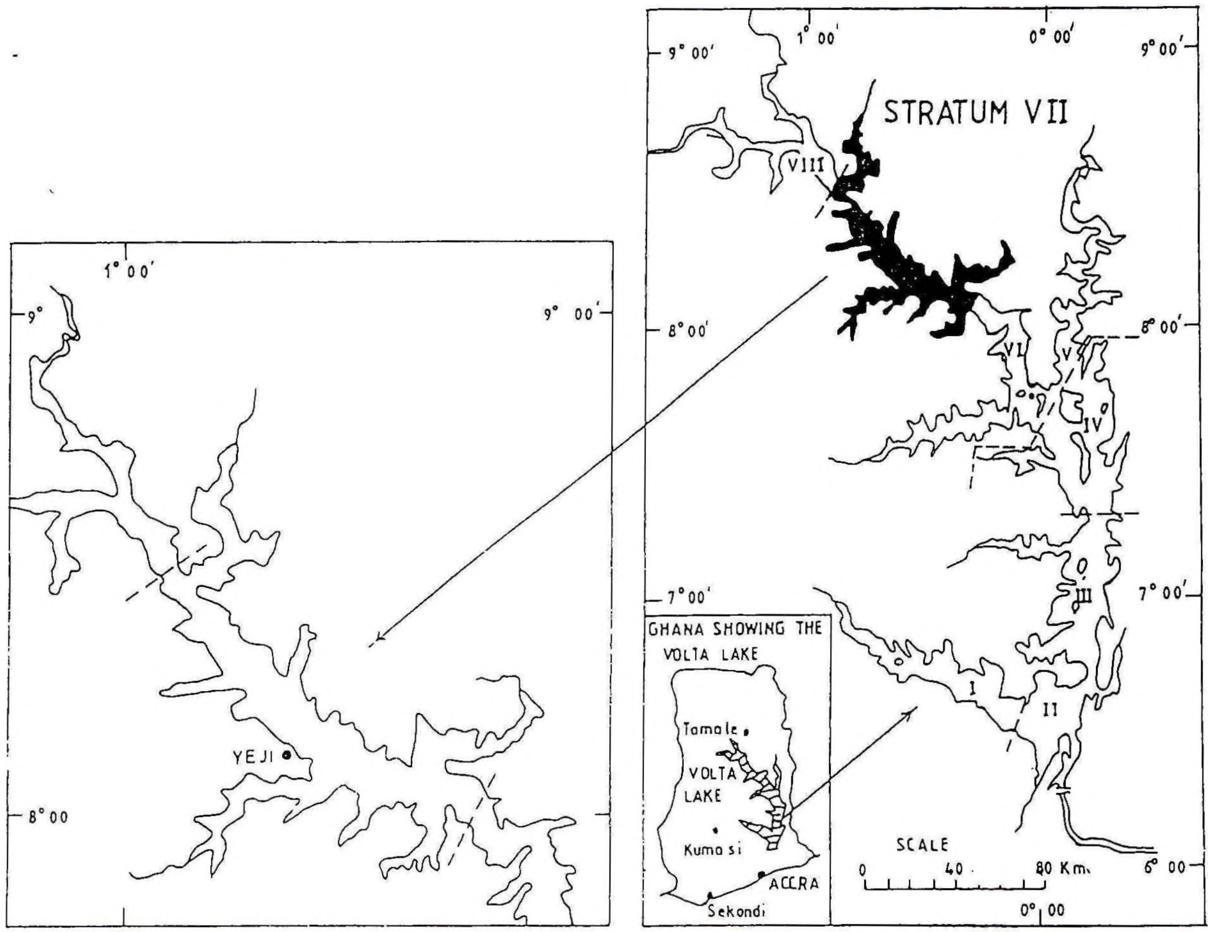


Fig. 1.1: Map of Lake Volta, Ghana

Although the reservoir was planned to provide cheap hydroelectric power for the industrialization of Ghana, the flooding of such a large area evoked changes in the environment which required some social and economic adjustments. For instance, some 80,000 people, formerly living in 600 towns and villages, had to be resettled in 52 townships (Anon, 1974). Also, the dam interrupted the biology and hydrology of the Volta River into the Gulf of Guinea to the detriment of fish species which migrate wholly within the fresh water and whose life-cycle is spent wholly in the river.

In the early days, there was a rush of fishermen into the lake area who settled anywhere they could find fish, even though some of the settlements were not easily accessible. By 1970, a total of 1,486 fishing villages were recorded as scattered along the entire shoreline of the lake (Bazigos, 1970a).

Apart from displacement of the population living in the Volta river valley, the formation of the lake negatively affected the lake basin in at least two other ways: the lake waters increased some health hazards (e.g. increased onchocerciasis and malaria) and several important communication links were cut by the new lake. On the other hand, the formation of the lake resulted in several potential advantages for the economy of the people in the Volta basin. For instance, there was formation of a vast fishing ground and provision of a source of water for large-scale irrigation. Also, the shores became sites of a particular form of seasonal cultivation, namely draw-down agriculture, and an important inland waterway from Akosombo to Yapei and Buipe in the northern region of Ghana was made possible. The lake basin also offered opportunity for the development of wildlife and tourism (e.g. the Duigya National Park between the Obosum and the Sene rivers), while the lush grasslands continue to support livestock production.

Thus, Lake Volta is of crucial socio-economic importance to the nutrition and welfare of the Ghanaian population as a major source of fish protein, reservoir of freshwater for irrigation and avenue of transportation. In 1986, Lake Volta was reported to provide 15.2% of national fish requirement (Agyenim-Boateng, 1986).

In its early life period, the lake passed through a phase of ecological instability to become a relatively stable ecosystem by 1973. During the last three decades (1964-1994), the lake has undergone tremendous changes in its ecology, limno-chemistry and socio-economy. For instance, increased pressure on land along the banks, has led to high rates of deforestation resulting in increased soil erosion and consequent transportation of high loads of silt and nutrients through rivers into the lake thereby contributing to changes in its limnology and silting. Furthermore, wetlands bordering the lake are being converted into agricultural land or land for grazing cattle and therefore may not be able to act as natural filters for nutrients and silt which served as breeding grounds for many fish species.

In anticipation of these problems, considerable multi-disciplinary studies under the Volta Lake Research and Development Project (VLR&DP) were undertaken mainly under the aegis of FAO/UNDP during the first decade of the lake's existence. The areas covered included fishery biology, fish stock assessment and fishery management, canoe and fishing village frame survey, fish catch assessment, fishing gear and methods, fish marketing and processing, limno-chemistry, environmental sanitation and health. Achievements of the VLR&DP in research aimed at improving the lake fishery were high. For instance, developments which followed the wake of stock assessment and gear studies included the introduction of nylon monofilament fishing nets (Taylor and Denyoh, 1968), boats and boatbuilding needs in Lake Volta were assessed and larger and more lakeworthy canoes propelled by outboard motor were designed and constructed (Devambez, 1970; Nordlund, 1970). This helped to increase the fishing range of the fishermen. There was also the conceptualisation of the development of lakeside markets into fishery complexes where facilities were anticipated to be provided in various forms e.g. supply house, boatyards, fishing training school, outboard motor repair shops, fish processing, landing facilities, weighing and storage sheds, wholesale and retail shed (Nordlund, 1970).

However, the above mentioned studies came to an end some twenty years ago when the VLR&DP was phased out in 1978, Since then systemmatic data collection from the lake's natural resources has been lacking thereby calling for renewed studies to facilitate their management.

Considering the importance of Lake Volta as inland fishery resource of Ghana, it would be of both scientific and economic importance to investigate the dynamics of the fish populations in the lake as well as the changes which may have occurred in the fish fauna 30 years after the impoundment of the Volta River.

1.2 LITERATURE REVIEW OF FISHERIES RELATED RESEARCH ON LAKE VOLTA

As early as 1915 a proposal was put forward by two Britsh scientists, Albert Kitson and Duncan Rose to dam the Volta River as a source of hydro-electric power for extraction of bauxite deposits at Mpraeso (Ewer, 1966). A serious examination of this proposal was initiated in 1952 and work on the scheme finally started in 1962, nearly five years after the country had gained independence.

The literature on the resulting Lake Volta is quite enormous. Some of the pertinent references may be summarized chronologically as follows:

1964 - 1968: In order to obtain information on the new ecosystem caused by the major environmental change and to make the best use of the potentials of Lake Volta, it was recognized that considerable research studies, both pure and applied, would be needed. Financial assistance for these studies was approved by the Governing Council of United Nations Development Programme (UNDP) in June, 1967, and the Food and Agriculture Organization (FAO) of the United Nations was designated as the executing agency (UNDP/FAO, 1971).

Research, however, did not await the commencement of the UNDP assisted project, Basic studies on fish biology, limnological and epidemiological aspects were executed by the Institute of Aquatic Biology (IAB) (Obeng, 1968; 1969).Also, the University of Ghana set up the Volta Basin Research and Development Project (VBR&DP) primarily to co-ordinate the work of the Departments in the University interested in problems within the Volta Basin (Ewer, 1966). It involved researchers in various disciplines including archaeology, history, geography, geology, the study of religions, economics, sociology and also biology (Petr, 1966; 1967a,b; 1968a,b; 1968c,d,e). The biological work started with the zooplankton as well as the water weeds of the river basin.

Limnological studies showed that the newly formed lake was unstable physically and chemically, and the w'ater mass was characterized by a highly variable level of oxygenation which did not penetrate significantly below 10 metres (Ewer, 1966).

Biologically, it was regarded both as a vastly broad river with fish still living predominantly on the shorelines and from the viewpoint of the plankton, as a large pond. Bottom fauna were found as really shore fauna, dominantly chironomids and Aufwuchs. The profundal zones were uninhabited not even oligochaetes or nematodes (Ewer, 1966). For this reason, the biomass of periplankton far exceeded the biomass of benthos (Petr, 1968c).

It was also reported that the dominant changes in composition of the fish fauna were characterized by the disappearance of certain fish families, and the establishment of species which were lowly represented in the river prior to the formation of the lake. For instance, mormyrids which formed a substantial part of catches in the Volta River, almost completely disappeared from commercial catches (Lawson, *et al.,* 1968). In the northern part of the Lake, characids, the dominant family in the river had well established themselves and by 1967 formed 51% in the total fish landings in 3.81cm mesh-sized gill nets in that area. This contrasted strongly with the situation in the southern part of the Lake, where characids formed only 1% of the total catch (Lawson *et al.,* 1968). Cichlids rapidly increased in number in the southern part, where in 1967 they composed 81% of the total catch. In the northern part, they comprised less than 1%. In open waters of the south over 90% of the total number in most months were reported to consist of the small pelagic *Pellonula afzeliusi,* a small transparent clupeid (Lawson, *et al.,* 1968).

According to Petr (1968a), there was a shift in the fish community from a system dominated by riverine towards a composition which was dominated by more lacustrine species. The majority of fishes in the lake, as they are a legacy from the river, were more or less pelagic (Roberts, 1967). A great diversity of feeding types was found (Roberts, 1967) and therefore it was suggested that there was no justification for introduction of exotic species until a definite need for them could be demonstrated, and all the possible consequences considered.

<u>1969 - 1972:</u> This period was marked by Phase I of the Volta Lake Research and Development Project (VLR&DP). It was financed by UNDP and executed by FAO with the Volta River Authority (VRA) as government co-operating agency. The purpose of the Phase I Project was to assist the Government of Ghana through the VRA in strengthening research on fisheries and hydrobiology, public health and resettlement of people displaced by Lake Volta (UNDP/FAO, 1971). During this project, efforts were made to undertake more detailed monitoring of the fisheries, including feeding habits, reproduction and growth and limnology. The studies showed that the entire shoreline was fished with the heaviest concentration of fishing effort being in those parts of the lake nearest to marketing facilities (Bazigos, 1970b).

A full frame survey was carried out in order to determine the number of canoes and fishermen operating on the Lake . A total of 12,650 canoes and 18,300 active fishermen were recorded (Bazigos, 1970b). According to this survey, fishermen on the lake could be classified as full-time and part-time.

Preliminary catch and stock assessment programmes were initiated which followed a stratified sampling technique (Bazigos, 1970c; Evans and Vanderpuye, 1969). In this survey, a fishing canoe with its crew and gear was taken as one unit of fishing for the purpose of assessment of the stocks. For sampling purposes, the lake was divided first into eight major strata. Further, each stratum was divided longitudinally into two sub-strata. Fishing villages within each sub-stratum were grouped into three minor-strata according to the number of canoes (small, medium sized, large) some of which were selected randomly for sampling. The first year of this survey was completed in April, 1970, and gave a point of estimate of the catch from May, 1969 to April, 1970 of 61,000 metric tons, with marked seasonal and spatial variations. Evans (1971) gave a critique of the main technical problems concerned with the methodology, changing pattern of Lake Volta, the effects of water level fluctuations on fish production and harvest, and also problems associated with vegetative clearing of reservoir basins prior to impoundment.

To supplement the sampling by gill nets, full scale rotenone (a fish toxin with no residual effect) sampling commenced in early 1970 (Evans and Vanderpuye, 1970). The results of the first round made in the dry season showed the presence of 58 species. A moderately high fish stock was found which averaged 170 kg/ha (or 151 lb/acre) (Loiselle, 1970). The information applied only to very shallow water usually not more then 4 metres from the shore. In addition, detailed studies were made on the feeding habits of both juvenile and adult fish (IAB, 1968; Whitehead, 1969). Although there were gaps, these studies covered in reasonable detail most of the more important species. Further fish biological studies resulted in the calculation of average length-weight ratios for many of the important commercial species (Lelek and Wuddah, 1969; Reynolds *et al.,* 1969). Studies were also undertaken in fish population changes in the lake (Petr, 1968a; 1969; Petr and Reynolds, 1969) as well as gear selectivity (Taylor and Denyo, 1968; Gilbert and Titiati, 1969).

This period also marked the birth of a proposal by Henle and Eckert (1970) for the fisheries development project at Kpando-Torkor and possibilities of improving traditional fish processing. McAlister and Taylor (1969) provided justification for the establishment of other ports at Yeji and Abotoase.

Devambez (1970) identified the main types of gear used on Lake Volta as gill-nets (including entangling nets), traps, long-lines, cast nets and spears. Gilbert and Titiati (1969) also identified static gear (e.g gill-nets and traps) as the most widely used fishing method employed in Lake Volta and described at length the methods for construction of open water nets for inshore fishing as well as the use of long-lines and traps. In the same report, the authors examined the possibilities of use of active gear for fishing in Lake Volta. Bottom trawling, mid-water trawling, open water seining were discussed with relevance to fishing in Lake Volta. They noted that bottom and mid>vater trawling would not be economical in view of the possibility of the gear being damaged by tree stumps in the Lake. Repair and maintenance cost was estimated to be more costly than the expected returns. They however, found the open water seine (Purse or Lampara) as best for adoption in selected parts of the lake, but found the canoes in use to be inappropriate for this method of fishing.

At the close of Phase I of the UNDP/FAO Project after synthesis of all information available of fish stocks, it was reported as part of the conclusions that there was no indication of overfishing (Evans, 1969) and that the fishing industry should be encouraged to continue its fast expansion without applying any controls.

1973 - 1979: This period marked Phase II of the Volta Lake Research and Development Project (VLR&DP). This phase strengthened research on fisheries, hydrobiology, public health and the resettlement of the people displaced by the lake (Evans, 1971; Evans and Vanderpuye, 1973a; 1973b; Henderson, 1974). A Fish Stock Assessment programme based on regular sampling with a set of gillnets (mesh sizes 12.5 200 mm) at 30 sampling sites, located in all the strata of the lake, was carried out by Evans and once every two years, a frame survey should be conducted in order to revise the statistical frame (UNDP/FAO, 1971). The project also recommended importation of small outboard motors between 4-10 hp for canoes and that training programme of boatbuilders be intensified, and accident-prone boats be replaced. Closing off coves of the lakes for intensive culture was also suggested by the project. Such areas were considered suitable for pen and cage culture. The project also set up a fish marketing survey at the major market places along the lake by counting the number of baskets containing fish landed. Some problems concerning fish preservation and human health were investigated. In 1975, the project carried out a completely new frame survey which recorded 13,800 canoes operated by 20,600 active fishermen. The results suggested an increase in fishing effort by approximately 12% since the previous frame survey in 1970 (Coppola and Agadzi, 1976; Agadzi, 1976). The Project was terminated in 1978.

1980 - 1994: The Department of Fisheries continued the monitoring programme.

Unfortunately, the results are not available. As a result, there is paucity of data on the fisheries of the lake from 1978 until 1989 when separate studies were carried out by researchers at the University of Ghana (UG) and the Institute of Aquatic Biology (Ofori-Danson and Antwi, 1994) on the limno-chemistry and fish biology in the Akosombo (gorge) area or (Stratum II). In 1989, various studies were undertaken in Stratum VII (near Yeji in the Brong Ahafo Region) under the DANIDA sponsored Integrated Development of Artisanal Fisheries (IDAF) Phase I Project with FAO as the executing agency.

Under the IDAF Phase I Project, a fisheries monitoring programme was carried out in Stratum VII. Catch data from different gears were collected. However, the number of samples taken was not sufficient for a stock assessment analysis and for the determination of the total catch of Stratum VII (Braimah,1990; 1991; Goudswaard and Avoke, 1992a,b,c,d,e) . Socio-economic surveys of Stratum VII were also carried out (Maembe, 1990; 1992). This survey indicated that the number of canoes operating in Stratum VII had increased by at least 300% since the mid 1970 from 1,700 to 6,500 by 1991 and these were utilized by an estimated 18,300 fishermen. The number of fishing villages correspondingly increased from 169 to 342 during the same period. The survey also indicated that active gears such as as purse seines and beach seines had been introduced into the lake by the fishermen. It was also reported that child labour in the fishing villages was common among the fishers in addition to the lack of certain socio-economic facilities otherwise enjoyed by rural communities engaged in farming and urban residents (Maembe, 1990; 1992). The villages also lacked any system for ensuring ready supply of fishing inputs, fuel and spare parts (Agyenim-Boateng, 1989; Yeboah, 1990).

<u>1995 - 1996:</u> IDAF carried out a full frame survey in Stratum VII of Lake Volta in 1995. In this survey (de Graaf and Ofori-Danson, 1996), all fishing villages were visited and interviews were held with groups of fishermen. Almost all fishermen interviewed (97%) believed that the fish catches were declining. A major reason suggested for the decline

was an increased population, followed by the low water level and the use of beach seines and winchboats. Under a contractual service agreement with IDAF, the Institute of Aquatic Biology (now Water Research Institute), undertook studies in limnology, benthic macro-invertebrate fauna and fish biology in Stratum VII of the lake (Abban and Biney, 1996). Analysis of food habits of some commercial fishes including *Alestes baremoze, Brycinus nurse, Schilbe intermedius, Schilbe mystus, Bagrus bajad, Clarias anguillaris* and *Labeo coubie* indicated that majority of the fishes depend on autochthonous material, especially larvae of chironomidae (Amakye, 1996). Estimates of the coefficient of condition (or condition factor) of major fish species studied suggested that resources provided by the lake environment were comparable to other segments of the Volta System since condition factor of the species was comparable (Abban and Biney, 1996).

1. 3 OBJECTIVES OF THE STUDY

The primary objective of the study is to obtain information which are relevant to the assessment, development and management of five major economic species in the Yeji area of Lake Volta (Stratum VII). Specific objectives with the view to identifying their management requirements include obtaining information on the state of the aquatic environment and possible environmental correlates of fish productivity, relative abundance of fish fauna and feeding habits of the fish species, determination of growth and mortality rates using suitable length-based stock assessment models, assessment of changes in the exploitation level of the major fishery resource and to determine the optimum for sustainable exploitation.

In relation to above, it was also the objective to identify potential management options which could be adopted to sustainably improve fish production from Lake Volta.

CHAPTER 2:

MATERIALS AND METHODS

2.1 GENERAL INFORMATION ON THE STUDY AREA

Lake Volta lies between longitudes 1° 30’ W and 0° 20’ E and latitudes 6° 15’ N and 9° 10’ N, at an altitude of 85 meters above sea-level at full capacity (Czemin-Chudenitz, 1971). Available morphological data of the lake at 85.33 m (280 ft) elevation indicate total length of 400 km, maximum width of 23.8 km, average width of 6.9km, maximum depth of 75 m, and an average depth of 18.8 m (Czemin-Chudenitz, 1971). The total shoreline (including islands) is estimated to be 5,200 km.

The average river flow before the dam was built was recorded by the Engineering Section of the VRA as 38,500 cubic feet per second (cusec) or 1,090 cubic metres per second (cumsec). A maximum of 500,000 cusec (14,150 cumsec) was recorded. The maximum out flow of two spillways with 12 floodgates (each 13.8m high and 11.71m wide) is estimated as 444,000 cusec (12,565 cumsec).

In the early life of the lake, the seasonal rise and fall were normally kept by VRA between seven and eleven feet (2.10 to 3.30 metres), but could be greater or less. Under

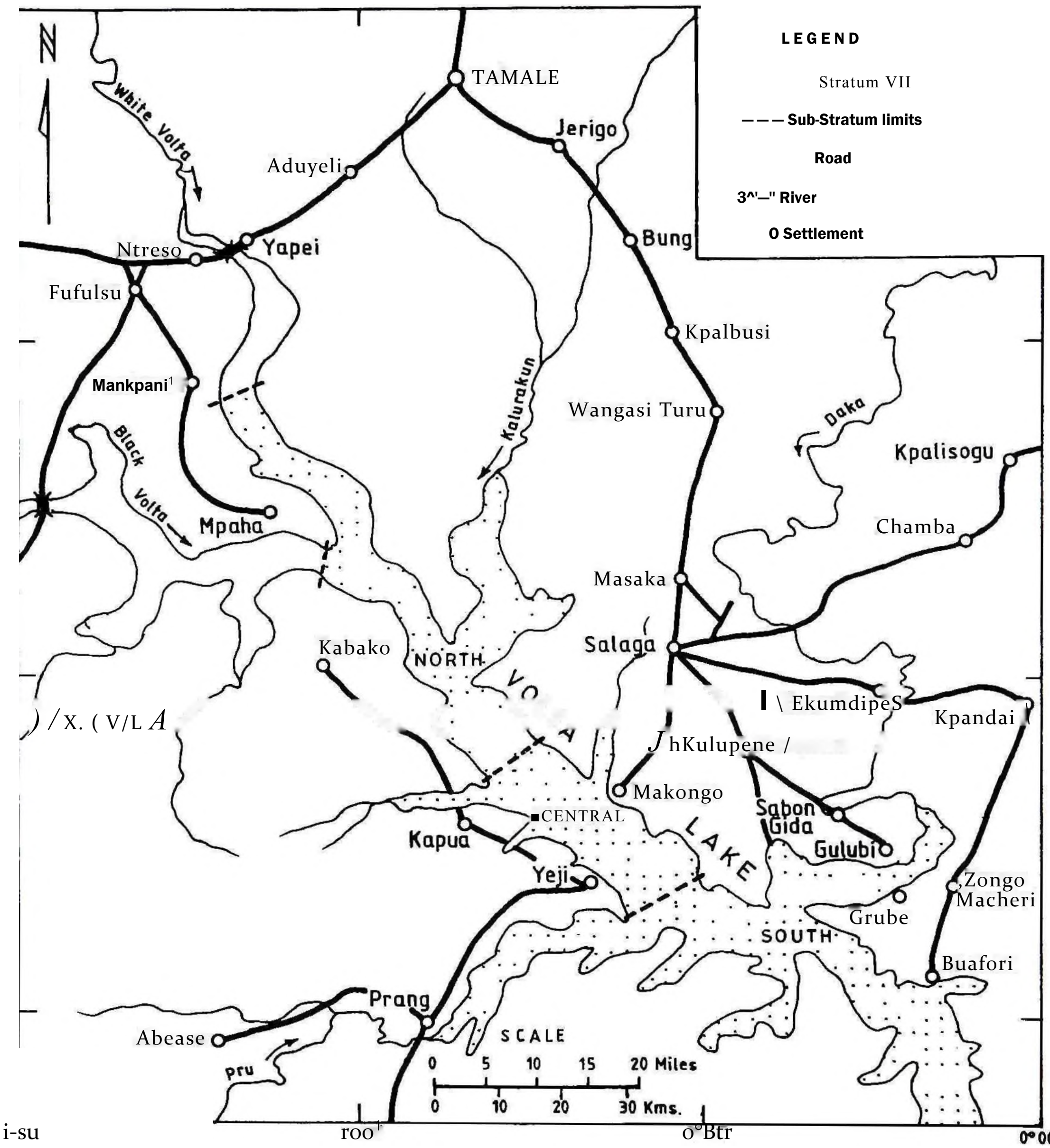


Fig. 2-1 Stratum VII of Lake Volta and its Sub-stratification

normal circumstances, the lake reaches the maximum level during the months of August and September and minimum water level just before the rains, that is in February-March.

This study focussed mainly on the area known as Stratum VII of Lake Volta which lies between longitude 0° 10’ to 1° 05’W and latitude 8° 8’ to 8° 20’N and extends for about 60 km south and 50 km north of Yeji (Fig.2.1). Stratum VII was chosen because it currently is one of the areas with the highest fishing activity and boasts of the largest fish market centre at Yeji. The Yeji market is known to serve a perimeter that extends beyond Wenchi, Sunyani, Kumasi and Nkawkaw (Agyenim-Boateng, 1989). Also, Yeji serves as a major ferry crossing point between northern and southern Ghana.

Stratum VII is influenced mainly by the Black Volta, White Volta, Daka, Pru, and Kalurakun rivers. Thus, the area may be regarded as riverine. The highest floods occur in August-December shortly after the onset of the rainy season in northern Ghana.

The peculiar feature about 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 coolness due to rapid evaporation from November to February when they blow over most of Ghana. The vegetation around Stratum VII is wooded savannah-grassland prone to bush fires in the dry season.

Scientists working in the lake during the 1980s found that trully lacustrine conditions existed from the dam up to Kpando; north of this, semi-lacustrine, and then riverine conditions prevailed. It is not likely that the situation has changed now. The earlier scientists found the water to be alkaline, except close to the bottom where sometimes the pH fell below 7.0.

2.2 DIVERSITY OF FISHING METHODS IN THE STUDY AREA

Lake Volta currently has diverse fishing methods. In 1970 and 1975, the principal fishing gears used on the lake were gill-nets, cast-nets, lines and traps (Bazigos, 1970d; Coppola and Agadzi, 1976). However, recently other gears have been introduced in Stratum VII including drive-in gear *(wangara),* bamboo-pipe fishing (specifically for *Chrysichthys*), combined gill-nets and traps (*nifa-nifa*) and some active gears, such as beach seines (*adranyi*), purse seines (*winch-nets*) and other forms of encircling gear (Braimah, 1989, 1991b). These active gears are supposedly illegal on the lake, but currently contribute between 65 and 70 % of the total fish landings of the lake (unpublished FAO/IDAF Project report, 1990).

The introduction of purse-seines (winch-nets) on the lake since the mid-1980s led to the deployment of a new type of craft for fishing, called winch boat. This craft measures between 9 to 13 m long and over 1 m wide. The boat has a deck which enables 10 to 15 fishermen to stand easily while drawing-in the net, which can be as long as 500 to 800 m and 20 to 30 m deep. As a result of tree stumps, winch-nets are used mainly in the original river bed. In areas where winch-nets operate, other fishing methods are compelled to fish in inshore waters because other gears are fouled by the winch-net operators. Winch-net fishing takes place in the deeper parts of the lake where bottom obstructions like dead tree stumps are absent especially in the main Volta river bed. According to Frame Survey undertaken in Stratum VII during 1995 (de Graaf and Ofori-Danson, 1996), there are 358 winchboats in that sector of the lake.

Fishing with bamboo pipes is also a relatively newly developed fishing technique in Lake Volta. In this method, bamboo stems are cut to pieces of three nodes. Holes are made in the pipes either on the side where a small part of each intemode is cut out or the internal wall between the nodes in the pipe is broken through. In the first case, three small holes are created while in the second, one long hole with two openings is made. Pipes are hanged on small ropes (snoods) which are attached on a main rope hanging between a number of tree stumps. The pipes are hanged in a mid-water position 2-3 metres below the surface of the water. Fishes, normally *Chrysichthys spp* enter the pipes and when the fisher lifts the pipes after a few days the fish is shaken out of the pipes into a canoe and caught. If catches are good, fishers check their pipes every 3-4 days but when catches are small, the pipes may stay for 7-10 days before being inspected, lifted and emptied. The pipes are known to last for about three years while some unknown number is lost due to broken ropes, cracks or storms.

Another novel fishing method is the Acadja fishiing. Accoding to Mensah (1979), this is an old traditional aquacultural practice in lagoons. It is likely that this fishing technique came from the lagoon fishers. In this method, several whole twigs or branches of trees are dumped in the water, especially in sheltered areas. These serve as fish aggregating devices and also feeding and spawning areas. The acadja fisher leaves the pile for two or three weeks for the environment to stabilize. Before harvesting, the area is surrounded with a net. The twigs and branches are then removed an put at a different but nearby area of the water. The net is closed, forming a bag, and the fish is collected. The target fish are cichlids but other species are also caught

2.3 SAMPLING

Although preliminary field trial studies started in October, 1994 regular sampling and data collection were carried out for two years between February, 1995 to January, 1997.

2.3.1 Stratification of the study area

Lake Volta was partitioned into eight commercial fishing areas or strata for stock and catch assessment purposes by Bazigos (1970a); Evans and Vanderpuye (1973b) (Fig.1.1). The same stratification was adopted in this study to facilitate comparison with results of earlier studies. For the purpose of sampling, the study area was divided into three sub-strata (Fig.2.1), namely: (i) Northern sub-stratum (ii) Central sub-stratum and (iii) Southern sub-stratum. Further stratification was based on the size of the fishing village and the number of canoes in operation. Three of such categories made were namely, small sized village (0- 10 canoes), medium sized village (11-50 canoes) and large sized village (more than 50 canoes) as adoption from Bazigos (1971a; Coppola and Agadzi, 1976). The characteristics of the different landing sites selected are presented in Appendix I.

2.3.2 Limnological factors

Between February 1995 and January 1996, vertical profiles of lake water samples were taken bi-monthly from the surface to the bottom of the lake using 1.71iter Bio-Hydro Water Sampler.

2.3.3 Fisheries-dependent data

2.3.3.1 Catch assessment data

Since a large number of fishing sites occur in each minor stratum and different types of fishing gears were employed, it was impossible to collect data on total catch and total fishing effort. Consequently, catch and fishing effort data were determined in a more specific Catch Assessment Survey (CAS). For this, three fish landing sites each were selected in the Northern and Southern sub-strata, and four sites in the Central sub-stratum.

The commercial winch-nets could not be sampled regularly as the fishermen/fish mongers did not permit measurement of the fish caught, and obtaining fish samples from them proved difficult. Therefore only canoe samples were used in this study.

Sampling for catch and determination of fishing effort were carried out at the selected sites in the Central sub-strata one day per week every month and once bi-monthly in the Northern and Southern sub-strata. At each landing site, the total number of operational and non-operational canoes were counted, and other vital information (e.g. mesh size of nets, types of gear, number of fishermen per canoe etc.) recorded on the day of sampling.

2.3.3.2 Fish species composition and relative abundance

Fish samples were obtained from commercial gillnet catches and examined for their species composition.

2.4 DATA COLLECTION AND ANALYSES

2.4.1 Limnological factors

The parameters of the water samples determined were: temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), alkalinity, total hardness, total dissolved solids (TDS), conductivity, sodium, calcium, magnesium, chloride, phosphate, nitrate, nitrite, ammonia, silicate, sulphate and transparency. The following methods used for determination of each of the mentioned limnological factors were adopted from standard methods for the examination of water and wastewater (APHA-AWWA-WPCF, 1985). Laboratory facilities at the Water Research Institute of the Council for Scientific and Industrial Research (CSIR) were utilized in making the measurements.

2.4.1.1 Temperature

Direct measurement of surface water temperature in degrees Celsius was made with Mercury-in-glass thermometer.

2.4.1.2 pH

Direct measurement of the pH of the water was made with Wagtech portable pH meter.

2.4.1.3 Conductivity

Direct measurement of conductivity of the water was made with Hach Model Conductivity Meter.

2.4.1.4 Total dissolved solids (TDS)

Direct measurement of the total dissolved solids in the water was made with Hach Model Meter.

2.4.1.5 Alkalinity

Measurment of alkalinity of the water was found by titration with acid using Methyl-Orange indicator.

2.4.1.6 Total hardness

This was measured using the Ethyl-diethyl-acetate (EDTA) titrimetric method.

2.4.1.7 Calcium

This was measured using the Ethyl-diethyl-acetate (EDTA) titrimetric method.

2.4.1.8 Magnesium

This was calculated from values obtained for total hardness and calcium hardness as: (Total hardness - Calcium hardness) x 0.243

2.4.1.9 Chloride

The chloride content of the water was calculated after Silver Nitrate titration.

2.4.1.10 Sodium

Measurement of sodium content of the water was obtained through the Flame photometric method.

2.4.1.11 Potassium

Measurement of sodium content of the water was obtained through the Flame photometric method.

2.4.1.12 Phosphate

This was measured using the Spectrophotometer. The spectrophotometric by Abscorbic Acid method was adopted in making measurements of the phosphate content of the water.

2.4.1.13 Nitrate

This was measured using the Spectrophotometer. The spectrophotometric by hydrazine reduction followed by diazotization with sulfanilamide was adopted in making measurements of the nitrate content of the water samples.

2.4.1.14 Ammonia-nitrogen

This was measured using the Spectrophotometer. The spectrophotometric by Direct Nesslerization method was adopted in making measurements of the ammonia-nitrogen content of the water samples.

2.4.1.15 Silicate

This was measured with the Spectrophotometer. The spectrophotometric by the molybdosilicate method was adopted in making measurements of the silicate content of the water samples.

2.4.1.16 Dissolved oxygen (DO)

The DO was determined by iodometric titration.

2.4.1.17 Biological oxygen demand (BOD)

The BOD was determined by iodometric titration after 5 days of incubation at 20°C.

2.4.1.18 Transparency

The depth of visibility was measured by Secchi disc disappearance.

2.4.2 Fisheries-dependent data

2.4.2.1 Estimation of catch and effort

For the purpose of recording the catch data, a number of fishing units (canoes) were selected and their catches weighed. This allowed an estimate of catch-per-unit of fishing effort (CPUE) as kilogram per canoe per day (kg canoe^{-1} d^{-1}). The total landings for the day were estimated by multiplying the estimated CPUE by the total number of operating that day. The data were entered in a Microsoft ACCESS database for processing by computer.

According to the IDAF Frame Survey of stratum VII carried out in **1995** (de Graaf and Ofori-Danson, **1996), 12%** of the villages did not fish at least one day of the week (Friday or Sunday). The fishing days in each month were adjusted to account for this observation and expressed as number of **canoe days** as follows:

(a) Gross canoe days = total number of canoes x total number of days month

(this means that all the canoes in the stratum work each day of the month)

(b) "Lost" canoe days = 12% of canoes x number of days without fishing (this means that 12% of the total number of canoes are grounded for about 4 days in the month, assuming 28 days in a month)

(c) Net fishing days = (a) - (b)

Given the estimated number of canoes in the Northern, Central and Southern sub-strata as 2,805; l,445;and 3,818 respectively (de Graaf and Ofori-Danson, 1996) the total annual catch by canoes in stratum VII was estimated as:

Total catch per year = Total number of canoes x mean annual catch per canoe

Analyses of data were facilitated by using the Microsoft EXCEL, and Microsoft ACCESS software.

2.4.2.2 Fish species composition and relative abundance

Fish samples obtained from the commercial catches were identified following keys by Leveque *et al,* (1992). The percentage composition of a given species by number and weight were calculated. The species encountered were classified according to their food habits after Evans and Vanderpuye (1973a) as: (i) Aufwuch detrital feeders & herbivores (ii) Semi-pelagic omnivores (iii) Benthic omnivores and (iv) carnivores. The species in classes three classes were considered as forage (F) fishes. In order to investigate the ecological balance between carnivorous fish and their prey populations, the total weights of forage (F) species to carnivores (C) was calculated and defined as the Forage-Carnivore (F/C) ratio after Blay (1985).

2.4.3 Fisheries-independent data

2.4.3.1 Morphometric and gravimetric data

The data collected were limited to the following species which altogether contributed more than 70% of the total landings in the study area: *Hemisynodontis membranaceus (Geoffrey St. Hilaire, 1809), Chrysichthys auratus (Geoffrey St. Hilaire, 1809), Chrysichthys nigrodigitatus (Lacepede, 1803), Schilbe intermedius (Ruppell, 1832),* and *Oreochromis niloticus (Linnaeus, 1757).*

The above fish species caught were measured for standard and total lengths to the nearest centimetre and weighed to the nearest gram. The sex was determined and gonad weighed to the nearest 0.01 gram. Gonad condition graded visually on a five-point maturity scale adopted from Bagenal and Braum (1968) is shown in Table 2.1.

Table 2.1 Description of gonad maturity stages (after Bagenal and Braum, 1968)

Stage	**State**	**Description**
0	Virgin	Very small gonads close under the vertebral column; testes and ovaries colourless; eggs invisible to naked eye.
I	Maturing virgin	Testes and ovaries translucent; small eggs can be seen with aid of magnifying glass.
II	Developing	Ovaries reddish; eggs visible to eye. Testes appear as tiny processes or strands.
III	Developed	Ovaries orange-reddish. Eggs clearly discernible. Ovaries occupy about two-thirds of central cavity. Whitish milt appears under slight pressure.
IV	Gravid	Ovaries filling ventral cavity, eggs completely round and released from ovary with little pressure on abdomen. Testes conspicuously bulky and whitish with milt flowing when punctured.
V	Spent	Not yet fully empty. No opaque eggs left in ovaries; ovaries large but flabby. Testes flabby and with remains of milt.

Samples for length frequency analysis were taken from the above species from February, 1995 to December, 1996 . Sampling was carried out through experimental fishing with purse-seine, (locally called winch-net) monthly in the Central part and bi-monthly in the Northern and Southern part of Stratum VII. The monthly length-frequency distributions were determined at 1.0 cm length intervals.

2.4.3.2. Gonadosomatic index (GSI), condition factor and spawning period

The fat in the viscera of the specimens was removed and weighed and the Relative Mesenteric Fat (RMF) calculated as: (weight of mesenteric fat /total body weight) x 100. Also calculated was the gonadosomatic index (GSI) from the relation:

$GSI = (GW/W)\ X100$ where, *GW* is the gonad weight and *W* is the total body weight in grams. The sex ratio was calculated for each month and significant deviations from 1:1 tested using the $\%^2$ test. These were related to abiotic factors of the environment and used to define the peak spawning periods for the target species.

The Condition Factor (*CF*) which measures the physiological well-being or fatnes of a fish was obtained from the relationship: $CF = (W/L^3)\ X100$ where *L* is the standard length in centimetres.

2.4.3.3 Length-weight relationships

The relationship between the standard length *(L)* and the total body weight *{W)* of the male and female fish was expressed by the equation:

$$W= a. L^b$$

where a is a mulitpliplicative constant factor, and *b* is an exponent. The values of *a* and *b* in the above equation were estimated by means of a “linearized” form of the equation, namely:

$$log\ W = log\ a + b.\ log\ L$$

that is by taking (base 10) logarithms on both sides and by estimating approximate values of *log a* and of *b* by means of ordingary least-square linear regression. The coefficient of determination (r) was also estimated when the above expression was fitted to the data.

2.4.3.4 Length at first maturity (L_m)

For the females, the percentage of mature fish (taken for fish of maturity stage III and above) at every half centimetre standard length was calculated. Standard length was plotted against mature fish. From the underlying sigmoid curve, the mean size at first maturity *(LJ,* was defined at 50% maturity level.

2.4.3.5 Length frequency data

To eliminate selectivity of purse seine nets for smaller fish, the original length frequencies were adjusted using the probability of capture for each length class in the samples. The probability of capture, *P,* was calculated for each length class by using the logistic curve equation:

$$P = 1/(1+ exp\ [-r(L- L_{cS0})\ ]) \qquad \text{(King, 1995)}$$

where L is fish standard length in centimeters, r is the slope, and L_{cS0} is the mean length at first capture. These corrected frequencies were calculated by dividing the number of fish in each length class by the probability of capture.

Using the Bhattacharya method as incorporated in FISAT software (Sparre and Venema, 1992), the corrected length-frequency data were analysed to separate the length-frequency distribution of pooled data from 1995 to 1996 into a series of normal distributions representing different cohorts.

In the Bhattacharya method, the bell-shaped curve of a length-frequency distribution is approximated as a parabola, which is then converted to a straight line of the form:

$$dt\ (In\ N) = a + b\ (L)$$

where, *dt (In N)* is the difference between the natural logarithms of the number of fish in one length class and the number in the preceding length class, and *L* is the upper limit of the preceding length class. The Separation index (SI) of Hasselblad (Sparre and Venema, 1992) expressed by (Gayanilo *eta!.,* 1995) as $SI = L_{(a+I)} - L_{(a)}/$,

(Standard deviation $_{(a+I)}$ + *Standard deviation*$_{(a)}$*/ 2)* was used in assessing the success of separation of successive cohorts. According to Hasselblad (1966) cited by Sparre and Venema (1992), when the value of *SI* is less than 2 it is virtually impossible to separate the components.

2.*4.3.6* *Estimation of growth parameters and growth performance index (o')*

The von Bertalanffy growth function (VBGF) has the basic form:

$L_t = L_{,,}$ *[1 - exp" $^{K(t't}$o>]* (Pauly, 1984; Sparre and Venema, 1992)

where L_t is the length at age *t,* *L,,* is the aysmptotic length, that is the mean length the fish of a given stock would reach if they were to grow indefinitely, *K* is the growth coefficient, t_0 is the theoretical age at length zero.

Estimates of the growth parameters L_ and *K* were obtained from the FISAT software (Gayanilo *et al,* 1995). In using the software preliminary values of *L_* were made from Wetherall plot (Sparre and Venema, 1992).

Arbitrary values of *K* were then entered and varied until reasonable estimates (measured by the “ index of goodnes of fit, *R”)* for and *K* were obtained. The theoretical age at length zero *(tj* was calculated from Pauly’s (1979) empirical equation:

$$Log_{10}(-t_0) = -0.392 - 0.275\ Log_{10}\ L\ „ - 1.038\ Log_{10}\ K$$

while the growth performance index *(&')* was computed from the equaton:

$o\ '= Log\ i_0\ K + 2\ Log\ io\ L$ ~ (Pauly and Munro, 1984).

2.4.3.7 Estimation of mortality parameters

The growth parameter estimates (as generated by FISAT) were employed for the estimation of *instantaneous total mortality (Z)* from the descending straight right arm of a length-converted catch-curve (Sparre and Venema, 1992). Estimation of *instantaneous natural mortality (M)* was made from the built-in empirical relationship of Pauly (1980) given as:

$$Log_{10}\ M = -\ 0.0066 - 0.279\ Log_{10}\ L\ \_ + 0.6543\ Log_{w}\ K + 0.4634\ Log_{J0}\ T$$

where *T* is the mean annual surface temperature of the lake in degrees Celcius. *The instantaneous coefficient of fishing mortality F,* was computed as the difference between instantaneous total and instantaneous natural mortality: $F = Z - M$ (Ricker, 1975) while exploitation rate ***(E)*** was calculated as the fraction of death caused by fishing: $E = F/Z$.

2.4.3.8 Length-structured virtual population analysis (VPA) for stock size and fishing mortality

The monthly length frequncy data were converted to total landings by using the raising factor ***(Rj)*** as follows:

Rf= Total weight of landings in a month / Total weight of sample in month

The adjusted data for 1995 and 1996 were pooled and the annual average frequencies obtained as inputs for Jones' length-based virtual population analysis (VPA) (Sparre and Venema, 1992). From the estimated values for the growth parameters £„ , ***K,*** and t_0 estimates of historic fishing mortality and stock numbers in a cohort of fish were made from the numbers of fish caught during commercial fishing operations.

The length groups were converted into age intervals by the inverse von Bertalanffy equation:

$$t_{(U)} = t_0 - 1/K \ln [1 - L_s/L_\infty] \qquad \text{(Sparre and Venema, 1992)}$$

where $t_{(Ll)}$ is the age at length $L_,$. The number of fish that attain length Lj, $N_{(L1)}$ = the number of fish that attain age $t_{,L1}p$ or $N_{t(U)}$, also called the number of survivors. The number of survivors, $N_{(U)}$, was calculated from the equation:

$$N(li) \sim [N (12) ^{x} H (L], LJ + C (Lj, LJ] x H (Lj, L?)$$

where,

$N (L2)$ = the number of fish that attain length L_2

= the number of fish that attain age $t_{(L2)}$

$C (Lj, L2)$ = the number of fish caught of lengths between $L_;$ and L_2

= the number of fish caught of ages between $t_{(U)}$ and $t_{(L2)}$

$H (Lj, LJ$ = $[(L. -Lj) / (L.\sim LJ]^{M/2K}$

= [the fraction of NLj which survive natural deaths during the time period from $t_{(L1)}$ to $t_{(L1)} + dt/2] \sim^{!}$

The calculation started with the last length group and used the length-based form of the catch equation:

$C (Lj, LJ — N (Lj) x F/Z x [1 - exp (-Zx dt)]$ (Sparre and Venema, 1992)

An initial guess was made of the *"terminal F/Z"* which refers to *F/Z* for the oldest age (length) group. The above calculations were facilitated by the FISAT software (Gayanilo *etal.,* 1995).

2.4.3.9 Relative yield- per- recruit (Y/R)' analysis

The FISAT programme was used to asess the optimum level of exploitation in relation to mean length at first capture L_{cS0} according to Beverton and Holt's (1966) model as modified by Pauly and Soriano (1986). This model assumes a knife-edge selection i.e. that all fish larger than L_{c50} which come into contact with the fishing gear have equal probability of capture. It also assumes a steady-stock structure, that is the total yield in any one year from all age classes remains the same over its whole life span. The relative yield-per-recruit *(Y/R)'* was calculated by the computer using the FISAT suite of programs (Gayanilo *et al.,* 1995). Complex as the model appears, it has only three main variables: *M/K, the exploitation rate E = F/Z),* $L_{cs(}/L$, which is the ratio between the length at first capture, L_{cso} i.e. the length at which 50% of the fish is caught by the gear and the asymptotic length *(L „).*

The Beverton and Holt's (1966) model of relative biomass-per-recruit *(B/R)'* was estimated from the relationship *(B/R)* '= *(Y/R)* '/*F*. The value of the exploitation level, *E,* was varied to enable estimation of $E_{o\ s}$, the value under which the stock is reduced to 50% of its un-exploited biomass which provides the relative maximum value of *Y/R'.*

2.4.3.10 Environmental parameters and fish production

The relationships between species number, fish abundance, fish biomass and water temperature, dissolved oxygen (DO), water level, depth, and total dissolved solids (TDS) between April 1995 and February 1996 were analysed using . stepwise regression evaluated at 95% level of confidence. The objective was to obtain appropriate models to facilitate assessment of the state of the fish stocks if any or a combination of the physico-chemical parameters is known.

In addition, potential fish yield was calculated using the *"morpho-edaphic index", MEI* of Ryder *et al.* (1974) expressed as total dissolved solids (TDS) divided by mean depth of the lake.

CHAPTER 3: PART I OFRESULTS

THE AQUATIC ENVIRONMENT AND POTENTIAL FISH YIELD

3.1 RAINFALL PATTERN

Lake Volta encompasses several different climatic zones in Ghana because of its great length. Figure 3.1 indicates the pattern of rainfall as shown by data obtained from the Meteorological Services Department for three different townships, Kete-Krachi, Salaga and Kpando along the lake during 1993-95.

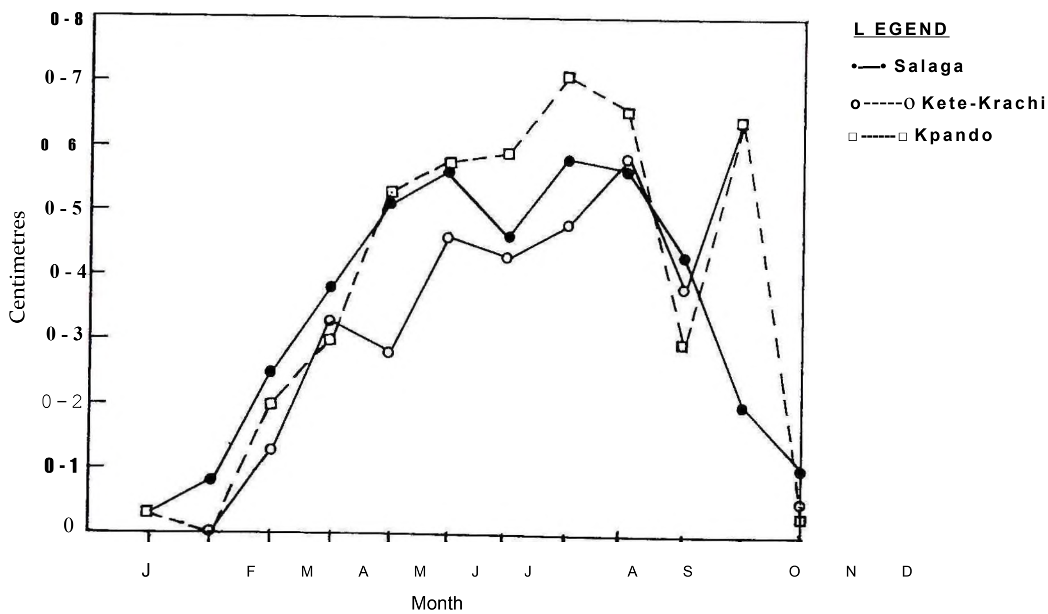


Fig. 3.1 Rainfall pattern for three towns along Lake Volta during 1993-95

The southern half town of Kpando, falls in the zone which has two peak rainy periods with maximum in May - June and another smaller peak in September-October (Fig.3.1). In the northern town of Salaga, the June peak becomes reduced and the maximum is reached in September (Fig.3.1). The average monthly rainfall in the townships ranged between' 0.0 to 0.81 centimetres.

3.2 WATER LEVEL FLUCTUATIONS

Analysis of data obtained from Volta River Authority(VRA) indicate that the average monthly water level, volume and surface area have consistently decreased since 1975. Figure 3.2 shows declining pattern of water level from November 1990 to October, 1995.

The poor rains in the catchment area and increasing demand for hydo-electric power generation could be contributing factors to the declining water levels.

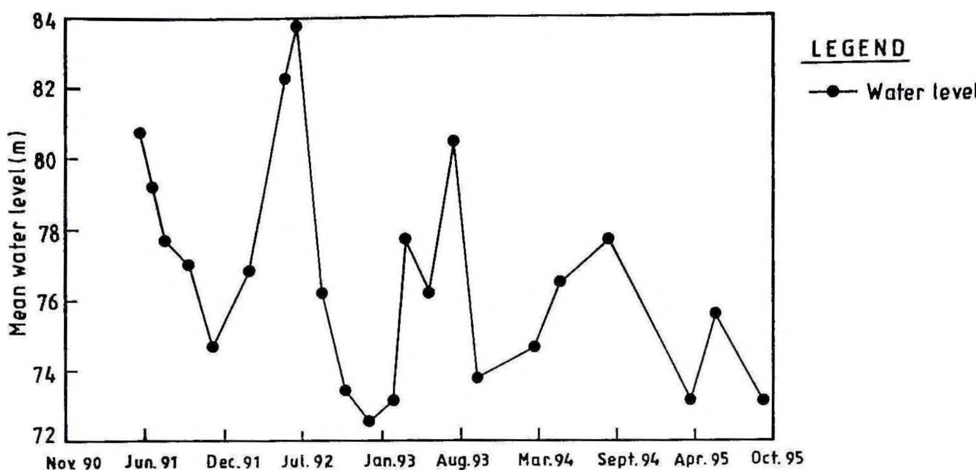


Fig. 3.2 Water level pattern of Lake Volta, November 1990 to October,1995

3.3 LIMNOLOGICAL FACTORS

A summary of the results on the physico-chemical analyses of the lake water at Yeji area in 1995/96 is presented in Table 3.1.

Table 3.1. Physico-chemical data of Lake Volta (stratum VII). (Values are mean over sampling period, January -December, 1995/96; values in parentheses are available data recorded in 1968/70 after Czernin-Chudenitz, 1971)

	Depth	**(m)**			
Limnological factor	**0**	**2**	**6**	**10**	**14**
Temperature (° C)	31.0	30.0	29.5	29.4	29.3
pH (pH units)	7.2 (7.3)	7.2	7.0	6.9 (6.9)	6.7
Dissolved Oxygen (mg I"^{1})	8.1	7.9	7.2	6.5	5.2
0$_2$ Saturation (%)	108.9	103.9	94.1	85.2	67.5
BOD (mgl'^{1})	3.9	-			
Alkalinity (mg l"^{1} CaC0$_3$)	44.3 (35.7)	44.3	41.7	40.2 (37.3)	38.5
Total Hardness (mg r'CaC0$_3$)	25.2	25.8	25.0	24.5	23.8
Total Dissolved Solids (mg 1")	42	40	38	38	40
Conductivity (nScm^1)	84	79	76	76	80
Sodium (mg I'^{1})	12.1(4.6)	9.6	11.0	12.1 (4.5)	11.7
Potassium (mg I'^{1})	9.6 (3.1)	9.0	9.1	8.7 (2.9)	7,6
Calcium (mg I'^{1})	9.4 (6.4)	9.6	10.5	9.3 (6.4)	11.1
Magnesium (mg I"^{1})	1.6 (4.4)	2.0	1.5	1.6 (4.5)	1.5
Chloride (mg I'^{1})	8.7 (1.8)	8.6	8.4	8.5 (3.9)	7.1
Phosphate (mg 1')	0.41 (0)	0.34	0.36	0.50(0.06)	0.39
Nitrate (mg I'^{1})	0.51(0.02)	0.63	0.66	0.82 (0.02)	0.97
Nitrite (mg l")	0.02	0.02	0.02	0.02	0.05
Ammonia-Nitrogen (mg I'^{1})	0.83 (0.08)	0.33	0.36	0.57(0.08)	0.43
Silicate (mg I'^{1})	12.5 (16.7)	12.6	12.6	13.4(16.7)	13.5
Sulphate (mg I"^{1})	7.0	7.5	8.5	9.8	7.2
Transparency = 50.2 cm		-			

3.3.1 Water temperature

According to Table 3.1, the lake showed nearly uniform temperature from the surface down to the 14m depth (ranging between 29.3°C and 31.0°C) during 1995/96. Although there were monthly variations in temperature, the mean water temperature recorded was 29.8°C, averaging between 29.3°C near the bottom and 31.0°C at the surface. The narrow difference in temperature (1.7 °C) between the surface and the bottom could be attributed to depth as well as solar radiation which depends on weather conditions and the near-riverine conditions which allow for mixing of the waters. This mixing may destroy any thermal discontinuities. As a result, practically no thermal stratification was found in stratum VII throughout the study period. Biswas (1969) made similar observation in the lake as a whole. In some african lakes with similar depths such as Lake Kariba (70m) and Lake Victoria (60m), similar observations have been found (Tailing,1969).

3.3.2 Transparency

The mean transparency of the lake during 1995/96 was 50.2 cm and ranged between 31 cm to 75 cm. Figure 3.3 shows the monthly fluctuations of some to the limnological factors.

A comparison of the average ionic composition of Lake Volta with other African and world fresh water is presented in Table 3.2.

Table 3.2 Average ionic composition of Lake Volta surface water compared to average for African and World fresh waters

Ion	**Lake Volta (1968/70) (mg r^{1})**	**Lake Volta (1995/96) (mg I^{1})**	**Lake Kariba (1965) (mg r^{1})**	**African freshwater (1963) (mg r^{1})**	**World freshwater (1957) (mg r^{1})**
Calcium	6.57	9.40	9.31	12.5	29.85
Magnesium	3.89	1.60	1.942	3.8	5.099
Sodium	3.92	12.10	3.51	11.0	8.27
Potassium		9.60			0.08
Chloride		7.1	-		
Source	Czernin-Chudenitz, 1971	Present study	Marshall, 1984	Livingstone, 1963	Gorham, 1957

By comparison with African and World fresh water (Table 3.2), the respective concentrations of Ca$^{H''}$ and Mg$^{'1}$ in the water of Lake Volta during 1995/96 were relatively low.

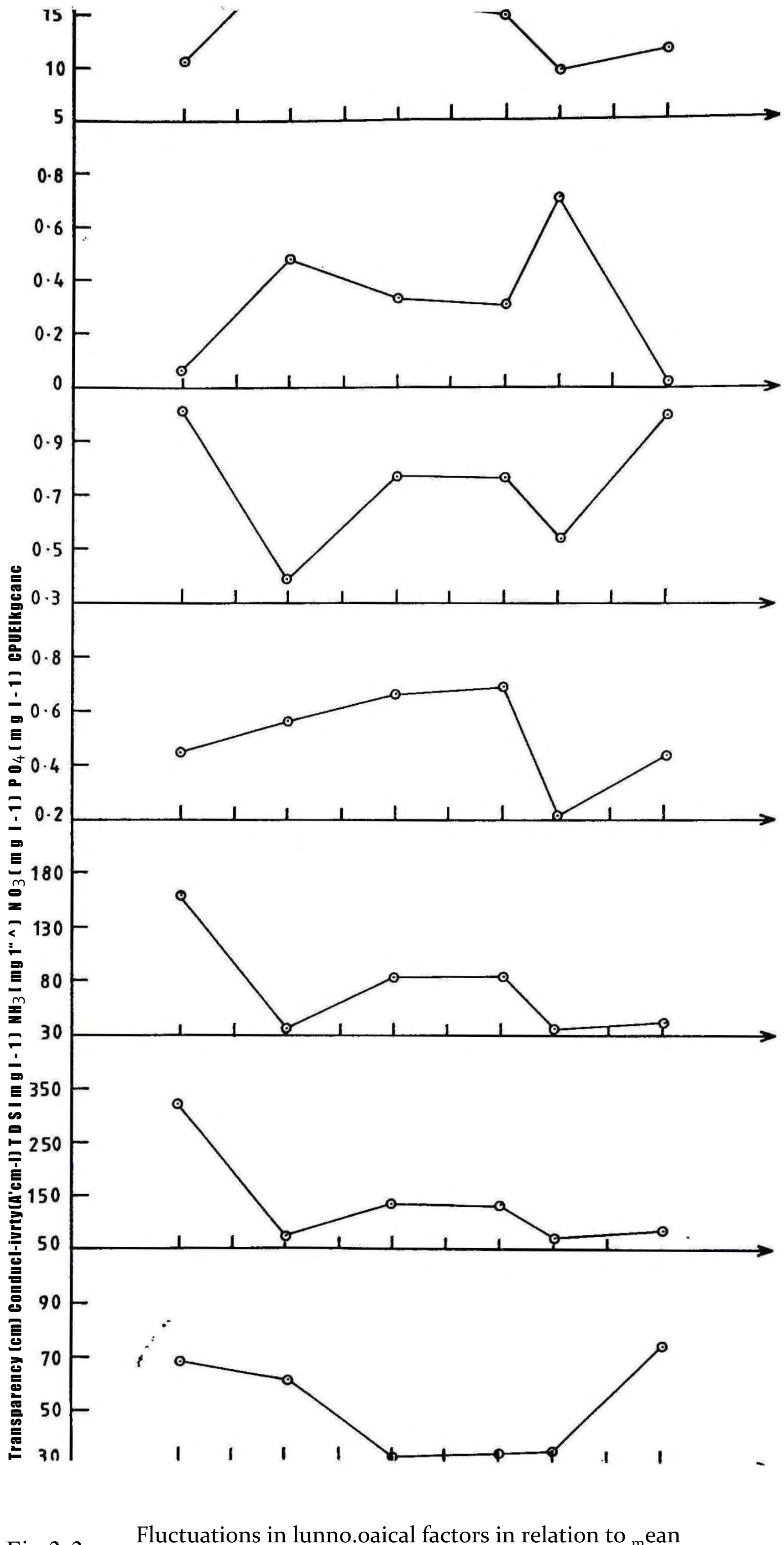


Fig 3-3 Fluctuations in lunno.oaical factors in relation to mean **monthly CPUE 1995/96**

3.3.3 Chemical parameters

3..3.3.1 pH

The pH of the lake varied with depth, dropping from 7.2 at the surface and became uniform from the 10 m depth to the bottom at pH value of 6,7 (Table 3.1).

3.3.3.2 Alkalinity

The alkalinity values recorded ranged between 44.3 and 38.5 mg I$^{'1}$ from the surface to the bottom.

3.3.3.3 TDS and conductivity

The mean values of TDS and conductivity followed similar pattern of fluctuation with depth (Fig.3.3). No previous TDS data is available for comparison. During 1995, the surface TDS and conductivity values were 42 mg I$^{"1}$ and 84 [iScmrespectively.

3.3.3.4 Major ions

The principal ions in the lake examined were Na, K, Ca, Mg and Cl. The vertical distribution of these ions in the lake did not follow any clear pattern. Sodium was the dominant ion with a mean concentration of 12.1 mg 1^{1} Generally, the ionic dominance pattern recorded in the lake was Ca > Na> K> Cl> Mg (Table 3.1).

3.3.3.5 Phosphates, nitrites and nitrates

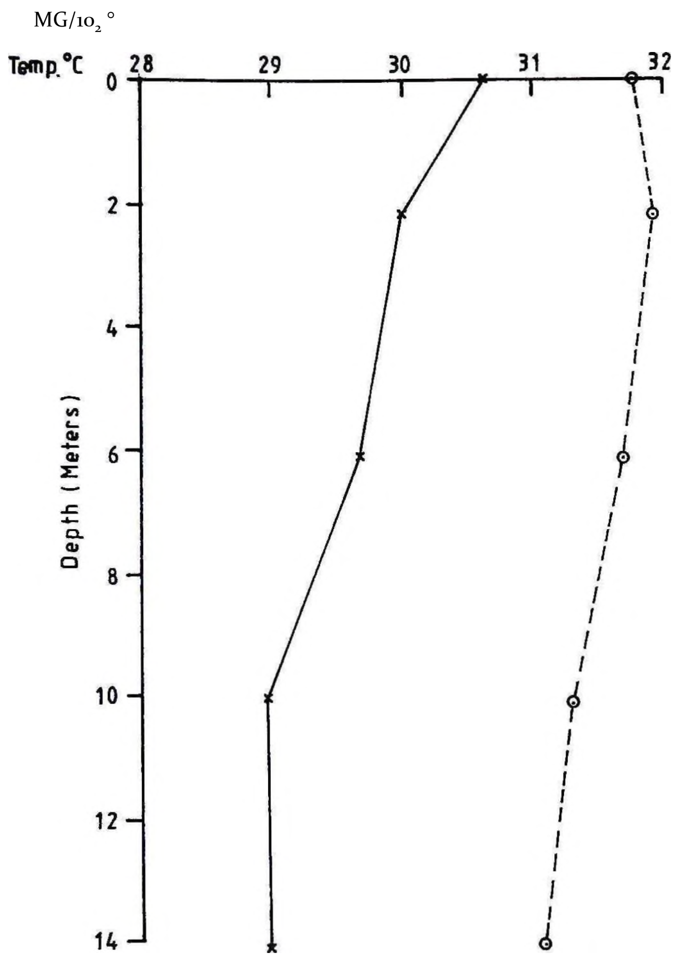
The values of these nutrients were in traces. For nitrites, values recorded ranged between 0.02 - 0.05 mg $I^{'1}$ while phosphates and nitrates had mean value of 0.40 and 0.71 mg 1^{1} respectively (Table 3.1).

3.3.3.6 Ammoniacal-nitrogen

The mean ammoniacal nitrogen concentration in Stratum VII was 0.50 mg $I^{'1}$ in 1995/96.

3.3.3.7 Dissolved oxygen

Table 3.1 shows that the surface waters of the lake were well oxygenated as mean values of dissolved oxygen (DO) throughout the studies was 6.98 mg $I^{'1}$. Also the dissolved oxygen content in the surface waters attained saturation levels higher than 100%. Figure 3.4 depicts vertical profiles of temperaure and oxygen in December 1995. The average DO was between 6.7 mg $I^{'1}$ near the bottom (at 14m depth) and 7.7 mg $I^{'1}$ at the surface.



LEGEND

o---------o ^2

*------------K Temperature

Fig.3- 4 Vertical temperature and oxygen distribution in Stratum VII of Lake Volta (December,1995)

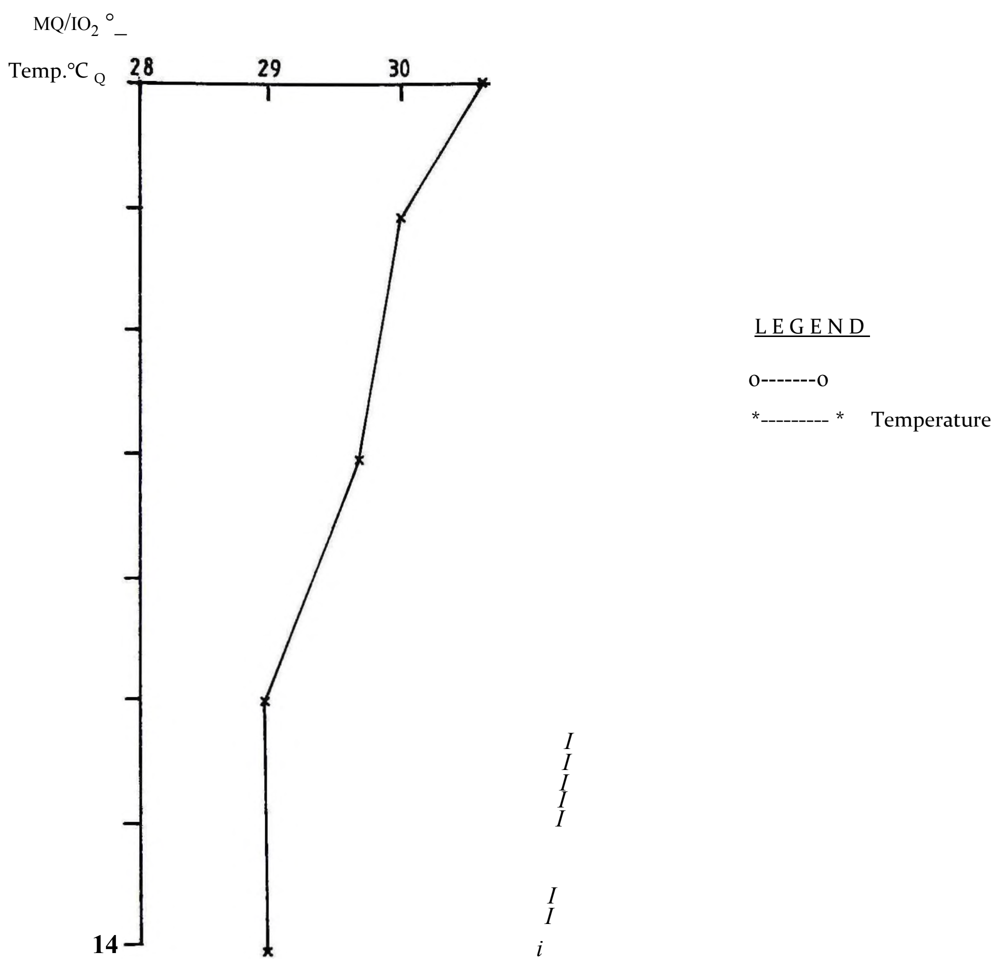


Fig. 3-4 Vertical temperature and oxygen distribution in Stratum VII of Lake Volta (December,1995)

3.4 RELATIONSHIP BETWEEN ENVIRONMENTAL FACTORS AND FISH CATCH

3.4.1 Correlation between the catch-per-unit effort (CPUE) of canoesand physico-chemical parameters

Bimonthly data obtained in 1995 for six environmental parameters, namely : the phosphates, nitrates, ammonia, TDS, and conductivity are presented in Figure 3.3 above. Partial correlation analysis were made between these factors and the CPUE of canoes utilizing gill-nets. The output from the correlation analysis is shown in Table 3.3. *ft*

Table 3.3 Correlation coefficients between the mean monthly CPUE of canoes" (kg canoe"[1] d'[1]) and some physico-chemical parameters measured in Stratum VII of Lake Volta during 1995

	CPUE	***PO_4***	***NO_3***	***NH_3***	***TDS***	***CONDUCTIVITY***
CPUE	**1**					
P04	**0.069**	**1**				
N03	**-0.492**	**-0.888**	**1**			
NH3	**0.810**	**-0.312**	**0.016**	**1**		
TDS	**-0.262**	**-0.519**	**0.613**	**0.207**	**1**	
CONDUCTIVITY	**-0.307**	**-0.521**	**0.616**	**0.087**	**0.943**	**1**
ME!	**-0.251**	**-0.538**	**0.580**	**-0.038**	**0.901**	**0.953**

According to Table 3.3, the monthly mean CPUE correlated positively only with ammonia concentration (partial correlation coefficient, r = 0.81). There was also a relatively high degree of inverse correlation between CPUE and nitrate ($N0_3$) concentration (r = - 0.492). Figure 3.5 indicates the plot of monthly mean CPUE in relation to the mean monthly ammonia concentration.

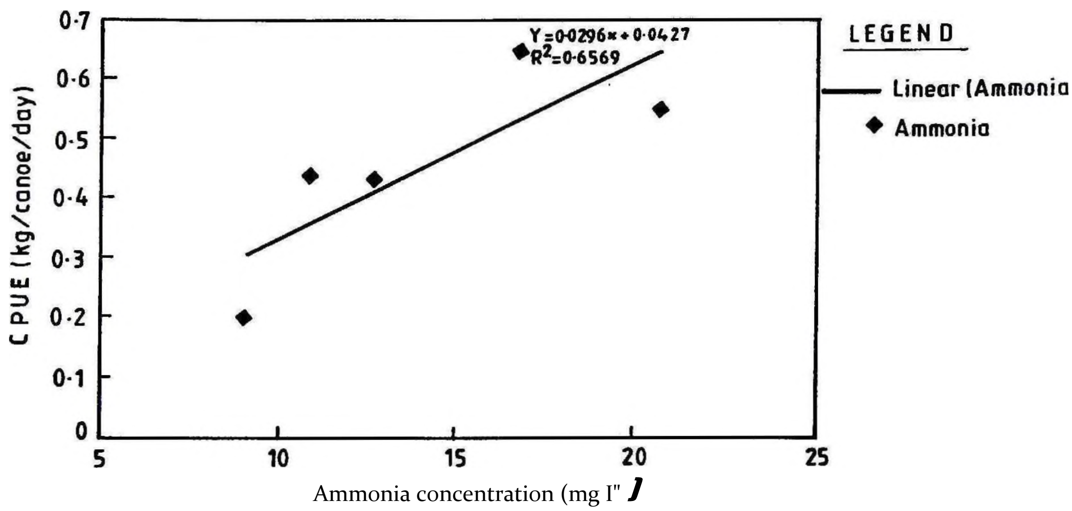


Fig. 3.5 Relationship between monthly CPUE and ammonia concentration in

Lake Volta

Figure 3.5 indicates the relationship between CPUE and ammonia concentration by the regression equation: ***CPUE = 0.0296 NH_3 + 0.0427 (r = 0.6569).***

3.5 POTENTIAL YIELD AS ESTIMATED FROM THE MORPHO-EDAPHIC INDEX (MEI)

According to Table 3.3 above, there was also a good measure of copulation between the morphoedaphic index (MEI) and nitrate concentration in the water(r - 0.58), and between MEI and TDS (r = 0.901). Conductivity was also found to be highly correlated with TDS (r = 0.943).

The potential yield of the lake was estimated by Henderson and Welcomme's (1974) model for African lakes:

Potential yield(y) = ***(8.7489)*** MEI^{03813}

Applying the above equation to Lake Volta based on the mean surface conductivity of 84 uS cm^{1} (See Table 3.1) and current mean depth of 18.6m from Pitcher and Hart (1995) the MEI was calculated as follows:

MEI = ***84.****0 jumhos* cm^{1} */**18.6** m* ***=4.516***

Inserting the calculated MEI in the above equation, the potential yield of the lake was calculated as follows:

Potential yield (y)= (8.7489) x 4.516 ^{038,3}

= <u>15.55 kg</u> hcft-yr ^{1}

Table 3.4 compares estimated potential yield of Lake Volta with other African man-made lakes. It can be seen from Table 3.4 that Lake Volta has a relatively low potential yield. This is because all the lakes had potential yield values greater than 34.0 kg ha'[1] yr [1] with the exception of Lake Kariba.

Table 3.4 Morpho-edaphic index and yield of some African lakes

Waterbody	**Estimated surface area (km^2)**	**MEI**	**Estimate yield (kg ha'Vr'1)**
Volta (Ghana) [1]	8,700	4.51	15.55
Volta (Ghana) [2]	8,700	6.1	32.77
Nasser-Nubia (Egypt)[2]	6,850[6]	9.2	40.40
Kainji (Nigeria)	1,270[7]	6.6	34.6
Kariba (Zimbabwe)[3]		2.8	23.2
Mwenje (Zimbabwe)[4]		10.0	42.1
Claw (Zimbabwe) [5]		17.2	54.2
Mazoe (Zimbabwe)[4]		34.6	75.2

Sources: 1. Present study (1995) 2. Henderson and Welcomme (1974) 3. Marshall *et al.* (1982) 4. Mitchell and Marshall (1974) 5. Thornton (1980) 6.Vanden Bossche and Bemcsek (1991) 7. Balogun and Ibeun(1995)

CHAPTER 4: RESULTS PARTII

BIOLOGICAL CHARACTERISTICS RELEVANT TO THE ASSESSMENT OF STOCKS OF MAJOR SPECIES

4.1 CURRENT ICHTHYOFAUNA IN STRATUM VII OF LAKE VOLTA

4.1.1 Checklist of species caught

A total of 66 species representing 39 genera and belonging to 19 families were recorded altogether from 1,440 observations made from gill-nets at all ten stations. A species which occurred in all the observations was expected to have a percentage frequency of occurrence (FO) in the catches as 100%. Table 4.1 presents the percentage frequency of occurrence (FO) values calculated for the various species encountered in the total observations.

Table 4.1 List of species caught by gill-nets in 1995-96, ranked according to % frequency of occurrence (FO) in total of 1,440 observations

FAMILY		SPECIES	% FO
CYPRINIDAE			
	1.	*Labeo coubie (Gunther, 1867)*	*67*
BAGRIDAE			
	2.	*Chrysichthys auratus (Geoffrey St. Hilaire, 1809)*	*54*
MOCHOKIDAE			
	3.	*Synodontisscha.il (Bloch & Schneider, 1801)*	*50*
BAGRIDAE			
	4.	*Chrysichthys nigrodigitatus (Lacepede,1803)*	*49*
SCHILBEIDAE			
	5.	*Schilbe intermedius (Ruppell,1832)*	*46*
MOCHOKIDAE			
	6.	*Hemisynodontis membranaceus (Geofroy St. Hilaire, 1809)*	*42*
DISTICHODONTIDAE			
	7.	*Distichodus rostratus (Gunther, 1864)*	*39*
BAGRIDAE			
	8.	*Bagrus bajad (Ruppell,1829)*	*38*
CICHLIDAE			
	9.	*Oreochromis niloticus (Linnaeus, 1757)*	*34*
	10.	*Sarotherodon galilaeus (Linnaeus, 1758)*	*30*
CHARA CIDAE			
	11.	*Hydrocynus forskalii (Myers, 1950)*	*26*
	12.	*Alestes baremose (Joannis,1835)*	*25*

T able 4.1 (continued)

FAMILY	SPECIES	%FO
SCHILBEIDAE		
	13. Schilbe mystus (Linnaeus, 1758)	*21*
MORMYRIDAE		
	14. Mormyrus rume (Valenciennes, 1846)	*20*
CHARA CIDAE		
	15. Brycinus nurse (Myers, 1929)	*14*
CITHARINIDAE		
	16. Citharinus citharus (Geoffroy St. Hilaire, 1809)	*13*
A UCHENOGLANIDAE		
	17. Auchenoglanis occidentalis (Valenciennes, 1840)	*12*
CLUPEIDAE		
	18. Odaxothrissa mento (Boulenger,1910)	*8*
	19. Sierrathrissa leonensis (Thys van den Audenaerde, 1969)	*5*
	20. Pellonula afzeluisi (Johnels,1954)	*4*
OSTEOGLOSSIDAE		
	21. Heterotis niloticus (Muller, 1829)	*3*
BAGRIDAE		
	22. Bagrus docmac (Ruppell,1839)	*2*
CYPRINIDAE		
	23. Barbus macrops (Boulenger,1911)	*2*

T able 4.1 (continued)

FAMILY SPECIES		%FO
CHARA CIDAE		
24.	*Brycinus leuciscus (Gunther, 1867)*	*2*
25.	*Brycinus longipinnis (Gunther, 1864)*	*2*
26.	*Brycinus macrolepidotus (Valenciennes, 1848)*	*2*
MORMYRIDAE		
27.	*Campylomormyrus tamandua (Gunther, 1862)*	*2*
28.	*Hippopotamyrus pictus (Marcusen,1864)*	*1*
29.	*Hyperopisus behe (Gunther, 1866)*	*1*
30.	*Marcusenius senegalensis (Steindachner, 1870)*	*1*
31.	*Mormyrops anguiloides (Leach, 1818)*	*1*
32.	*Mormyrus macropthalmus (Gunther, 1856)*	*1*
33.	*Mormyrus hasselquistii (Cuvier & Valenciennes, 1846)*	*I*
34.	*Petrocephalus bane (Lacepede, 1803)*	*I*
35.	*Petrocephalus bovei (Valenciennes, 1842)*	*I*
36.	*Petrocephalus simus (Sauvage, 1878)*	*/*
37.	*Pollimyrus isidori (Valenciennes,1846)*	*/*
38.	*Pollimyrus Ihyusi (Steindachner, 1870)*	*1*

Table 4.1 (continued)

FAMILY SPECIES		%FO
CICHLIDAE		
39.	*Chromidotilapia guntheri (Sauvage,l882)*	*1*
40.	*Hemichromis bimaculatus (Gill, 1862)*	*1*
41.	*Hemichromis fasciatus (Peters, 1857)*	*1*
42.	*Steatocranus irvinei (Trewavas, 1943)*	*1*
43.	*Tilapia dageti (Thys van den Audenaerde, 1971)*	*1*
44.	*Tilapia guineensis (Bleeker in Gunther, 1862)*	*I*
CLARIIDAE		
45.	*Clarias anguillaris (Linnaeus,1758)*	*1*
46.	*Clarias gariepinus (Burchell, 1822)*	*1*
A NA BA N TIDA E		
47.	*Ctenopoma kingsleyae (Gunther, 1896)*	*I*
DISTICHODONTIDAE		
48.	*Distichodus engycephalus (Gunther, 1864)*	*1*
49. Distichodus brevipinnis (Gunther, 1864)		*1*
GYMNARCHIDAE		
50.	*Gymnarchus niloticus (Cuvier, 1829)*	*I*
CYPR1NIDAE		
51.	*Labeo senegalensis (Cuvier &Valenciennes, 1842)*	*1*
52.	*Labeo parvus (Boulenger, 1902)*	*1*

Table 4.1 (continued)

FAMILY SPECIES		%FO
CENTROPOMIDAE		
53.	*Lates niloticus (Cuvier, 1828)*	*1*
MA LAPTERIIRIDA E		
54.	*Malapterurus electricus (Gmelin, 1789)*	
SCHILBEIDAE		
55.	*Parailia pellucida (Boulenger,1901)*	*1*
56.	*Siluranodon auritus (Geoffroy St. Hilaire, 1827)*	*1*
MOCHOKIDAE		
57.	*Synodontis clarias (Linnaeus, 1758)*	*1*
58.	*Synodontis filamentosus (Boulenger,1901)*	*1*
59.	*Synodontis gambiensis (Gunther, 1864)*	*I*
60.	*Synodontis ocellifer (Boulenger, 1900)*	*I*
61.	*Synodontis sorex (Gunther, 1864)*	*1*
62.	*Synodontis velifer (Norman, 1935)*	*1*
63.	*Synodontis eupterus (Boulenger, 1901)*	*1*
TETRAODONTIDAE		
64.	*Tetraodon lineatus (Boulenger, 1907)*	*I*
POL YPTERIDAE		
65.	*Polypterus endlicheri (Heckel,1849)*	*1*
66.	*Polypterus senegalus (Cuvier, 1829)*	*1*

When ranked according to percentage frequency of occurrence (FO), 2 species *(Labeo coubie* and *Chrysichthys auratus)* occured in more than 50% of the total observations and 10 species occured in 25-50 % of the total observations (Table 4.1). The remaining 54 species encountered were relatively less frequently encountered in the gill-net catches.

4.1.2 Changes in species composition and relative abundance of gill-net catches

The species composition by number and weight of fish of caught in gill-nets are presented in Appendices II and III respectively. Those obtained by weight in 1996 are presented graphically in Figure 4.1. The Figure shows that by weight, gillnet catches in Stratum VII were dominated by the two bagrid species, *Chrysichthys nigrodigitatus* and *Chrysichthys auratus* with a composition of 19.0%, and the cyprinid, *Labeo coubie* (19%). Following these were the mochokid, *Hemisynodontis membranaceus* (10%) and the schilbeid, *Schilbe intermedius* (7%). Twenty-seven species which together formed 32% of the species composition were grouped as “others” because each of them contributed less than 1% to the species composition by weight. The cichlids, *Oreochromis niloticus* and *Sarotherodon galilaeus* together formed 7% of the species composition.

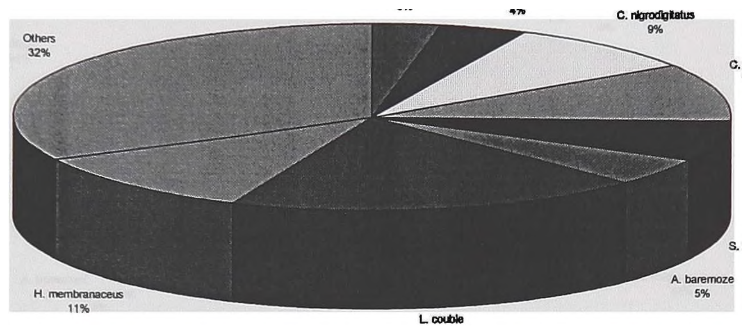


Fig. 4.1 Species composition by weight in gillnet catches during 1996

4.1.3 Relative abundance of species in winch-net catches

Regular monthly experimental fishing surveys were carried throughout 1995-96 using the purse- seine net (winch-net). In the combined catch composition, the contribution of the catfish, *Hemisynodontis membranaceus* was by far the highest by weight (45%), followed by *Chrysichthys spp.* (8.5%) (Fig.4.2).

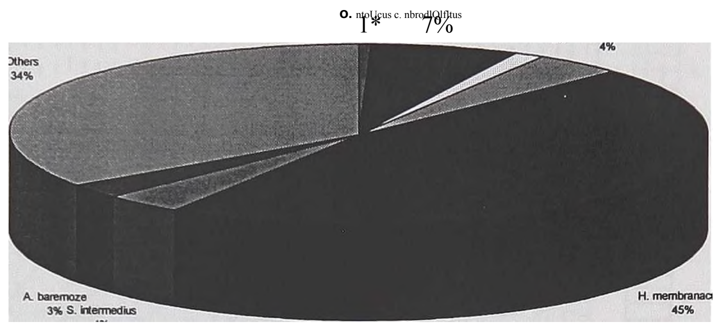


Fig. 4.2 Species composition by weight in winch-net catches during 1996

Although the cichlids, *Oreochromis niloticus* and *Sarotherodon galilaeus* formed a major component of the market survey at Yeji, they were poorly represented in winch-net catches. It could be that they were absent from the fishing ground of this gear which was mainly operated in the main channel of the lake in the off-shore water.

4.1.4 Seasonality of species composition

The species composition was marked by monthly fluctuations, with intermittent peaks and troughs (Fig.4.3). As a result, a regular seasonal pattern in species composition could generally not be detected.

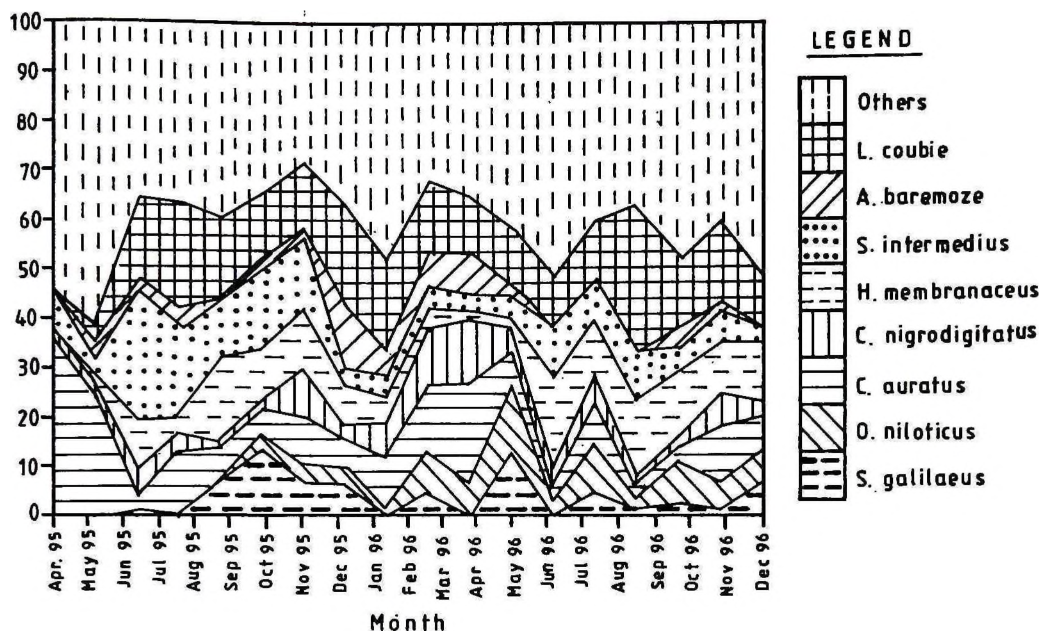


Fig. 4-3 Seasonality in species composition of gill-net catches in stratum VII during 1995/96

4.2 RELATIVE ABUNDANCE AT DIFFERENT TROPHIC HABITS

On the basis of their food habits 14 major fish species (> 5% frequency of occurrence in gillnet catches) were classified (after Evans and Vanderpuye, 1973a) as **forage (F)** species, in this instance Aufwuchs/Detrital feeders, Herbivores, Semipelagic omnivores and Benthic omnivores; and 2 species classified as Carnivorous (C) species, which refered to piscivores.

Table **4-2.** Relative abundance of different trophic types in gillnets in stratum VII of Lake Volta, 1995-96 (W= total catch in kilograms)

Feeding Types	W	% of total catch	Feeding Types	W	% of total catch
1. **Aufwuchs-Detritus& Herbivores**			**3. Piscivores**		
			Characidae		
Osteoglossidae			*Hydrocynus forskalii*	0.27	2.40
Heterotis niloticus	0.12	1.06			
Cyprinidae			**Bagrifdae**		
Labeo coubie	1.29	10.01	*Bagrus bajad*	0.38	4.22
Mochokidae					
Hemisynodontis sp	3.06	24.18			
Synodontis schall	0.54	3.58			
Cichlidae					
Sarotherodon galilaeus	0.41	2.55			
Oreochromis niloticus	0.21	16.01			
Total	**5.63**	57.39		**0.65**	**6.62**
2. Semipelagic Omnivores			**4. Benthic Omnivores**		
Characidae			**Mormyridae**		
Brycinus nurse	0.17	1.99	*Mormyrus rume*	0.21	2.82
Alestes baremoze	0.38	4.23			
Schilbeidae			**Bagridae**		
Schilbe intermedius	0.65	6.54	*Chrysichthys*		
Distichodontidae			*auratus*	0.97	9.31
Distichodus rostratus	0.31	2.63	*C. nigrodigitatus*		
			A..	0.77	7.31
			occidentalis	0.07	0.56
Total	**1.51**	**15.39**		**2.02**	**20.59**
F/C Ratio	**14.09 ***				

$$\frac{\mathbf{5.63 + 1.51 + 2.02}}{\mathbf{0.65}} = \mathbf{14.09}$$

The results are presented in Table 4.2. From this table, the feeding groups by numbers were in the following order of importance: Aufwuchs/Detrital feeders, and Herbivores (57.39%) > Benthic omnivores (20.59%) >Semipelagic omnivores (15.39%) > Piscivores (6.62%). Consequently, the Aufwuchs/Detrital feeders and Herbivores were regarded as the most important feeding group. These consisted primarily of *Labeo coubie, Hemisynodontis membranaceus, Sarotherodon galilaeus* and *Oreochromis niloticus.* On the other hand, the strict piscivores like *Hydrocynus forskalii* and *Bagrus bajad* were poorly represented.

The total weights of forage (F) species to carnivores (C) was defined as the Forage-Camivore (F/C) ratio (Blay, 1985). This F/C ratio by weight was estimated as 14.09 (Table 4.2) and was found to be outside the range of 1.4-10.0 observed for balanced populations (Blay, 1985).

43 REPRODUCTIVE AND RECRUITMENT PATTERNS OF MAJOR SPECIES

4.3.1 Sex-ratios

The monthly male: female ratio of the major species varied throughout the study period (Tables 4.3a-4.3e).

Table 4.3a: Monthly sex-ratios (males: females) of *H. membranaceus* during1995-96.
*** = significant difference**

Month	No. of males	No. of females	Male: female Sex-ratio	Chi-square	P0.05
2/95	35	25	1.4:1.0	1.66	3.84
3/95	53	33	1.6:1.0	4.65	3.84*
4/95	27	34	0.8:1.0	0.80	3.84
5/95	9	17	0.5:1.0	2.46	3.84
6/95	25	25	1.0:1.0	0.00	3.84
7/95	30	27	1.1:1.0	0.16	3.84
11/95	23	25	0.9:1.0	0.08	3.84
12/95	85	37	2.3:1.0	18.89	3.84*
1/96	73	33	2.2:1.0	15.09	3.84*
2/96	29	21	1.4:1.0	1.28	3.84
3/96	29	26	1.0:1.0	0.16	3.84
4/96	34	31	1.1:1.0	0.14	3.84
5/96	60	30	2.0:1.0	10.00	3.84*
6/96	68	27	2.5:1.0	17.69	3.84*
7/96	19	32	0.6:1.0	3.31	3.84
8/96	84	14	6.0:1.0	50.00	3.84*
9/96	34	34	1.1:1.0	0.00	3.84
10/96	5	12	0.4:1.0	2.88	3.84
11/96	40	31	1.3:1.0	1.14	3.84
12/96	0	1	-	--	-
Overall	762	514	1.5:1.0	48.20	3.84

Table 4.3b: Monthly sex-ratios (males: females) of *Chrysichthys auratus* during1995-96. * = significant difference

Month	No. of males	No. of females	Male: female Sex-ratio	Chi-square	P0.05
2/95	6	12	0.5:1.0	2.00	3.84*
3/95	60	96	0.6:1.0	8.31	3.84*
4/95	36	144	0.3:1.0	64.8	2.84*
5/95	48	132	0.4:1.0	39.2	3.84*
6/95	8	120	0.4:1.0	98.0	3.84*
7/95	138	102	1.4:1.0	5.40	3.84*
11/95	30	54	0.6:1.0	6.86	3.84*
12/95	6	102	0.3:1.0	85.33	3.84*
2/96	-	-	-	--	-
3/96	0	12	--	-	--
4/96	12	24	0.5:1.0	4.00	3.84*
5/96	6	36	0.2:1.0	21.42	3.84*
6/96	12	12	1.5:1.0	0.00	3.84
7/96	90	168	0.7:1.0	200.53	3.84*
8/96	36	54	0.7:1.0	3.60	3.84
9/96	120	210	0.6:1.0	24.55	3.84*
10/96	60	90	0.7:1.0	6.00	3.84*
11/96	-	-	-	-	-
Overall	716	1,404	0.5:1.0	233.28	3.84*

Table 4.3c. Monthly sex-ratios (males: females) of *Chrysichthys nigrodigitatus* during 1995-96. * = significant difference

Month	No. of males	No. of females	Male: female Sex-ratio	Chi-square	P0.05
2/95	39	33	1.2:1.0	0.50	3.84
3/95	21	42	0.5:1.0	3.57	3.84
4/95	30	60	0.5:1.0	10.0	3.84*
5/95	12	63	0.2:1.0	34.68	3.84*
6/95	27	45	0.6:1.0	4.50	3.84*
11/95	19	48	1.4:1.0	12.55	3.84*
12/95	39	48	0.8:1.0	0.93	3.84
1/95	29	21	1.4:1.0	1.28	3.84
2/96	20	33	1.6:1.0	3.19	3.84
3/96	3	0	-	-	-
4/96	12	0	-	-	-
5/96	38	54	0.7:1.0	2.78	3.84
6/96	41	137	0.3:1.0	51.78	3.84*
7/96	90	69	1.3:1.0	2.77	3.84
8/96	15	12	1.3:1.0	0.33	3.84
9/96	47	36	1.3:1.0	1.46	3.84
10/96	8	26	0.3:1.0	9.53	3.84*
11/96	6	15	0.4:1.0	3.86	3.84*
12/96	16	15	1.1:1.0	0.03	3.84
Overall	512	757	0.7:1.0	47.30	3.84*

Table 4.3d: Monthly sex-ratios (males: females) of *Schilbe intermedius* during1995-96. * = significant difference

Month	No. of males	No. of females	Male: female Sex-ratio	Chi-square	P0.05
3/95	18	12	1.5:1.0	1.20	3.84
4/95	2	18	0.1:1.0	12.80	3.84*
5/95	6	18	0.3:1.0	6.00	3.84*
6/95	24	40	0.6:1.0	4.00	3.84*
7/95	18	46	0.4:1.0	12.25	3.84*
11/95	14	20	0.7:1.0	1.06	3.84
12/95	4	10	0.4:1.0	2.57	3.84
1/96	0	12	-	-	-
2/96	-	-	-	-	--
3/96	2	12	0.2:1.0	7.14	3.84*
4/96	2	4	0.5:1.0	0.67	3.84
5/96	10	16	0.6:1.0	1.38	3.84
6/96	2	24	0.1:1.0	12.46	3.84*
7/96	7	70	0.1:1.0	51.55	3.84*
8/96	0	16	-	-	-
9/96	17	58	0.3:1.0	22.41	3.84*
10/96	2	16	0.1:1.0	10.89	3.84*
11/96	0	12	-	-	-
12/96	4	6	0.7:1.0	0.40	3.84
Overall	133	410	0.3:1.0	141.31	3.84*

Table 4.3e: Monthly sex-ratios (males: females) of *Oreochromis niloticus* during1995-96. * = significant difference

Month	No. of males	No. of females	Male: female Sex-ratio	Chi-square	P(>.05
3/95	26	32	1.8:1.0	0.62	3.84
4/95	17	42	0.4:1.0	10.59	3.84*
5/95	11	22	0.5:1.0	3.67	3.84
6/95	10	48	0.2:1.0	24.90	3.84*
7/95	26	32	0.8:1.0	0.62	3.84
1/96	3	2	1.5:1.0	0.20	3.84
Overall	93	178	0.5:1.0	26.66	3.84*

Males dominated the females of H. membranaceus with an overall male: female ratio of 1.5:1.0 (Table 4.3a). In contrast, mature females of *Chrysichthys auratus* and C. *nigrodigitatus, Schilbe intermedius,* and *Oreochromis niloticus* (Table 4.3b-e), were significantly more numerous in the samples than the males.

4.3.2 Seasonal variation in gonad maturity stages

Data on maturity stages of males were irregular due to difficulty in staging immature individuals. The analysis therefore of seasonal variation in maturity therefore considered only females excluding those at maturity stage V. This was because stage V ovaries normally had shed eggs and were sometimes difficult to differentiate from non-ripening females. The monthly variations in percentage of the stages O to IV developmental stages of the ovaries for the key species are shown in Figures 4.4 to 4.8. For *H. membranaceus* (Fig.4.4), almost all species encoutered during January to April were immature females (Stage O), with no representation of mature females (Stage IV) over the same period. Relatively large numbers of individuals with highly developed ovaries of this species at Stage IV were found in July and September suggesting two peaks in spawning activity during the year. The period of breeding activity could therefore be of short duration, lasting about three months (July to September). Stages II and III individuals were numerically dominant after these months, i.e. from September to October. It was therefore possible that these categories included fish that had undergone spawning as well as the young maturing fish.

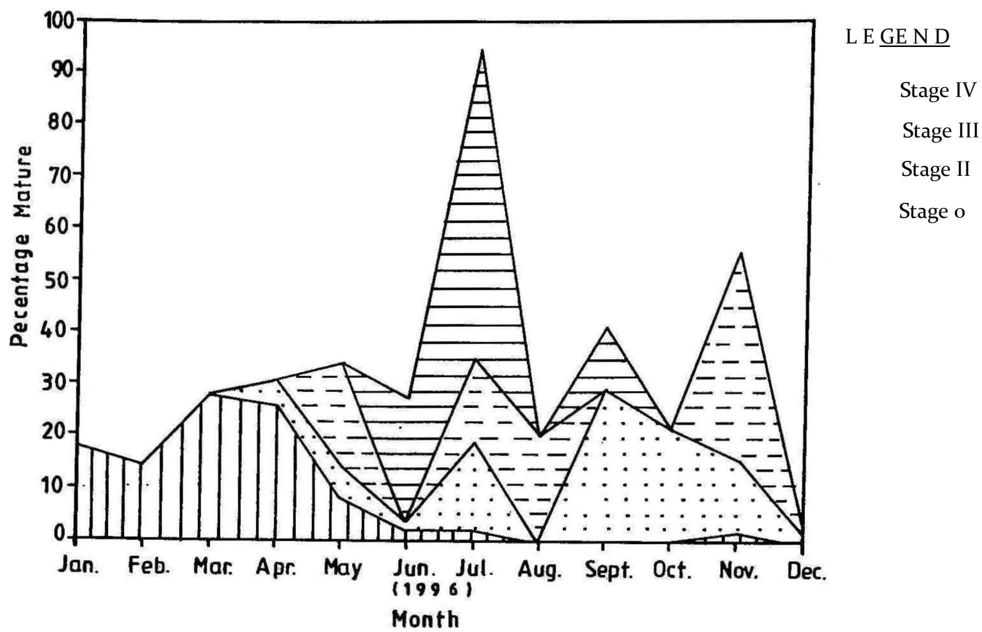


Fig. 4.4 Percentage of female *H. membranaceus* in five diferent development stages (data combined from 1995-96)

With regard to *C. nigrodigitatus,* two peaks of relatively high proportion of ripening individuals occurred during the year (Fig.4.5). A major peak in July and and a minor one in September. These two peaks of spawning activity were more clearly illustrated in the case of *C. auratus* (Fig.4.6).

The two peaks could be distinguished from a period of rapid decline in percentage of Stage IV individuals in August (Figure.4.5 and Figure 4.6). This month could possibly mark a major period for release of the eggs, and needs future verification through egg survey monitoring in the aquatic environment.

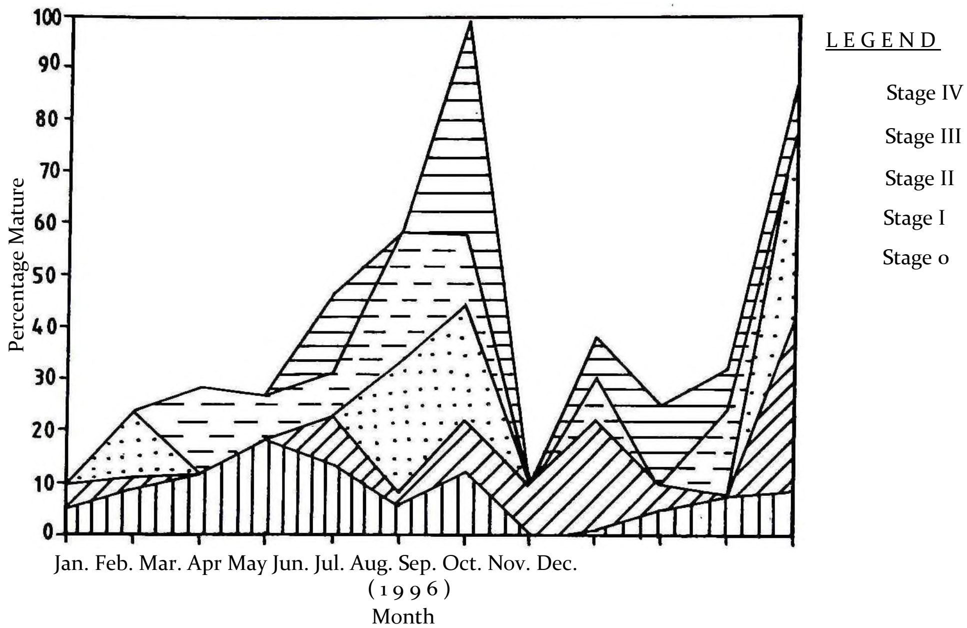


Fig. ^.5 Percentage of female *C. nigrodigitatus* in five different development stages (combined data 1995-96)

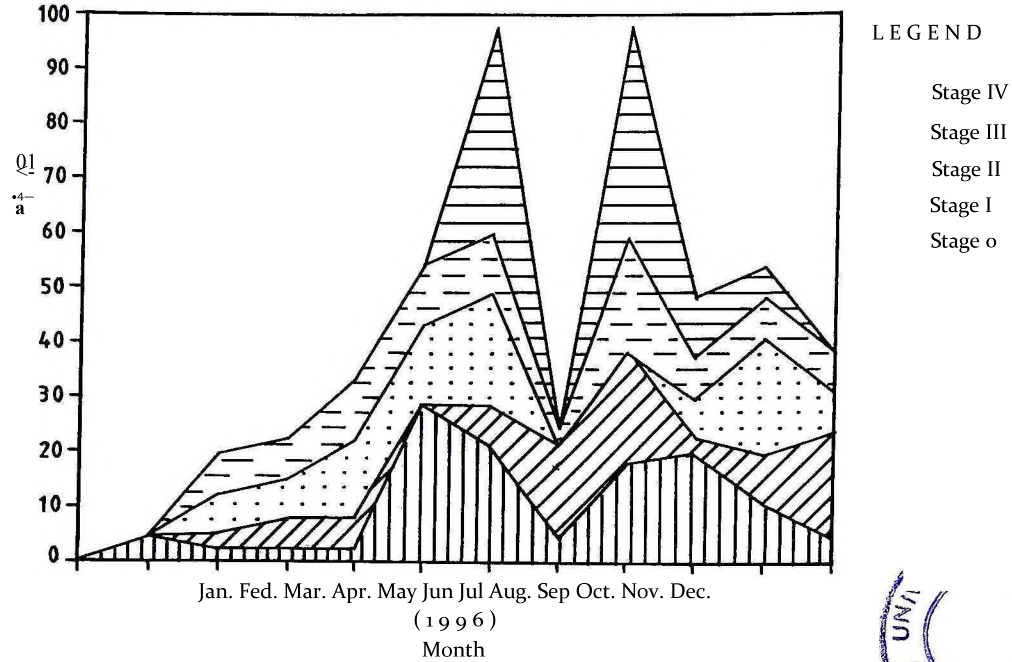


Fig. 4.6 Percentage of female *C. auratus* in five different developmentstages (combined data 1995-96)

With the exception of the months of January and February, some specimens of *Chrysichthys spp* with advanced stage of gonad development were present in the samples during most of the year indicating continuous spawning of the species for most part of the year.

Considering *Schilbe intermedius,* one clear peak of spawning activity was observed similar to what was found for *H. membranaceus.*

Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.
(1996)
Month

Fig. 4.7 Percentage of female ***S. intermedius*** in different development stages during 1996

The data for ***Oreochromis niloticus*** were relatively inconsistent due to their low representation in the samples. However, it appeared that some mature individuals with advanced gonad stages were present during most of the year (Fig.4.8) suggesting continuous spawning, which is a known behaviour among many cichlids.

In general, peak spawning activity in June and July seemed to be a common phenomenon among the species studied. This period of major spawning activity coincided with the second major rains.

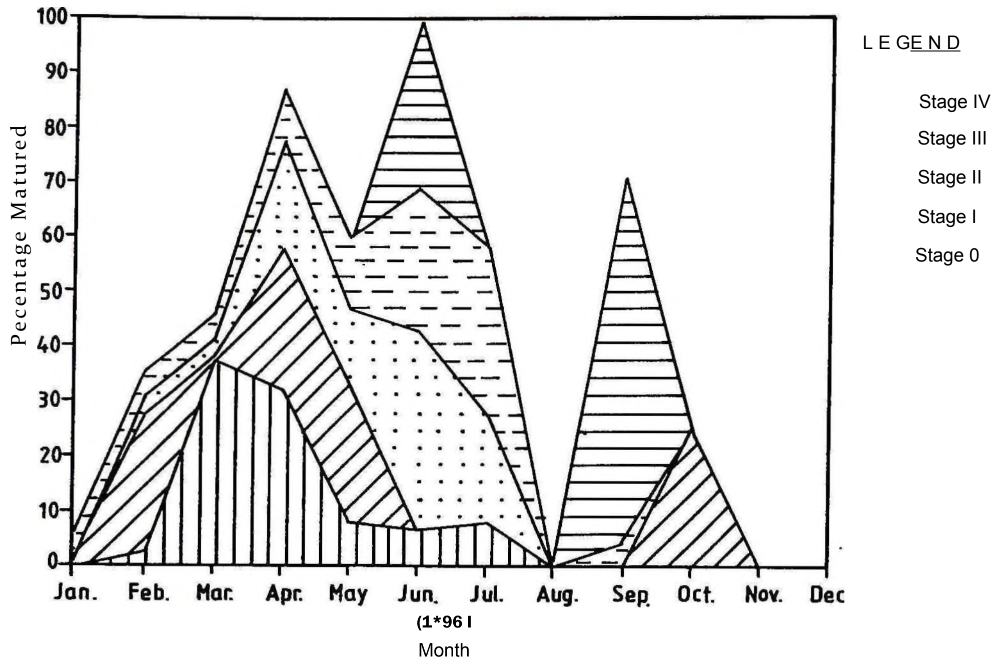
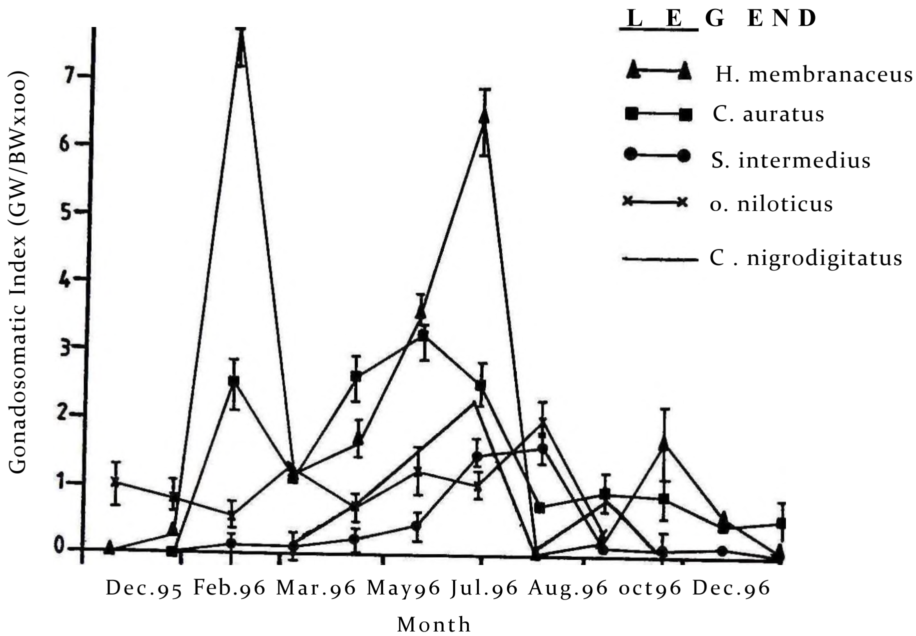


Fig. 4.8 Percentage of female ***O. niloticus*** in five different development stages (combined data 1995-96)

4.3.3 Seasonal variation in gonadosomatic index (GSI)

Data on gonad weight of males were irregular because the testes when immature were too small to be weighed. Unlike the females, there was therefore no clear pattern in seasonal variation in monthly mean GSI for males and so only the GSI values of females were monitored.

Monthly mean GSI values for the females of species studied are presented graphically in Figure 4.9. The seasonality in GSI supported the timing of the major spawning seasons deduced from observations on seasonal variation in gonad maturity.



-ig. 4-9 Monthly variation in gonadosomatic index (GSI) of females of major species

43.4 Size at first maturity (L_m)

The mean size at first maturity (L,,,) was defined as the length at which 50% were in reproductive condition. Plots of standard length versus cumulative percentage of mature individuals were generally S-shaped or sigmoid (Fig. 4.10). From the underlying sigmoid curves in Figure 4.10, the 50 % point suggested that the average standard length for a first time spawner was 26.7cm, 8.5cm, 10.5 cm, 13.5 cm, and 16.8 cm respectively for ***H. membranaceus, C. auratus, C. nigrodigitatus, O. niloticus*** and ***S. intermedius.***

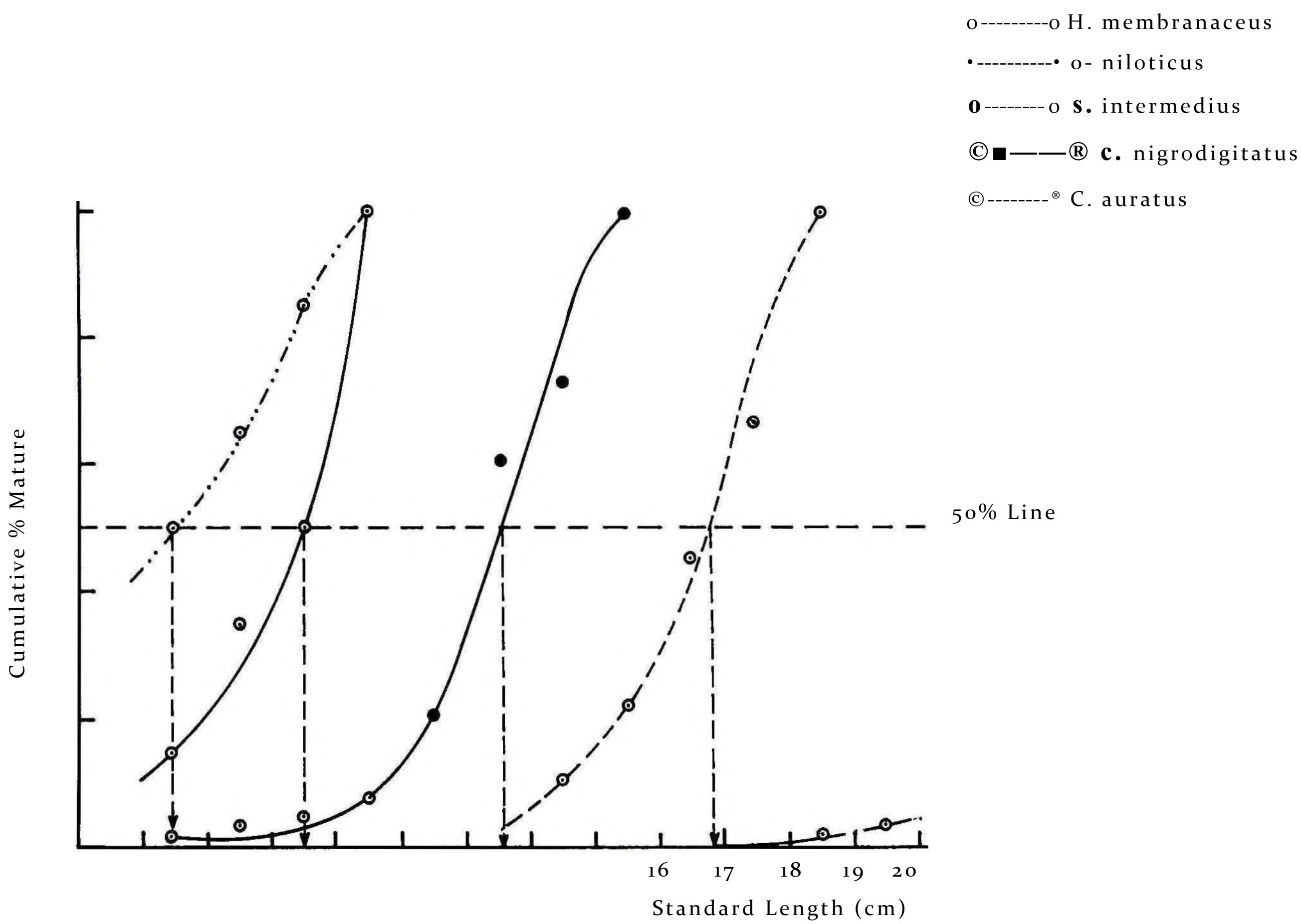


Fig. 4,10 Mean size at first maturity (Lm) as defined from underlying sigmoid curves for the major species.

4.3.5 Length at first capture (L_{c50})

The length at first capture (L_{c50}), was considered proportional to the mesh size of the cod-end of trawl-type of nets as suggested by Pauly (1984). The length at first capture (L_{c50}) was estimated from the relationship between mesh size and length at first capture as: ***Lrfo = Selection Factor (SF) x Mesh Size*** (Pauly, 1984), where the proportionality constant is called the selection factor ***(SF).***

To obtain a mesh size that will, in general, retain 50% of the fish of size (or L,,,), the length at first capture (L_{c50}) was considered equal to L_m. This was used in conjunction with Pauly's (1984) nomogram, expressing the graphical relationship between the selection factor and depth ratio (standard length/ maximum body depth) of fish (Fig.4.11).

Fig. 4.11 Nomogram for the estimation of selection factors of fishes from their body proportion (from Pauly, 1984).

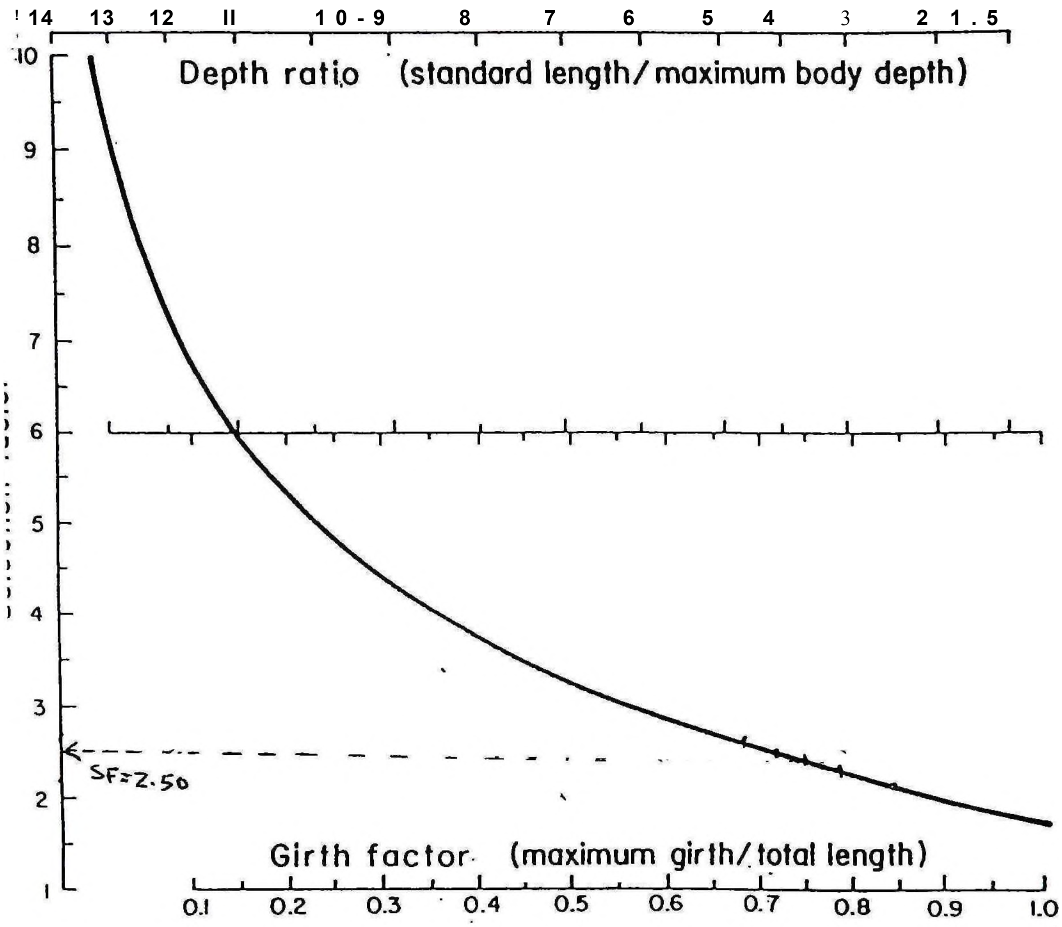


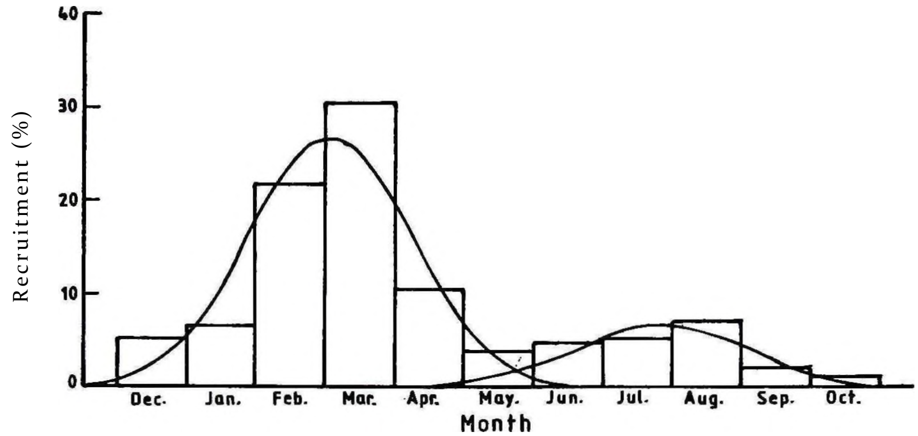
Table 4.4: A summary of estimated length at first maturity (Lm) and otherderived parameters for the major species

Species	Estimated *Ko*	Estimated Ln, (cm)	t-n/Eoo ratio	Estimated depth ratio (Standard Length/max. depth)	Estimated Selection Factor (SF) (Paugy's 1984 nomogram)	Estimated mesh size to ensure 50% retention (LJSF) (cm)
H. membranaceus	44.0	25.25	0.57	3.29	2.50	10.1
C. auratus	31.0	17.28	0.56	4.45	2.65	6.57
C. nigrodigitatus	44.5	21.08	0.47	4.29	2.45	8.60
0. niloticus	33.5	19.73	0.59	2.43	2.20	8.97
Schilbe intermedius	30.0	20.75	0.69	3.69	2.30	9.02
Mean	36.6	20.81	0.58	3.63	2.42	8.64

From Table 4.4, mean size estimate of 8.64 cm was calculated for the major species together which is higher than the legal mesh size limit of 6.35 cm (or 2.5 inches) (Fisheries Law, 1991). The ratio Lm / Loo averaged 0.58 for the major species which fell below Holt's (1962) average value of 0.64 found for most fishes

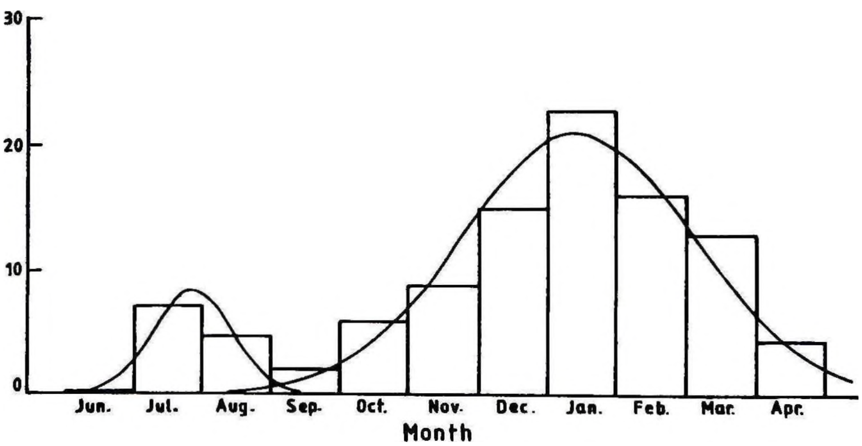
4.3.6 Recruitment pattern

The annual recruitment patterns for the major species are provided in Figures 4.12 to Figure 4.16. The figures show that with the exception ***of S. intermedium,*** recruitment occurs throughout the year, with conspicuous major and minor peaks.



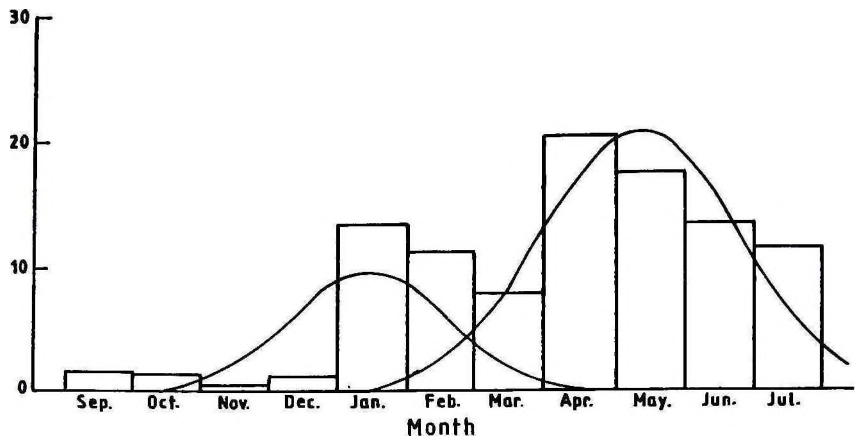
Loo = *USun* K 0-55 C= 0-65, WP = 0 35, t_0 = -0-26<j r

Fig. 4-12 Recruitment pattern Of *Hemisynodontis membranaceus* in Stratum VII of Lake Volta



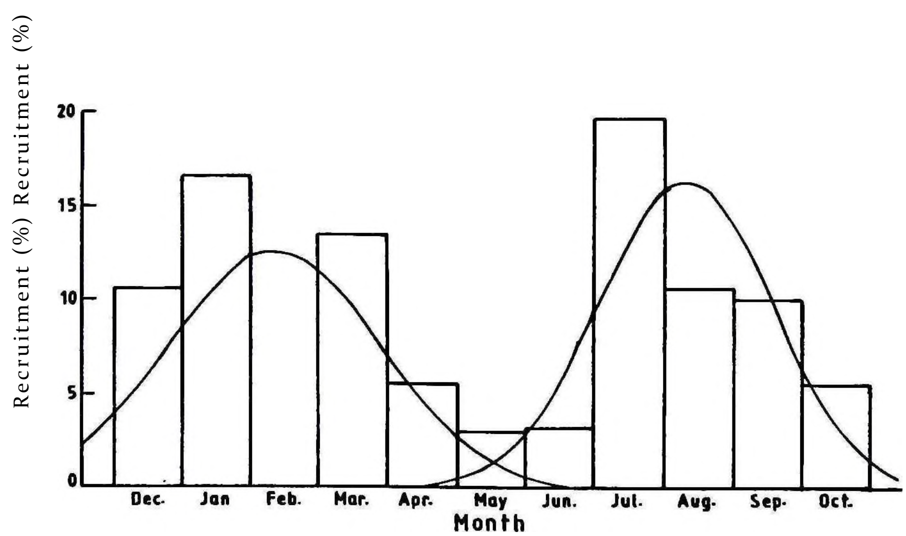
Lao - 31 CM K = 0-6y-* ^ =0-35, WP = 0-4, ■ *V*

Fig. 4-13 Recruitment pattern of *chrysichthys auratus* in Stratum VII of Lake Volta



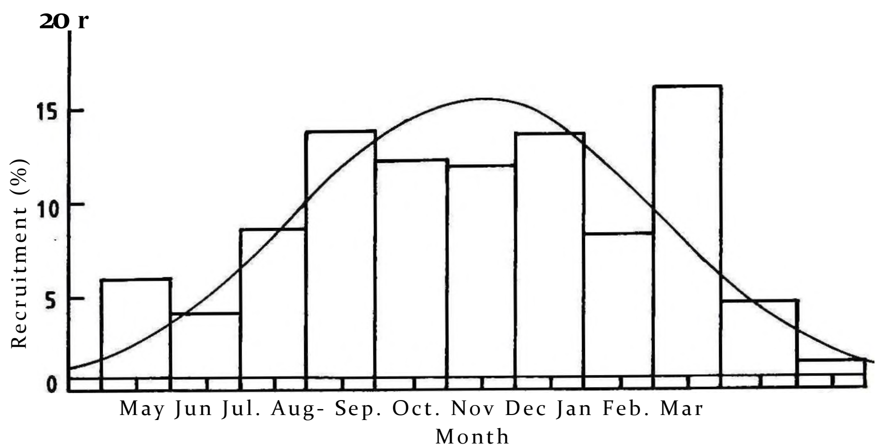
Loo = 46-Se-> K = 0-6S3r-' C = 0-5 WP = 0-1 t_0 ^-0-22^

Fig. A--14 Recruitment pattern Of *Chrysichthys nigrodigitatus* in Stratum VII of Lake Volta.



Loo = 33-5CM K = 0-3S C r 0-95 WP = 0-19 t_0 =-0-*5y

Fig. 4-15 Recruitment pattern of *Oreochromis niloticus* in Stratum VII of Lake Volta



loo = 30<llt K = o*83,-'C =0.1 , WP =0-155, t,, =-03Oy

Fig. 4-16: Recruitment pattern of *Schilbe intermedius* in Stratum VII of Lake Volta

CHAPTER 5: PART III OF RESULTS

THE POPULATION DYNAMICS AND ASSESSMENT OF MAJOR FISH STOCKS

One major aim with the fisheries was the determination of the effects of fishing on the stocks. The first step considered analysis of changes in fishing intensity and the resulting catches. This was followed by estimation of growth and mortality parameters which were then used in length-based cohort analysis for the estimation of stock biomass and yield.

5.1 CHANGES IN COMMERCIAL CATCH

5.1.1 Catches from canoes utilizing gill-nets

The mean monthly CPUE and number of canoes in the Northern, Central and Southern area of Stratum VII are shown in Tables 5.1 to 5.3 respectively. With these data, it was possible to calculate the total monthly catch estimates which are also shown in Tables 5.1 to 5.3.

Table 5.1: Mean monthly CPUE and estimated catches in the northern sub-stratum

Month	CPUE (kg canoe'1 d') (a)	Number of Canoes (b)	Days in month (c)	Gross canoe days [bxc] (d)	"Lost" canoe days [12% x (b) x 4 days] (e)	Net fishing days (d)-(e) (0	Fraction of total canoes fishing (g)	Catch in kgs (a x f x g)
1/96	12.11	2,805	31	86,955	1,346.4	85,608.6	0.58	601,297.7
2/96	35.34	2,805	28	78,540	1,346.4	77,193.6	0.63	1,718,653.7
3/96	35.34	2,805	31	86,955	1,346.4	85,608.6	0.63	1,906,007.0
4/96	13.34	2,805	30	84,150	1,346.4	82,803.6	0.88	972,048.0
5/96	13.34	2,805	31	86,955	1,346.4	85,608.6	0.88	1,004,976.5
6/96	18.42	2,805	30	84,150	1,346.4	82,803.6	0.63	960,902.7
7/96	18.42	2,805	31	86,955	1,346.4	85,608.6	0.63	993.453.6
8/96	9.09	2,805	31	86.955	1,346.4	85,608.6	0.39	303,491.0
9/96	9.09	2,805	30	84,150	1,346.4	82,803.6	0.39	293,547.0
10/96	10.62	2,805	31	86,955	1,346.4	85,608.6	0.59	536,406.4
11/96	10.62	2,805	30	84,150	1,346.4	82,803.6	0.59	518,830.8
12/96	11.03	2,805	31	86,955	1,346.4	85,608.6	0.40	377,705.1
TOTAL								10,187,368.8

Table 5.2: Mean monthly CPUE and estimated catches in the central sub-stratum

Month	CPUE (kg canoe" d-'> (a)	Number of Canoes (b)	Days in month (c)	Gross canoe days [bxc] (d)	"Lost" canoe days [12% x (b) x 4 days] (e)	Net fishing days (d) - (e) (D	Fraction of total canoes fishing <g)	Catch in kgs (a x f x g)
1/96	8.16	1,445	31	44,795	693.6	44,101.4	0.58	208,723.1
!/96	6.87	1,445	28	40,460	693.6	39,766.4	0.52	140,200.4
1/96	8.10	1,445	31	44,795	693.6	44,101.4	0.51	182,182.9
1/96	14.29	1,445	30	43,350	693,6	42,656.4	0.70	426,692.0
i/96	17.04	1,445	31	44,795	693.6	44,101.4	0.66	495,982.0
i/96	13.00	1,445	30	43,350	693.6	42,656.4	0.58	321,629.3
796	12.56	1,445	31	44,795	693.6	44,101.4	0.73	404,356.9
i/96	8.35	1,445	31	44,795	693.6	44,101.4	0.65	293,360.3
>/96	10.41	1,445	30	43,350	693.6	42.656.4	0.55	244,229.2
0/96	8.82	1,445	31	44,795	693.6	44,101.4	0.58	225,605.1
1/96	7.39	1,445	30	43,350	693.6	42,656.4	0.55	173,376.9
2/96	7.35	1,445	31	44,795	693.6	44,101.4	0.61	197,728.6
'OTAL								3,260,066.7

Table 5.3: Estimation of mean montly CPUE and monthly catches in the southern sub-stratum

Month	CPUE (kg canoe"' d-^{1}) (a)	Number of Canoes (b)	Days in month (c)	Gross canoe days [bxc] (d)	"Lost" canoe days [12% x (b) x 4 days] (e)	Net fishing days (d) - (e) (f>	Fraction of total canoes fishing (g>	Catch in kgs (a x f x g)
1/96	15.37	3,818	31	118,358	1,832.6	116,525.4	0.44	788,038.0
2/96	15.55	3.818	28	106,904	1,832.6	105,071.4	0.44	718,898.5
3/96	15.55	3,818	31	118,358	1,832.6	116,525.4	0.65	1,177,780.5
4/96	23.66	3,818	30	114,540	1,832.6	112,707.4	0.65	1,733,327.1
5/96	23.66	3,818	31	118,358	1,832.6	116,525.4	0.59	1,626,624.7
6/96	23.55	3,818	30	114,540	1,832.6	112,707.4	0.59	1,573,327.7
7/96	23.55	3,818	31	118,358	1,832.6	116,525.4	0.65	1,783,712.6
8/96	21.77	3,818	31	118,358	1,832.6	116.525.4	0.65	1,648,892.7
9/96	21.77	3,818	30	114,540	1,832.6	112,707.4	0.59	1,447,647.7
10/96	8.65	3,818	31	118,358	1,832.6	116,525.4	0.59	594,687.4
11/96	8.65	3,818	30	114,540	1,832.6	112,707.4	0.53	516,707.1
12/96	12.22	3,818	31	118,358	1,832.6	116,525.4	0.53	754,688.4
TOTAL								14,364,332.4

Tables 5.1 to 5.3 show that during the study period, the total catches in the Northern, Central and Southern areas were 10,187 tonnes, 3,260 tonnes and 14,364 tonnes respectively. This gave the total canoe catch as 27,811 tonnes. The whole set of monthly mean CPUE for 1995/96 are presented graphically in Figure 5.1.

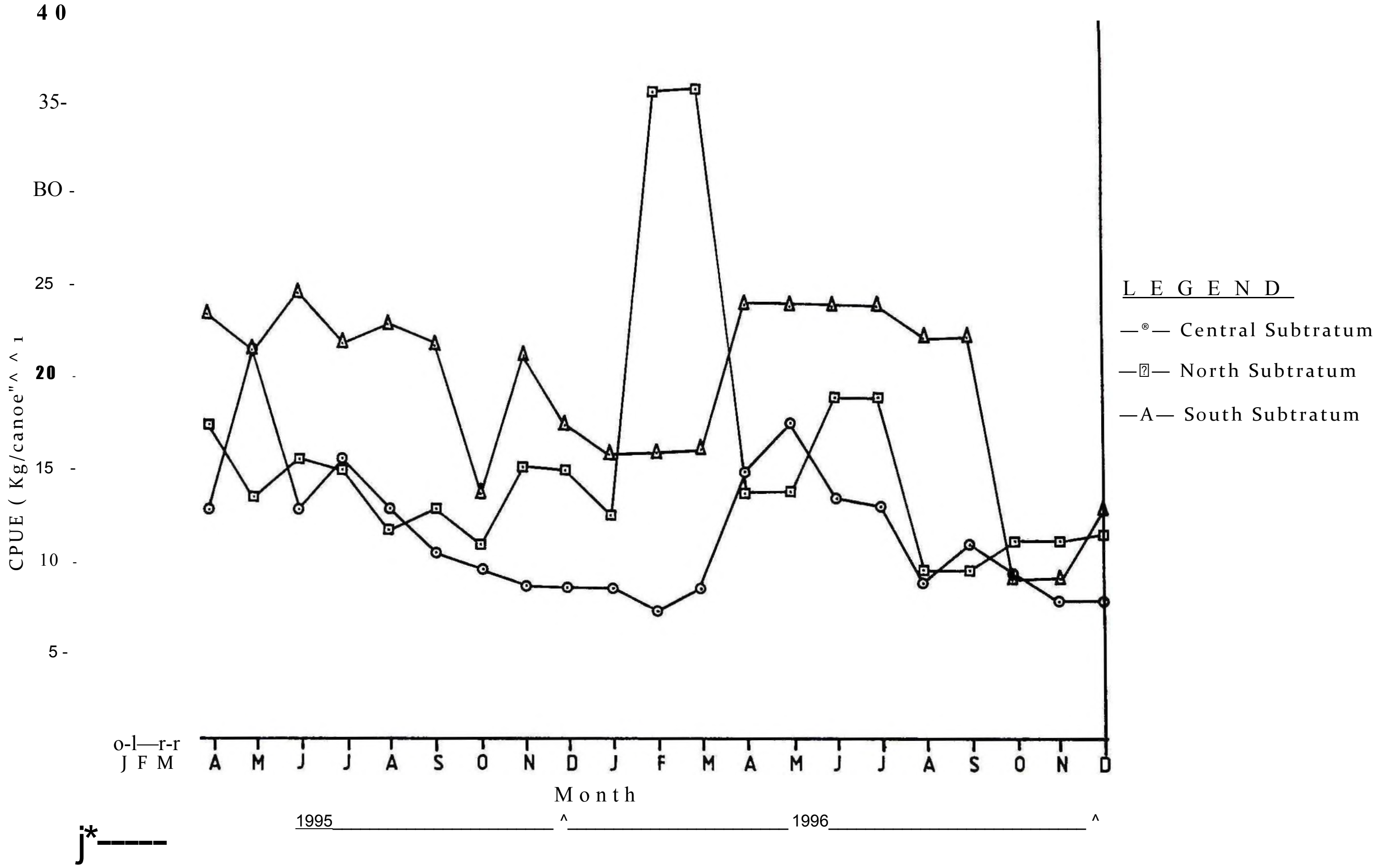


Fig. 5.1 **Variation in monthly mean CPUE of three sub-strata in stratum VII of Lake Volta •**

The monthly mean CPUEs showed fluctuations (Fig.5.1). There appeared an outlier in February, 1996, when an unusually high catch was observed in the Northern sub-stratum possibly due to exceptional rains during that month in the area, otherwise low catches occurred in the season of low water levels from November to March. The results of analysis of variance (ANOVA) to test the significance of differences in catch rates between substrata and months of investigation are shown in Table 5.4. From the analysis there was no significant difference in catch rates between substrata or between months of investigations (P < 0.001).

Table 5.4 ANOVA table to test significance of differences in catch rates in 1996 between substrata and months of investigation

Source of variation	Sum of squares	D.F.	Mean square	F	Signif.
SUBf-STRATA	395.173	2	197.586	4.722	0.020
MONTH	543.577	11	49.416	1.181	0.354
ERROR	920.588	22	41.845		
TOTAL	9752.180	36			

The data from the three sub-strata were therefore combined (i.e. regarded as unstratified) and presented in Figure 5.2. But for the exceptionally high catch in the Northern sub-

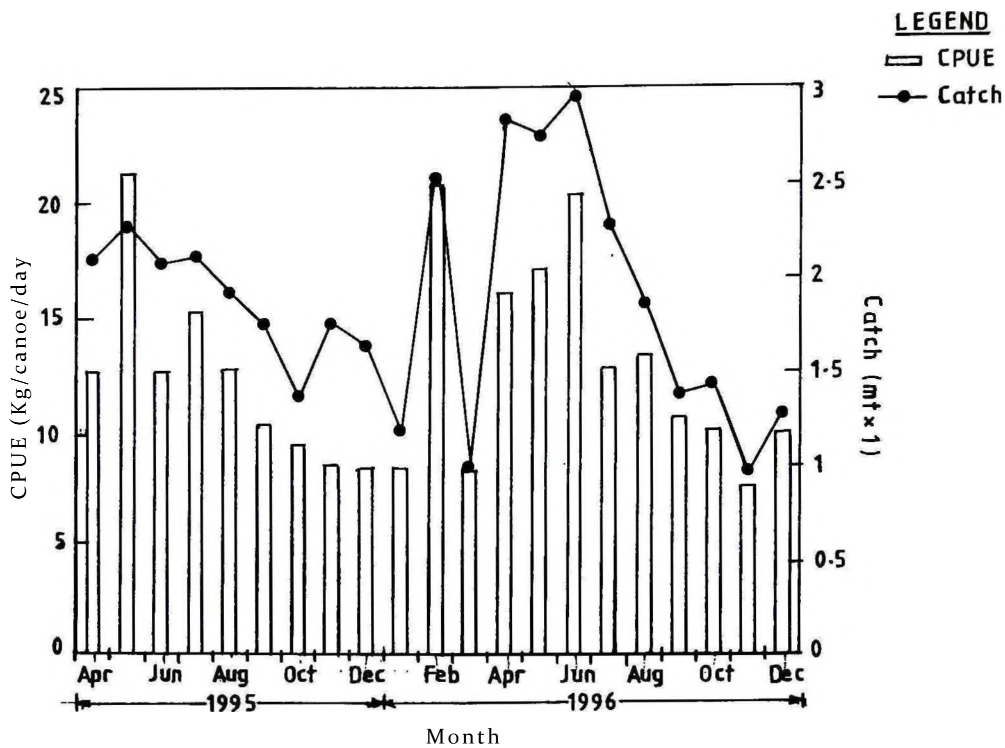


fig. 5.2 Variation in catches of canoes in stratum VII (without stratification) of Lake Volta during 1996

stratum in February 1996, the highest catches generally occurred in April to June which marked the season of high water levels. The estimated mean CPUE was 14.28 ± 4.02 kg canoe ’d'^{1} and 11.33 ± 3.45 kg canoe "'d'^{1} in 1995 and 1996 respectively which indicated a reduction in catches. The mean CPUE for 1995 and 1996 was calculated as 12.81 ± 2.09 kg canoe "’d'^{1}.

5.1.2 Total fish production from the canoes

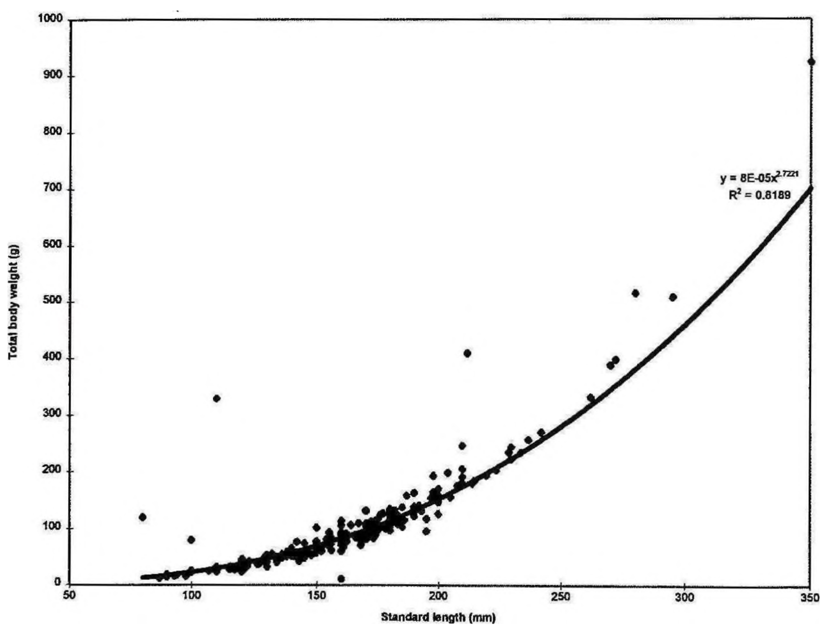
Given that there is a total of 8,068 canoes in stratum VII (de Graaf & Ofori-Danson, 1996) of which 80% (or 6,454 canoes) on average went fishing in a month in stratum VII for an average of 25 fishing days with the estimated mean CPUE of 12.81 kg canoe "d'^{1}, the total mean annual catch during the 1995/96 study period was—calculated as 24.802,722.0 kgs i.e. about **25,000 metric tonnes.**

Assuming that the surface area of stratum VII is about 18.4% of the total surface area of the lake (taken as 4,840 km^{2}), the surface area of Stratum VII is calculated as 890.78 km^{2} or 890,780 hectares . The production from the lake considering gill-net fishery in stratum VII could be projected as: 25,000 tonnes x 1000 kg / 890,780 ha = **28.07 kg** ha'^{1} **yr"^{1}.** This estimate is about 1.8 times higher than the potential yield of **15.55 kg** ha'Vr’^{1} estimated from the morpho-edaphic index.

5.2 LENGTH-BASED ASSESSMENT OF THE MAJOR FISH STOCKS

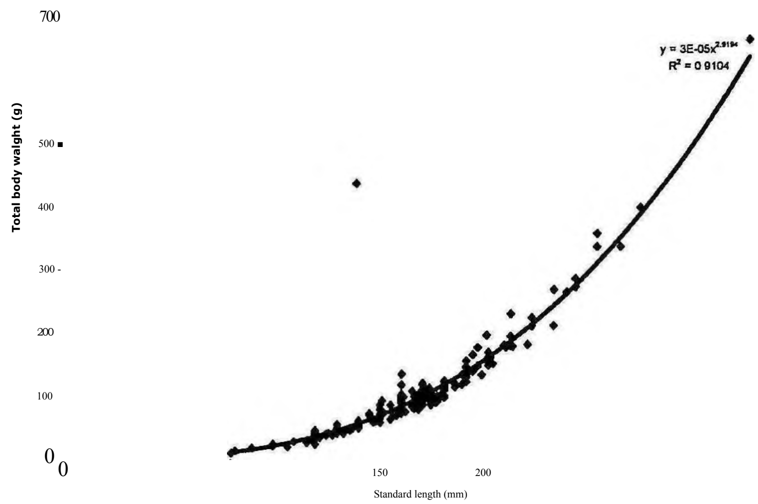
5,2.1 Length-weightrelationship

Figures 5.3 and 5.7 show the length-weight relationship for males and females of the major species.



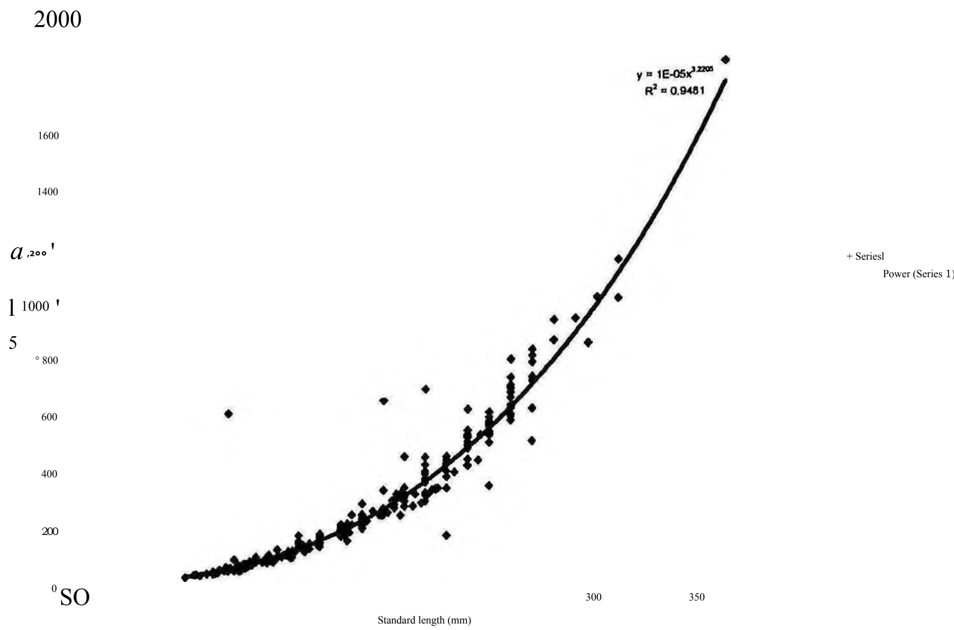
N = 252 y = 8E-05X^{27221} $r^2 = 0.8199$

Fig. 5.3a Length-weight relationship for female C. ***nigrodigitatus***



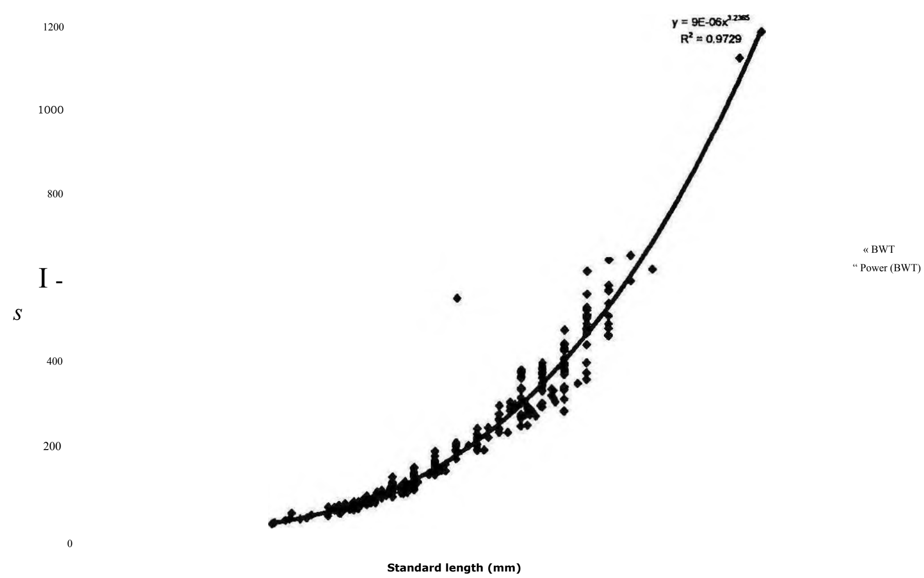
N= 185 y = 3E-05X 29194 r^2 = 0.9104

Fig. 5.3b Length-weight relationship for male ***C. nigrodigitatus***



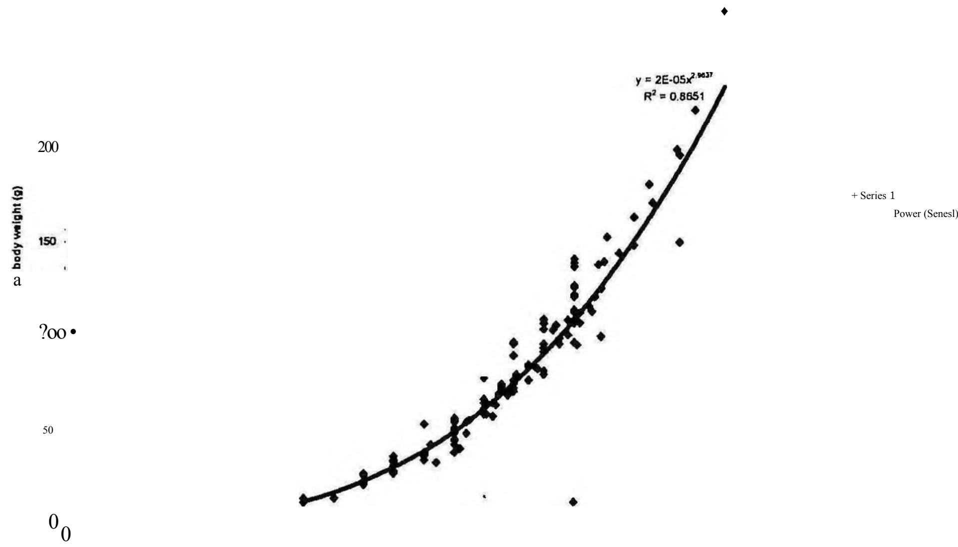
N= 258 $y = 1E\text{-}05X^{3.2205}$ $r^2 = 0.9481$

Fig. 5.4a Length-weight relationship for female *H. membranaceus*



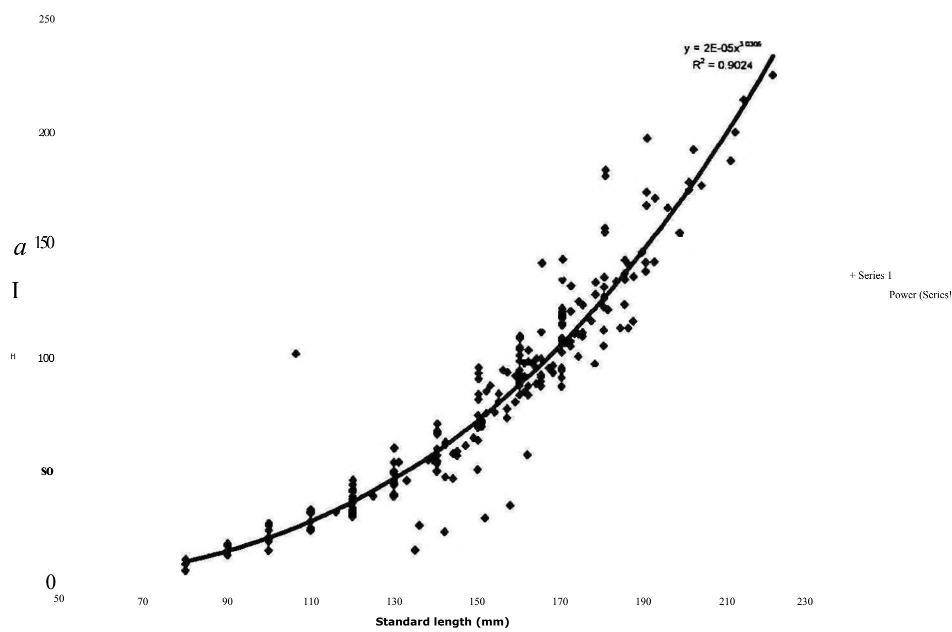
N = 286 $y = 9E\ X^{2.9368}$ $r^2 = 0.9729$

Fig. 5.4b Length-weight relationship for male *H. membranaceus*



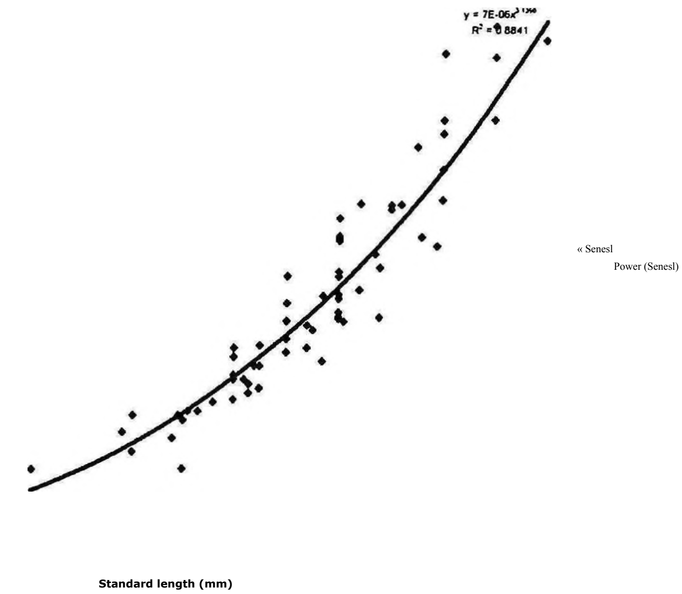
N= 125 $y = 2E\text{-}05\ X'^{2983\,7}$ $r^2 = 0.8651$

Fig. 5.5a Length-weight relationship for male *C. auratus*



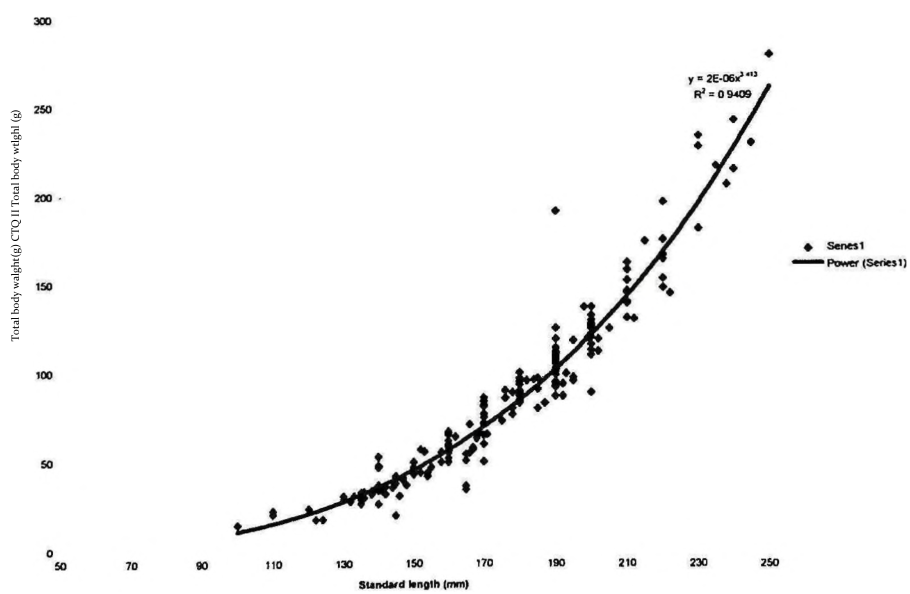
N = 234 *I* = 2E-05 $X^{3\,0306}$ $r^2 = 0.90$

Fig. 5.5b Length-weight relationship for female *C. auratus*



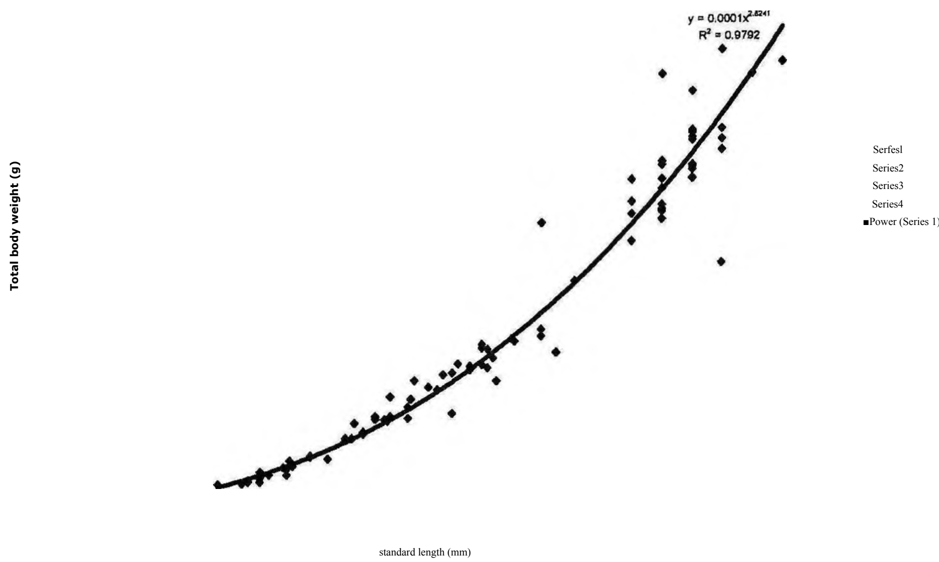
66 y= 7E - 06X ^{31398} r^2=0.8841

5.6a Length-weight relationship for male *S. intermedius*



N= 204 y= 2E - 06X $^{3\ 413}$ r^2 = 0.9409

— — — - — — **female 5.** *intermedius*



N= 86 $y= 0.0001\ X^{2,8241}$ $r^2 = 0.9792$

Fig. 5.7a Length-weight relationship for male *O. niloticus*

50 100 150 200 250 300 350 400

Standard length (mm)

N= 96 y= 7E-05 $X^{2\ 9077}$ $r^2 = 0.9673$

Fig. 5.7b Length-weight relationship for female *O. niloticus*

A summary of the parameters of the length-weight relationship by sex for the major species caught are provided in Table 5.5.

Table 5.5 Length-weight relationship by sex for the major species caught in stratum VII of Lake Volta. All data fitted to $Y = a X^b$ where Y =Total body weight in grams, X = Standard length in millimetres, a = multiplicative constant factor and b = exponential (r^2 = coefficient of determination)

Species	n	Standard Length range (mm)	a	b	r^2
H. membranaceus					
males	286	148-320	9E-06	2.9368	0.9729
females	258	220-300	IE-05	3.2205	0.9481
C. auratus					
males	125	120-190	2E-05	2.9837	0.8651
females	234	110-190	2E-05	3.0306	0.9000
C. nigrodigitatus					
males	185	80-320	3E-05	2.9194	0.9104
females	252	87-295	8E-05	2.7221	0.8199
0. niloticus					
males	87	111-300	0.0001	2.8241	0.9792
females	96	85-268	7E-05	2.9077	0.9673
S. intermedius					
males	66	100-200	7E-06	3.1398	0.8841
females	204	100-250	2E-06	3.4130	0.9409

From Table 5.6, the proportion of the total variation in Y (total body weight) that is explained or accounted for by the fitted curve (r^2), is in all cases >0.8 indicating "good" fitness of the curves; and both males and females generally had the exponents (b) approximately equal to 3, indicating that weight growth was isometric,i.e. that growth occurred with unchanging body proportions and specific gravity. However, there were differences in the relationship for males and females.

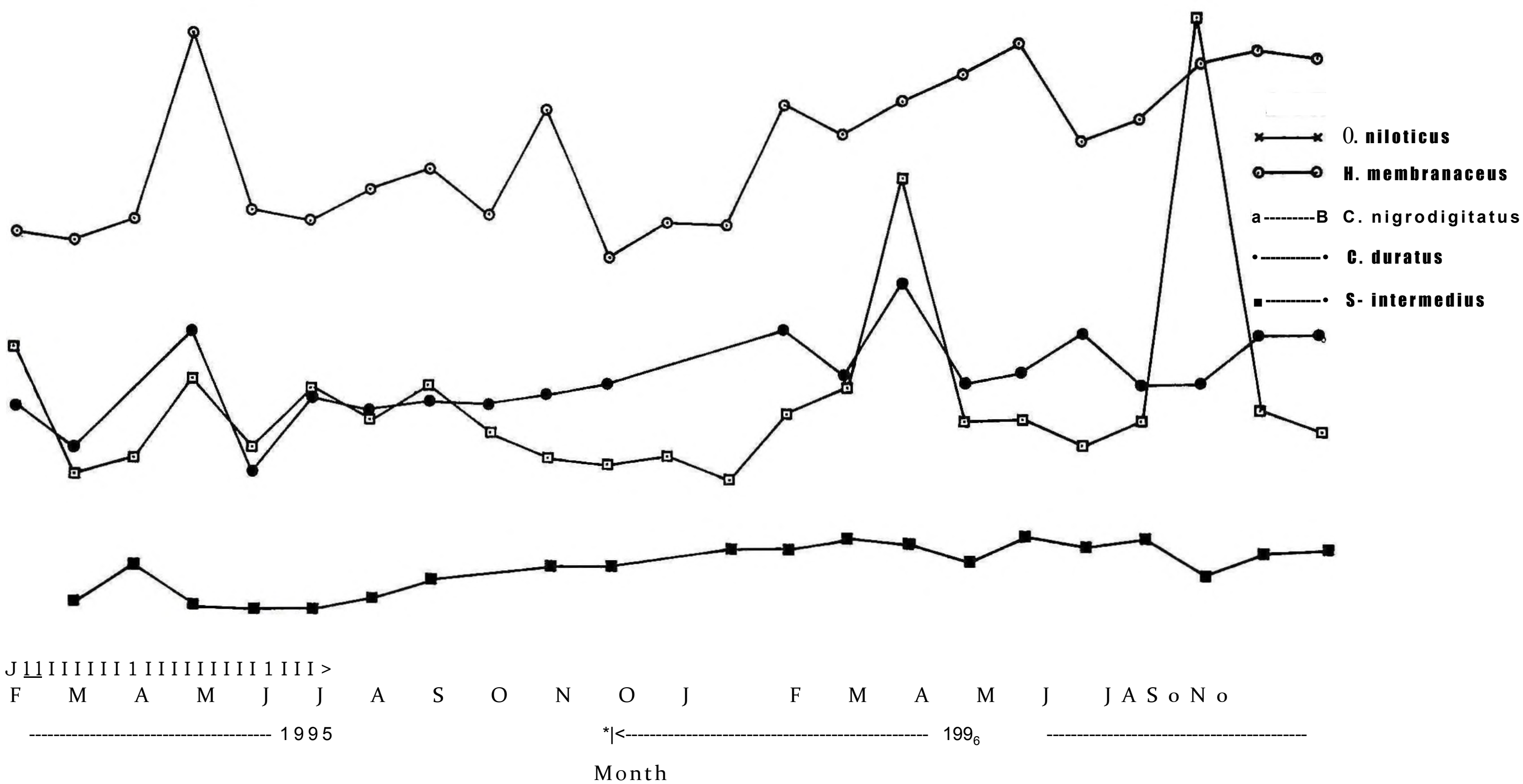


Fig. 58 Seasonal variation in mean condition factor (C.F) estimates for the major species

5.2.2 Condition factor (CF) of major species

Another way of relating length and total body weight was to define a Condition Factor *(CF)* such that:

$$CF = W \times 100/L^3$$

where *W* is the total body weight in grams and *L* is the standard length in centimeters. The overall mean *CF* value of $4.25 \pm 0.20 \times 10^{-3}$ was calculated for *O. niloticus* and $3.28 \pm 0.32 \times 10^{-3}$ for *H. membranaceus* during 1995-96. For *C. auratus, C. nigrodigitatus* and *S. intermedius* overall mean *CF* was $2.26 \pm 0.18 \times 10^{-3}$; $2.19 \pm 0.45 \times 10^{-3}$; and $1.46 \pm 0.11 \times 10^{-3}$ respectively. Figure 5.8 shows seasonal fluctuations in *CF* for the major species. There was poor ($r < 0.5$) relationship between *CF* and other indices of the well-being of the fish species i.e *CF* and gonadosomatic index *(GSI), CF* and Hepatosomatic index *(HSI), CF* and Relative mesenteric fat *(RMF)*.

5.2.3 Correction of length frequency data for gear selectivity using selection ogives

The monthly length frequency data for the major species caught from experimental fishing with winch-net are presented in Appendices IV- VIII. From these data it was found that the major fish measured 5 - 44 cm standard length. Figures 5.9 to 5.13 show the 50% retention points or mean length at first capture (or L_{c50}) as predicted from the selection curves obtained from logistic equation. The L_{c50} value of 19.95 cm standard length was found for *H. membranaceus* (Fig.5.9) while those for the bagrids *C. nigrodigitatus* and-C *auratus* were 13.09 cm and 16.85 cm standard length respectively (Fig.5.10 and Fig.5.11). For *O. niloticus* and *S. intermedius* theL_{c50} value was 13.61 cm and 15.82 cm standard length respectively (Fig. 5.12 and Fig. 5.13).

Using the inverse von Bertalanffy equation (Sparre and Venema, 1992) : $t_{(L)} = l_0 - 1/K$ $(1- L_{C50}/ L .)$ the age at which the fish is caught at L_{C50} is respectively calculated as 0.97 yr, 0.78 yr, 0.97 yr, 0.85 yr and 0.15 yr for *H. membranaceus, C. auratus, C. nigrodigitatus, O. niloticus* and *S. intermedius*. This indicates that the major species are caught before they are one year old.

For the purpose of adjustment of the length-frequency data (to account for gear selectivity), the estimated L_{c50} was used to estimate the probability of capture for each length class by the logistic equation. The corrected or adjusted length frequency data for each length class (= sample frequency/ Probability of capture at given length class) were used in estimation of growth parameters in the next section.

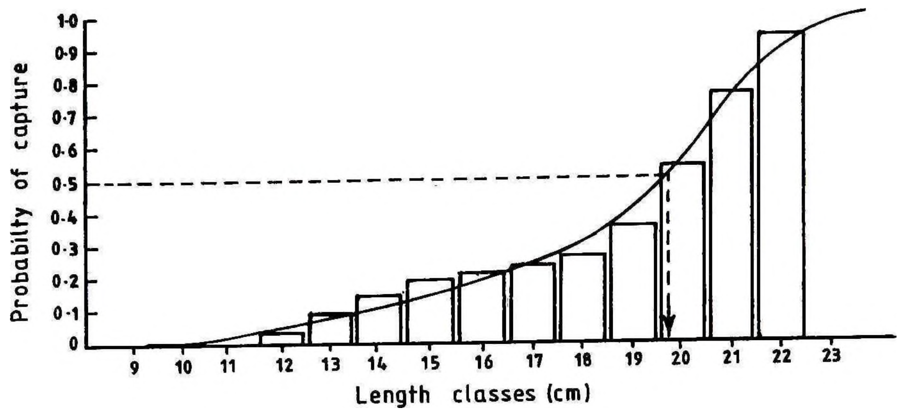


Fig. 5.9 The 50% retention point defined from selection curve using length frequency data of ***H. membranaceus*** lLcso = 19-95 cm)

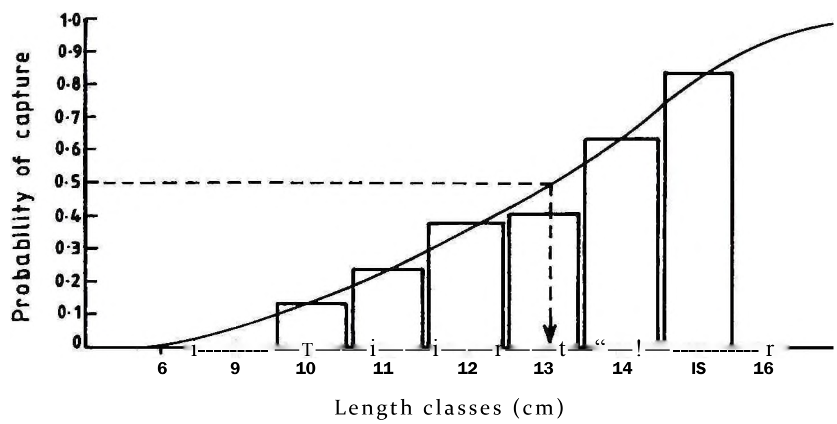


Fig. 5.10 The 50% retention point defined from selection curve using length frequency data of ***Chrysichthys nigrodigitatus*** (Lcso = 13 09cm)

Length classes (cm)

Fig. 5-11 **The** 50% **retention point defined from selection curve using length frequency data of *Chrysichthys auratus*** (Lcso = 15*85 cm)

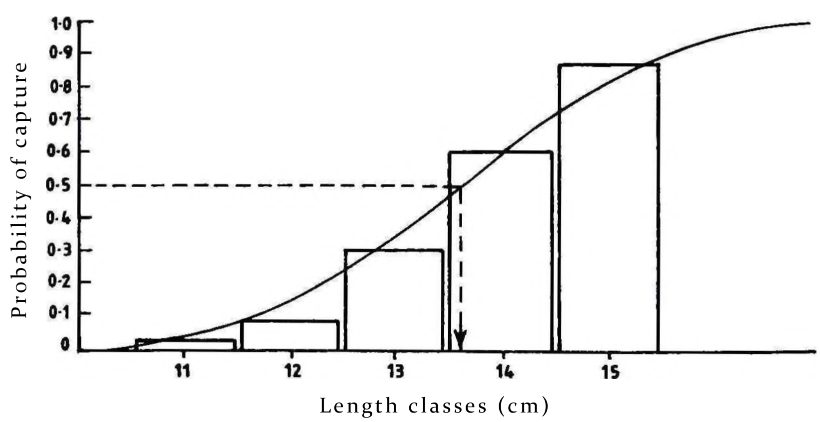


Fig. 512 The 50% retention point defined from selection curve using length frequency data of *Oreochromis niloticus* (Lcso = **1361cm)**

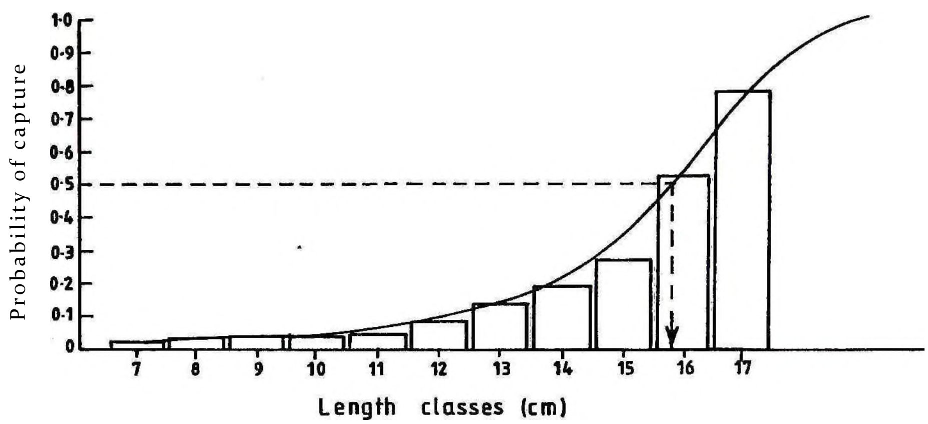


Fig. 513 **The** 50% **retention point defined from selection curve using length frequency data of** ***Schiibe intermedius*** (Lcso = 15-82 **cm)**

5.2.4 Estimation of growth and mortality parameters from corrected length frequency data

5.2.4.1 Modal lengths for different cohorts of major species

Figures 5.14 to 5.18 show the respective computer output from the Bhattacharya analysis for the selected species which were either bimodal or polymodal. It was generally possible to separate at least three cohorts from the length frequency distribution of the selected species which indicate that the fishery operated on at least three pseudo-cohorts of the different populations.

The component groups were assumed to represent separate age classes. A summary of the mean lengths of the age classes or components which were obtained (i.e. where Separation Index is > 2) from the analyses is shown in Table 5.6.

The first cohort or age-class was esimated as having mean sizes of 13.57 ± 1.28 cm; 11.62 ± 0.53 cm; 10.36 ± 0.98 cm; 11.86 ± 2.39 cm; and 7.32 ± 0.98 cm standard length for *H. membranaceus, C. auratus, C. nigrodigitatus, O. niloticus* and *S. intermedins* respectively (Table 5.6). The second cohort and third cohorts ranged between 12.66 to 18.84 cm and 17.32 to 23.12 cm standard length respectively.

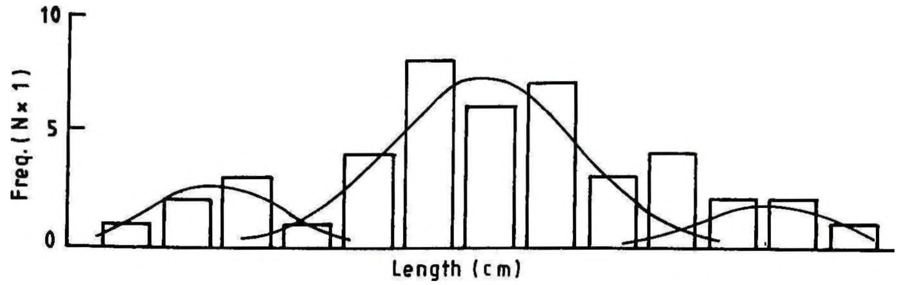


Fig. 5.14- Output from Bhattacharya analysis for *C. nigrodigitatus*

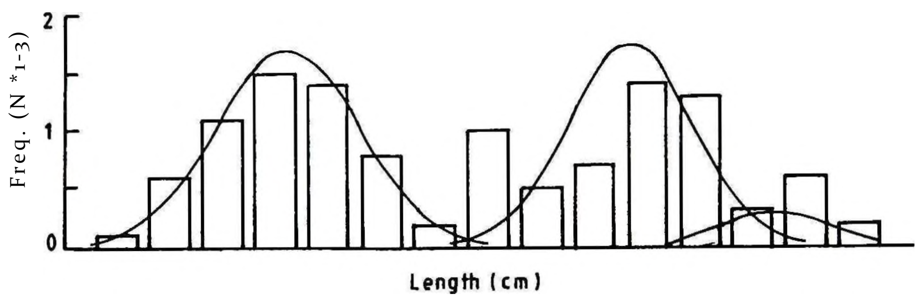


Fig. 5.15 Output from Bhattacharya analysis for *C. auratus*

2

FlPi

Pl

Oa

Length (m)

Figure 5.16 Output from Bhattacharya analysis for *H. membranaceus*

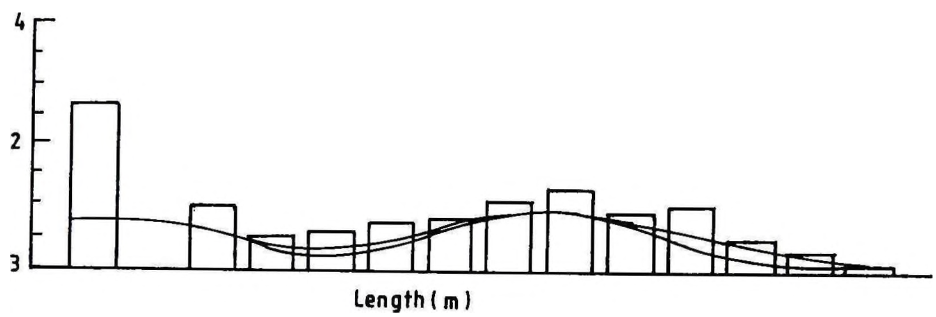
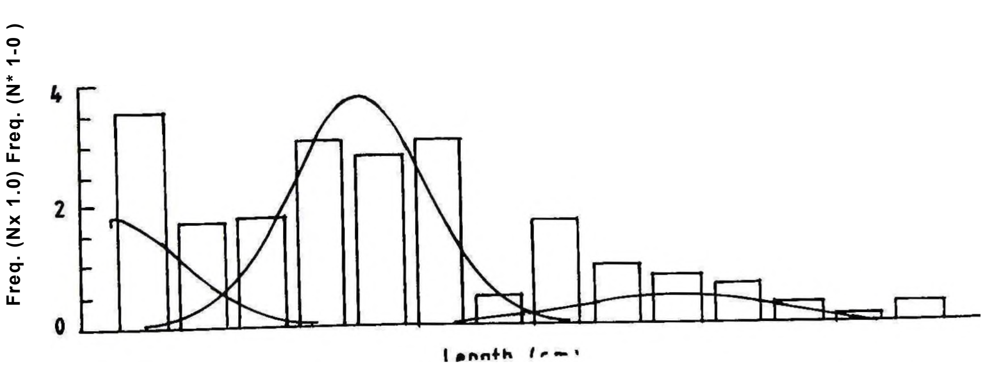


Figure 5.17 Output from Bhattacharya analysis for *O. niloticus*



Output from Bhattacharya analysis for *S. intermedius*

Table 5.6 Bhattacharya analyses mean modal standard length values (cm) for major species in Stratum VII during 1995-96 . (Standard deviation in brackets)

Species	1st component	2nd component	3rd component	4th component
H. membranaceus	13.57(1.28)	18.84 (1.95)	23.12 (2.28)	27.88 (2.64)
C. auratus	11.62(0.53)	15.93 (1.34)	20.08 (1.79)	. . . X
C. nigrodigitatus	10.36 (0.98)	16.07 (1.48)	21.49(1.43)	26.68(1.22)
0. niloticus	11.86(2.39)	16.89(2.84)	21.81 (2.72)	---
S. intermedius	7.32 (0.98)	12.66 (0.93)	17.32 (0.82)	22.03 (1.45)

5.2.4.2 Estimation of growth parameters (L^ K and tj using the FISAT software

Growth of the species was inferred from apparent shifts in modal values of lengths (commonly called Modal Progression Analysis, *MPA)*. In this approach peaks or modal values which belong to the same cohort of the various samples are inter-connected and arranged sequentially in time.

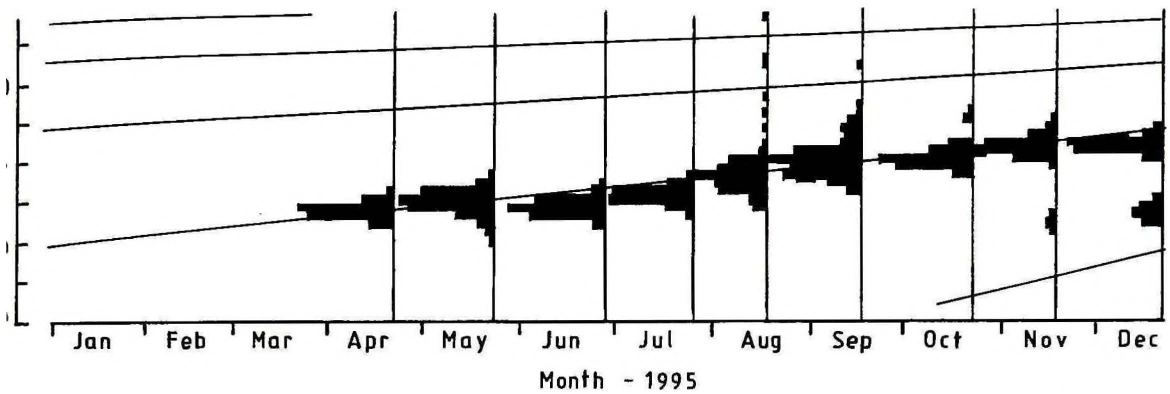
The method is based on the following tenets suggested by Pauly (1980):

(i) Length growth in the fishes is at first rapid, then decreases smoothly and is, for the population as a whole, best approximated by a long continuous curve, rather than by several, short straight segments.

(ii) A single smooth growth curve interconnecting the majority of the peaks of sequentially arranged length frequency samples is likely to represent the average growth of the fishes of a given stock.

(iii) The growth patterns repeat themselves from year to year (also an assumption when the “annuli” of otoliths or scales are counted for age studies).

The growth curves are drawn directly upon the length-frequency samples sequentially arranged in time. The modal lengths corresponding to various cohorts (or age classes) can be read off the curves at regular time intervals (thereby providing age-length data). The length frequency distribution output and the superimposed growth curves from FISAT (Gayanilo *et al.,* 1992) analyses are shown in Figures 5.19 to 5.23.



L OD 4400
K 0-550
C - 0 650
WP 0-350
SS 10
SL 10-50
Rn 0 12 2

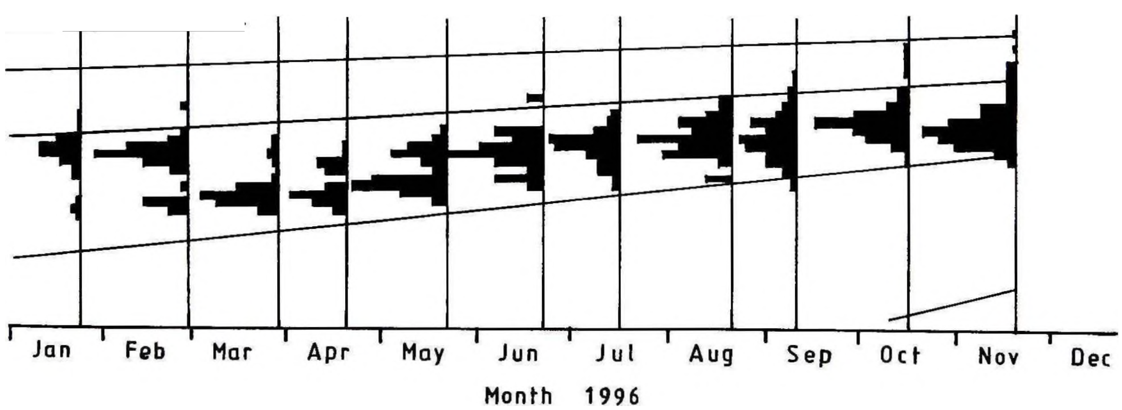
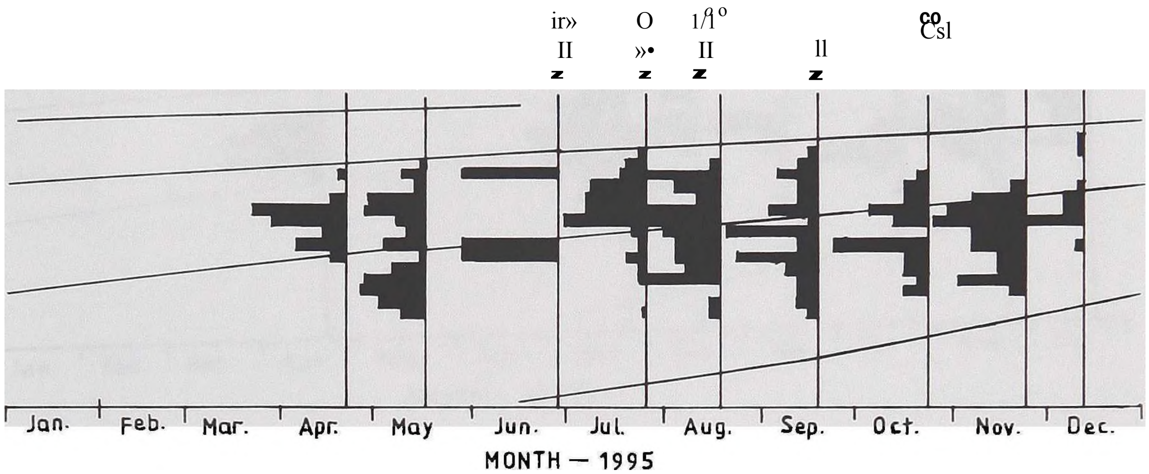
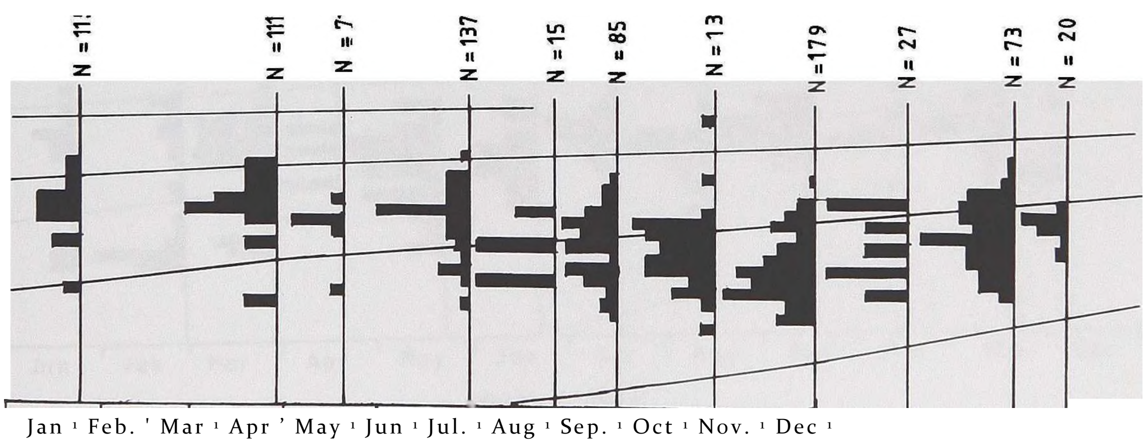


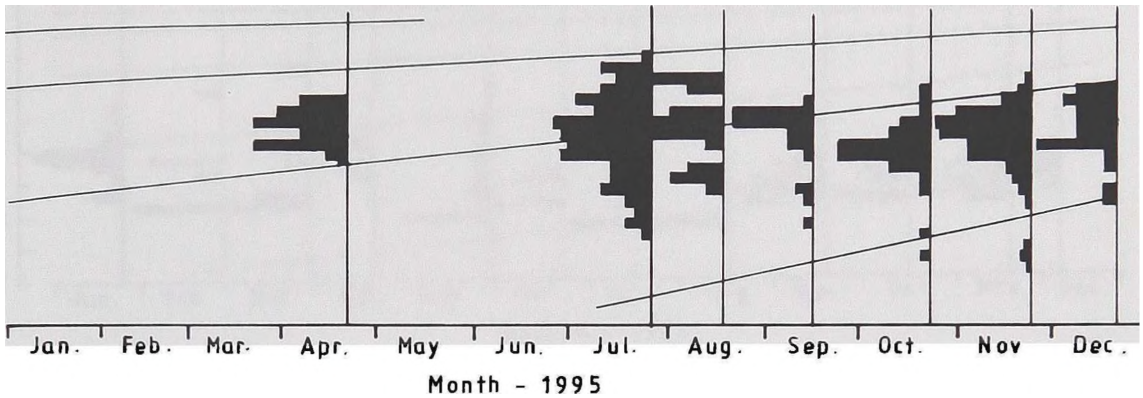
Fig. 5 -19: Length frequency distribution output from FISAT with superimposed growth curves for *H. membranaceus*



L_{∞} = 31.00
K = 0.600
C = 0.350
WP = 0.400
SS = 5
SL = 15.50
Rn = 0.102



Pig 5 . 20: Length frequency distribution output from FISAT with superimposed growth curves for *C.auratus*



CO. 30 00
K 0-800
C 0 3 50
WP 0-100
SS 5
SL = 8-50
Rn = 0-101

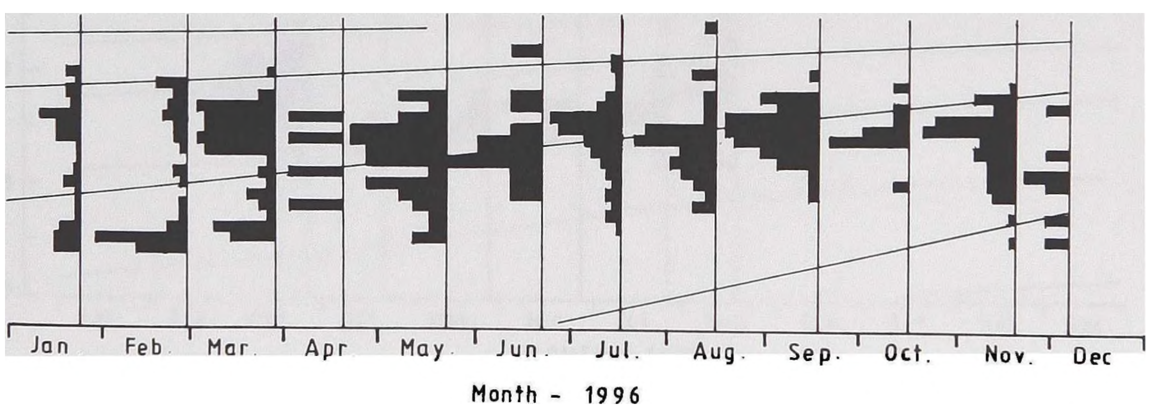
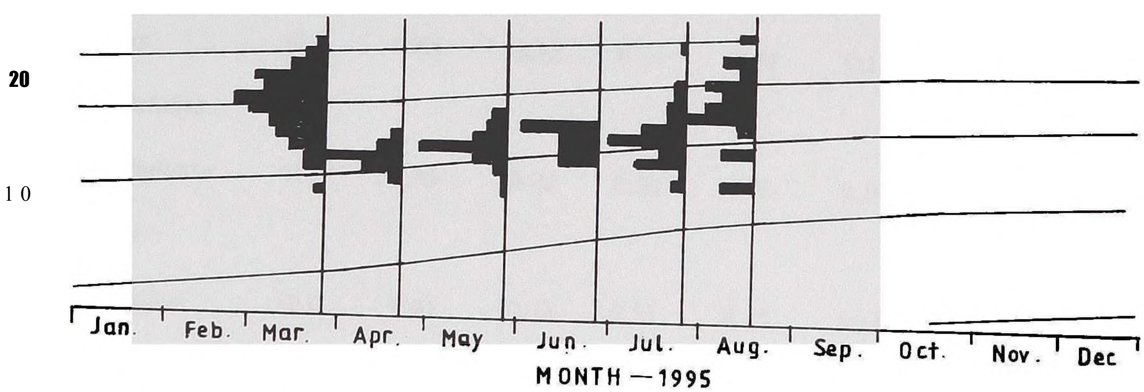


Fig. 5 21 * Length frequency distribution output from FISAT with superimposed growth curves for S. *intermedius*

MONTH — 199 6

L oo = 44 · 50
K = 0-665
C = 0-500
WP - 0-300
SS = 11
SL — 17-50
Rn = 0-110

fig. 5.22 Length frequency distribution output for FISAT with superimposed growth curves for *C. nigrodigitatus.*



L 03 SS 33 . 50
K = 0 350
C = 0 · 600
WP 0 ■ 950
SS 3
SL = 1 4 • 00
Rn - 0 • 110

Fig. 5-23: Length free * ■ UUIUUI || superimposed curves for *O. niloticus.*

For each of the species, at least three growth curves are indicated (reflecting the production of several broods per year). The von Bertalanffy growth parameters (K, L,,,) for each of the species were obtained from the age-length data (obtained from the growth curves) using ELEFAN I program of the FISAT software (Gayanilo *et al.,* 1992). The parameters (K, L -) that describe growth in length as obtained from Figures 5.19 to 5.23 and t_0 have been summarized in Table 5.7.

Table 5.7 Estimated growth and other derived parameters of major species in stratum VII of Lake Volta

Species	L_ (cm)	K(yr)	to(vr)	C (yr)	WP (yr)	Rn	0[1]
Hemisynodontis membranaceus	44.0	0.55	-0.26	0.65	0.35	0.232	3.027
Chrysichthys auratus	31.0	0.60	-0.12	0.35	0.40	0.120	2.760
Chrysichthys nigrodigitatus	44.5	0.65	-0.22	0.50	0.00	0.146	3.129
Schilbe intermedius	30.0	0.80	-0.38	0.35	0.10	0.155	2.857
Oreochromis niloticus	33.5	0.35	-0.45	0.60	0.95	0.191	2.590

The values of oscillation parameter (C) and Winter Point (WP) or period of slowest growth, indicate that growth oscillated seasonally. This was because when C and WP were set at zero value (i.e that there was non-seasonal growth), the " index of goodness of fit" or R_n, were lower than those presented in Table 5.7 above. In other words, growth oscillated with periods of relatively more rapid growth and those of little or slow growth.

The results in Table 5.7 show that the growth performance index or phi-prime (0^1) for the bagrids, *Chrysichthys auratus* and *Chrysichthys nigrodigitatus* which are the only species belonging to the same taxa or genus are similar. This is in agreement with Pauly's (1979) discovery that phi-prime values are very similar within taxa. Since phi prime values are very similar for the bagrids. The parameter estimates could be considered reasonable.

Inserting the estimated values of the growth parameters, the von Bertalanffy growth model for the major species were described as follows:

H. membranaceus: $L_t = 44.0 \; [1 - \exp(-0.55(t + 0.26))]$

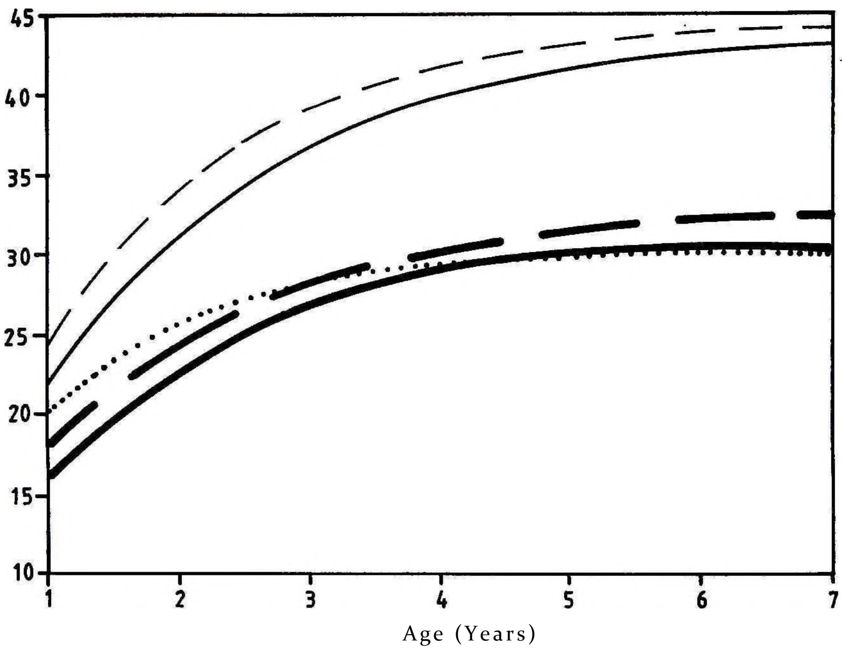
C. nigrodigitatus: $L_t = 44.5 \; [1 - \exp(-0.65(t + 0.22))]$

C. auratus: $L_t = 31.0 \; [1 - \exp(-0.60(t + 0.12))]$

O. niloticus: $L_t = 33.5 \; [1 - \exp(-0.55(t + 0.45))]$

S. intermedius: $L, = 30.0 \; [1 - \exp(-0.80(t + 0.38))]$

The resulting growth curves from the above equations are presented graphically in Figure 5.24.



5.24 Growth curves as obtained from estimated growth parameters for the major species

The growth curves placed the fish species in two categories: those with higher or “convex shaped” growth curvature indicating relatively faster growth rate; and those with more or less flattened growth curvature or slower growth rate. The former group consisted of *H. membranaceus and C. nigrodigitatus* while the latter consisted of *C. auratus, O. niloticus and S. intermedins.*

5.2.4.3 Mortality parameters (M, F and Z)

The instantaneous coefficient of natural mortality *(M)* as estimated for the major species using Pauly's (1980) empirical model is shown in Table 5.8.

Table 5.8 Estimated values of natural mortality coefficient (M) by Pauly's (1980) empirical method

Parameter	*H. membranaceus*	*C. auratus*	*C. nigrodigitatus*	*S. intermedius*	*O. niloticus*
M (yr^{-1})	1.12	1.30	1.23	1.59	0.90
M/K ratio	1.29	1.37	1.22	1.26	1.09

The reliability of the estimated values for M was ascertained using the M/K ratios because this ratio has been reported to be within the range of 1.2 and 2.5 (Beverton and Holt, 1966). The calculated values of the M/K were found to be in this range (Table 5.8) hence the estimate of M were considered reasonable.

The estimated growth parameters served as input for construction of linearised length-converted catch curves for the major species using the FISAT software. The output are presented in Figures 5.25 to 5.29.

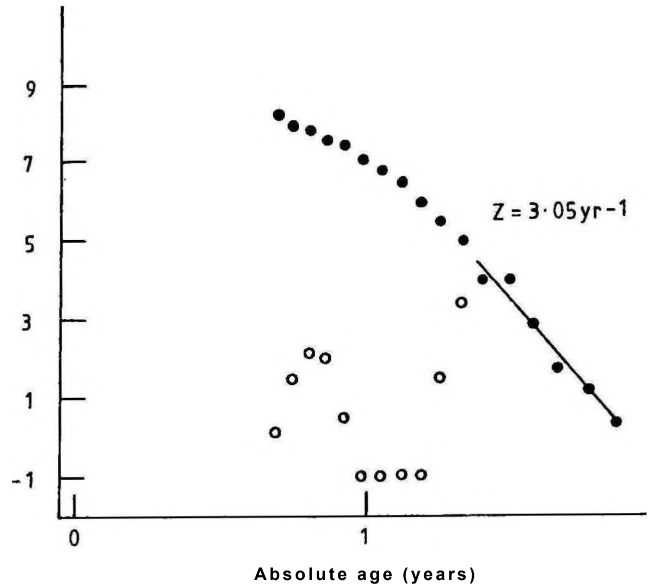


Fig. 5 25: FISAT output of linearized length-converted catch curve for *H. membranaceus* Loo = **44- 00 cm K=0-55kjr'1**

t_0 =-0-2 6 yr

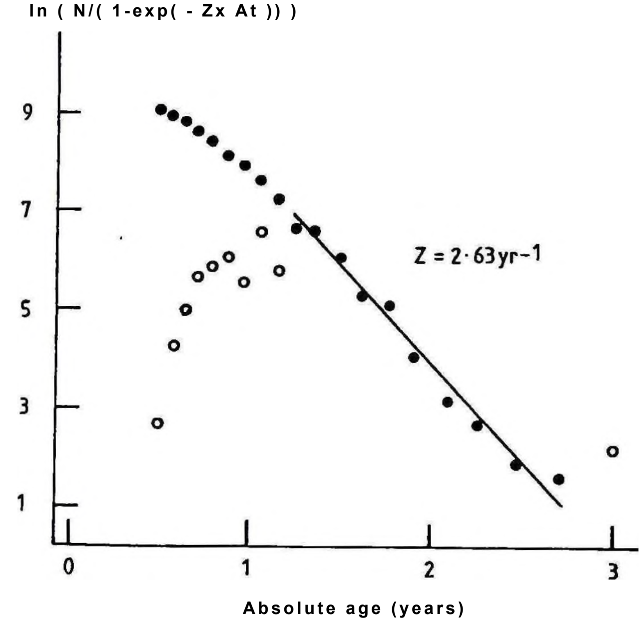


Fig. 5-26 :FISAT output of linearized length-converted catch curve for *C. auratus* **Lao* 31-00 cm K= 0 60**

tg =- o -12 tjv

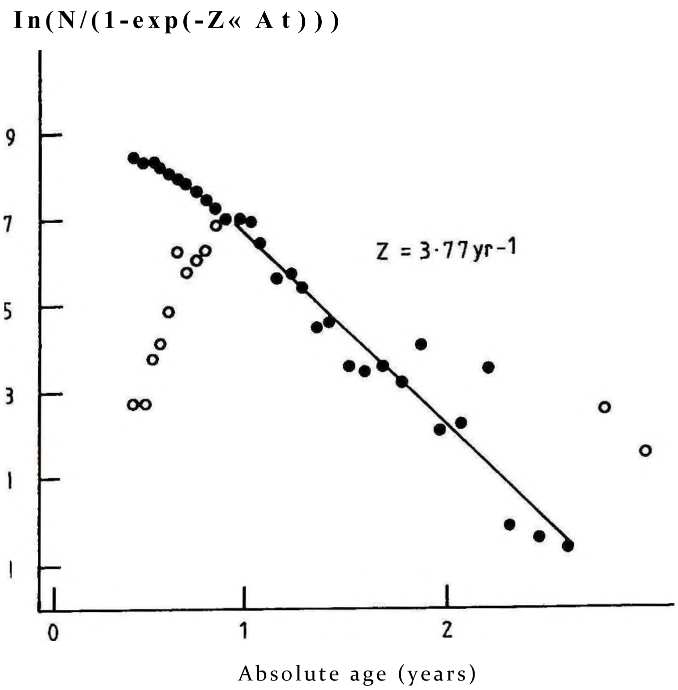
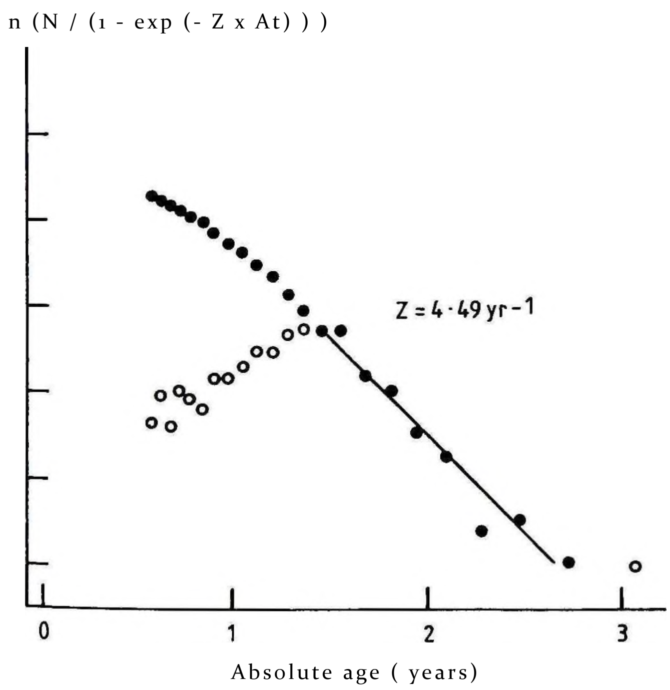


Fig.5-27: FISAT output of linearized length - converted catch curve for^
C. nigrodigitatus Leo = 44 K = 0- 62; t° --0-22$_{yr}$



ig. 5-28 : FISAT output of linearized length-converted catch curve for
5. intermedius , Loo = 30 00 cm K = 0-80$_{y}$r-' .
t_0 = - 0- 38 vj$_r$

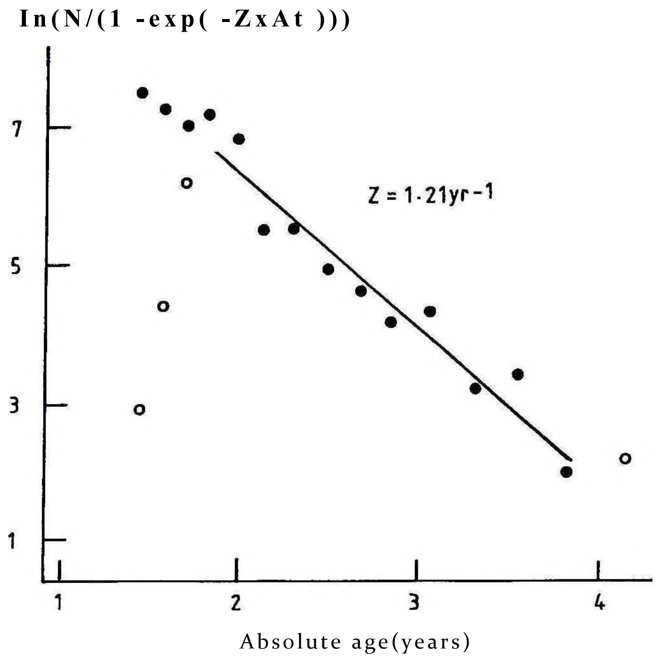


Fig. 5 - 29 : FISAT output of linearized length-converted catch curve *for 0.niloticus*
Loo =33-50 cm K= 0-3 5'vjr-1

t_0 =-0-38$_r$

Estimated instantaneous total mortality (Z) and instantaneous fishing mortality parameters (F) obtained from the linearised catch-curves are summarized in Table 5.9 below:

Table 5.9 Estimated instantaneous fishing mortality **(F)** and instantaneous total mortality (Z) coefficients for major species in stratum VII of Lake Volta

Parameter	*H. membranaceus*	*C. auratus*	C. *nigrodigitatus*	*S. intermedins*	*O. niloticus*
Z (from catch curve) yr	3.05	2.63	3.77	4.49	1.21
F = Z - M (yr'1)	1.93	1.33	2.53	2.90	0.31

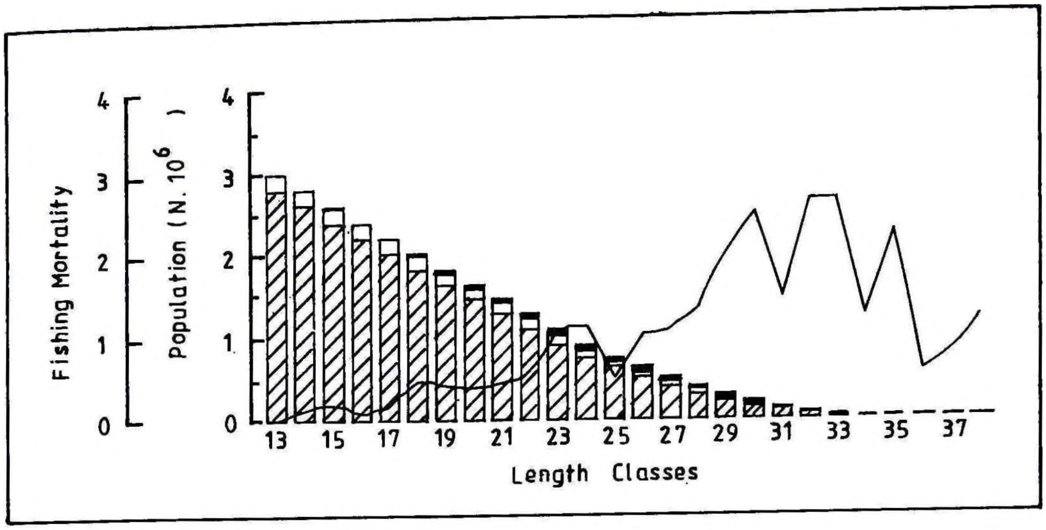
5.2.5 Estimation of fishing mortality and stock sizes based on length-structured virtual population analysis (VPA)

The input parameters for the VPA are given in Table 5.10.

Table 5.10 Input parameters for the Jones' length converted cohort analyses estimated from Figures 5.19 to 5.23. Values for L,,, K (from Table 5.7) and M (from Table 5.8)

Parameters	*H membranaceus*	*C. auratus*	*C. nigrodigitatus*	*O. niloticus*	*S. intermedius*
L- (cm)	44.0	31.0	44.5	33.5	30.0
K(yr‘1)	0.55	0.60	0.65	0.55	0.80
M (yr'1)	1.12	1.30	1.23	0.90	1.59
Terminal F/Z	1.20	0.80	1.10	0.50	0.70
a in W=a L ^{b} (g>cm) (unsexed)	0.0005	0.0001	0.0001	0.0004	0.0001
b in W=a L ^{b} (unsexed)	2.5390	3.0183	2.7600	2.8416	3.1483

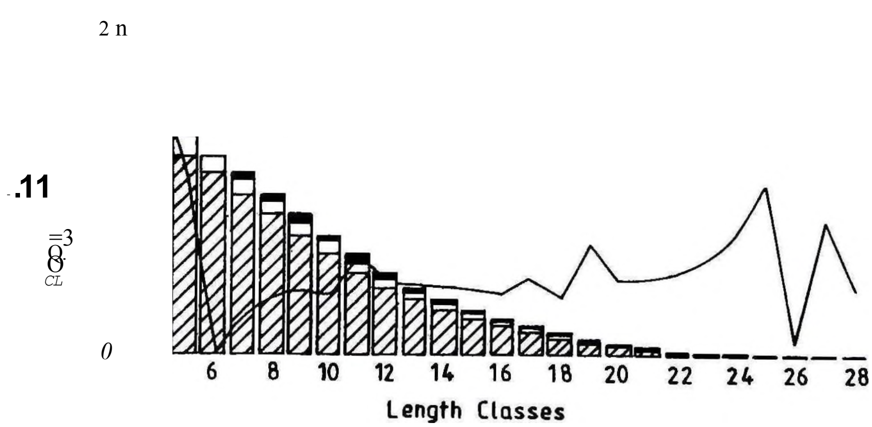
The output of the results from FISAT are presented graphically in Figures 5.30 to 5.34 by plotting fishing mortality against length.



L∞ =44cm K = 0·55yr-1 Natural M = 1·12 yr-1 Terminal F = 1·200yr-1 Mean E = 0·314

Mean F = o-5Uyr-1 LEGEND: M Catch ▨ Natural losses *VZA* Survivors Fishing mortality

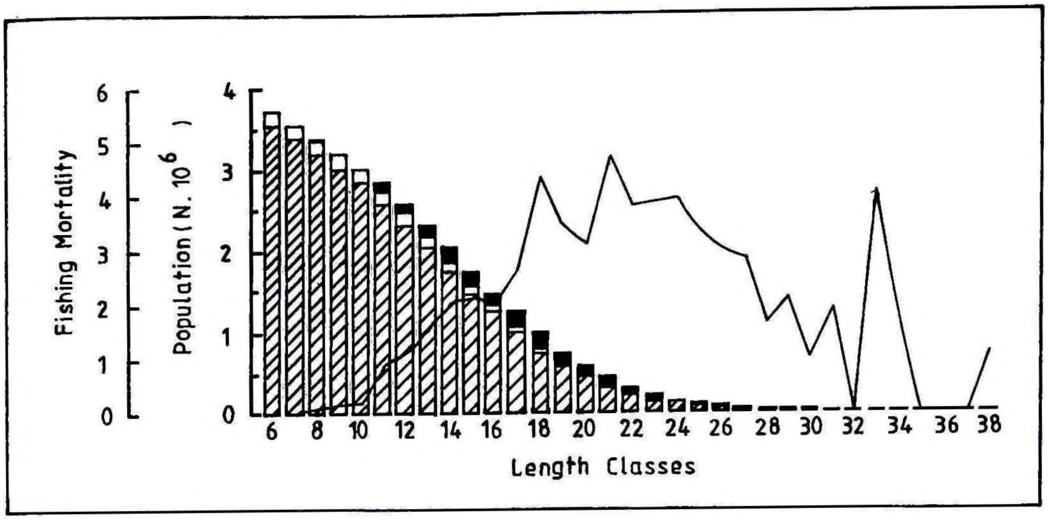
Fig. 5-30 FISAT output of length structured virtual population analysis for *H. membranaceus*



Loo=3icm K = o-6oyr-1 Natural M = 1 - 3 yr -1 Terminal F = o-8ooyr-1 Mean E=o-48o

Mean F= 1-2oo yr-1 LEGEND: ▨ Catch ▨ Natural losses E22 Survivors Fishing mortality

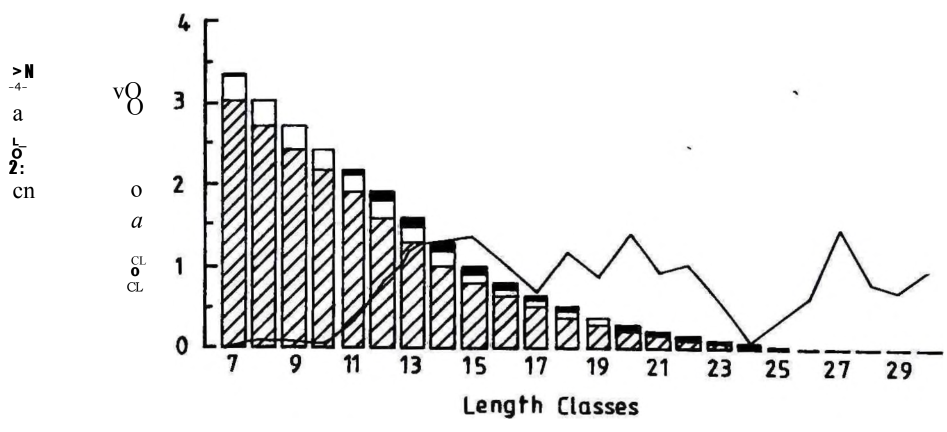
Fig. 5-31: FISAT output of length structured virtual population analysis for *C. auratus*



Loo = 45Scm K =0-6Syr-1 Natural M=1-23yr-1 Terminal F = 1 • 100yr-1 Mean E = 0-499

Mean F = 1-224yr-1 LEGEND: § Catch EH Natural losses E23 Survivors Fishing mortality

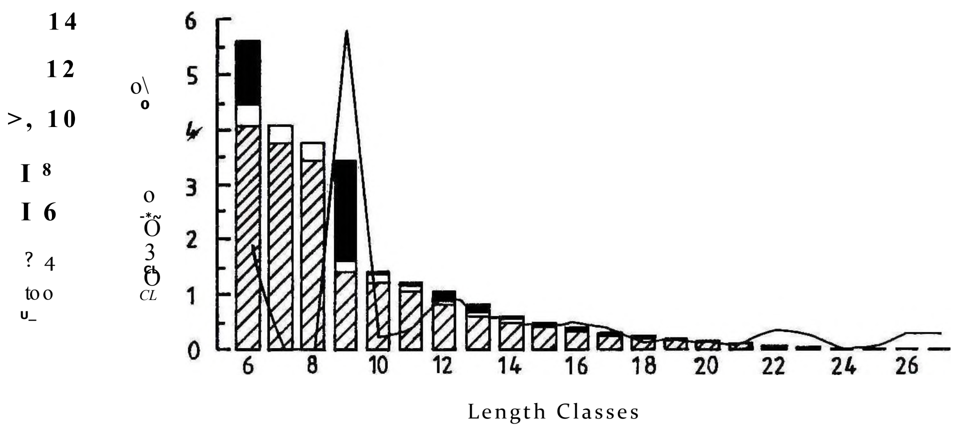
Fig. 5-32: FISAT output of length structured virtual population analysis for *C.nigrodigitatus*



LCD = **33-5**cm K=0-35yr-1 Natural M= 0-9yr-1 Terminal F =0 Sooyr-1 MeanE = 0-238

M.an F = 0-291 yr-1 LEGEND, Cotch CTlNaturnl Co^.s E3su„i„o,-s —Fishing

Fig.5-33: FISAT output of length structured virtual population analysis for *0. niloticus*



Loo = 30cm K=0-80yr-1 Natural M = 1S9yr-1 Terminal F 0-700yr-1 Mean E =0-620

Mean F = 2-598 LEGEND : HI Catch 1__i Natural losses YZ& Survivors --------Fishing mortality

Fig. 5-34: FISAT output of length structured vitual population analysis for *S. intermedius*

Table 5.11 VPA output for *H. membranaceus (a = 0.0005; b = 2.5390)*

CM (YEARS)	MEAN N M .	CATCH (tonnes)	STEADY-STATE BIOMASS
13.00 0.059	715187.88	0.17	0.27
14.00 0.061	627340.25	0.78	0.29
15.00 0.063	4&5147.94	1.24	0.27
16.00 0.065	386542.00	' 0.33	0.25
17.00 0.067	342672.41	0.31	0.26
18.00 0.070	267641.44	0.72	0.26
19.00 0.073	228057.44	0.60	0.23
20.00 0.076	180773.16	0.54	0.21
21.00 0.079	140443.81	0.53	0.19
22.00 0.083	141733.32	0.28	0.17
23.00 0.087	92132.67	0.27	0.16
24.00 0.091	76525.14	0.18	0.14
25.00 0.096	66833.38	0.07	0.14
26.00 0.101	58678.97	0.14	0.14
27.00 0.107	49632.45	0.14	0.13
28.00 0.114	40886.74	0.15	0.11
29.00 0.121	31457.84	0.20	0.10
30.00 0.130	22166.83	0.18	0.07
31.00 0.140	15846.09	0.08	0.06
32.00 0.152	10999.31	0.11	0.04
33.00 0.165	'6744.42	0.07	0.03
34.00 0.182	4442.39	0.02	0.02
35.00 0.202	2958.12	0.03	0.01
36.00 0.228	1992.14	0.01	0.01
37.00 0.260	1507.74	0.01	0.01
38.00 0.204	2288.33	0.01	0.01
Total	3990632.50	7.18	3.60

Table 5.12 VPA output for *C. auratus (a = .0001; b = 3.0183)*

CM (YEARS)	MEAN N	CATCH (tonnes)	STEADY-STATE BIOMASS
4.00 0.062	100527232-00	0.67	0.07
4.00 0.064	3285722.50	0.30	0.04
6.00 0.067	1001740.06	1.00	0.02
7.00 0.069	920529.31	0.04	0.03
8.00 0.072	799780.1.3	0.06	0.04
9.00 0.076	678351.75	0.08	0.05
10.00 0.079	576513.5	0.07	0.06
11.00 0.083	483847.06	0.11	0.07
12.00 0.088	403727.81	0.08	0.07
13.00 0.093	346050.59	0.07	0.08
14.00 0.098	2&8213.88	0.07	0.09
15.00 0.104	255580.23	0.07	0.09
16.00 0.111	2.18231.36	0.07	0.09
17.00 0.119	183269.27	0.09	0.09
18.00 0.128	152081.63	0.07	0.09
19.00 0.139	120979.46	0.12	0.09
20.00 0.152	9t3016.73	0.07	0.08
21.00 0.167	72038.62	0.07	0.07
22.00 0.185	53882.09	0.06	0.06
23.00 0.209	38116.11	0.06	0.05
24.00 0.239	24534.71.	0.05	0.04
25.00 0.278	13236.66	0.04	0.02
26.00 0.334	7659.31	**0.00**	0.01
27.00 0.419	4313.69	0.01	0.01
28.00 0.561	2500.00'	**0.00**	0.01
Total	**20561148.00**	**3.34**	**1.44**

Table 5.13 VPA output for *C. nigrodigitatus (a = .0001; b = 2.76)*

CM (YEARS)	MEAN N	CATCH (tonnes)	STEADY-STATE BIOMASS
6.00 0.040	146993.53	0.00	0.00
7.00 0.041	143717.08	0.00	0.00
8.00 0.042	140174.58	1.00	0.00
9.00 0.043	136197.70	0.00	0.01
10.00 0.045	137075.41	0.00	0.01
11.00 0.046	125871.24	0.01	0.01
12.00 0.047	117285.4'!	0.01	0.01
13.00 0.049	107448.13	0.02	0.01
14.00 0.050	95993.01	0.03	0.01
15.00 0.052	84228.94	0.03	0.01
16.00 0.054	73600.73	0.03	0.02
17.00 0.056	63163.43	0.04	0.02
18.00 0.058	59703.56	0.06	0.01
19.00 0.060	39444.03	0.04	0.01
20.00 0.063	31541.53	0.04	0.01
21.00 0.065	24093.25	0.05	0.01
22.00 0.068	17763.72	0.03	0.01
23.00 0.072	13315.54	0.03	0.01
24.00 0.075	9799.98	0.03	0.01
25.00 0.079	7254.14	0.02	0.01
26.00 0.083	!5493.5	0.02	0.00
27.00 0.088	4166.85	0.01	0.00
28.00 0.093	3280.88	0.01	0.00
29.00 0.099	2641.47	0.00	0.00
30.00 0.106	2159.52	0.00	0.00
31.00 0.114	1760.24	0.00	0.00
32.00 0.123	1490.9	0.00	0.00
33.00 0.134	1109.1	0.00	0.00
34.00 0.147	• 720.36 ;	0.00	0.00
35.00 0.162	595.00	0.00	0.00
36.00 0.181	541.55.-	0.00	0.00
37.00 0.205	487.12	0.00	0.00
38.00 0.237	909.09	0.00	0.00
Total	1586020.50	0.50	0.23

Table 5.14 VPA output for 0. *niloticus (a = .0004; b = 2.8416)*

CM (YEARS)	MEAN N *f*	CATCH (tonnes)	STEADY-STATE BIOMASS
7.00 0.108	391544.84	0.01	0.04
8.00 0.112	359765.91	0.01	0.05
9.00 0.117	327707.03	1.02	0.07
10.00 0.122	299641.28	0.01	0.08
11.00 0.127	271091.28	0.04	0.10
12.00 0.133	236318.31	0.07	0.11
13.00 0.139	200639.41	0.08	0.12
14.00 0.147	168364.86	0.08	0.12
15.00 0.154	140109.83	0.08	0.12
16.00 0.163	116704.72	0.06	0.12
17.00 0.173	98886.57	0.04	0.12
18.00 0.184	82424.06	0.07	0.12
19.00 0.197	67255.72	0.05	0.12
20.00 0.212	53483.25	0.08	0.11
21.00 0.229	41595.11	0.05	0.10
22.00 0.249	32403.44	0.04	0.08
23.00 0.272	25194.81	0.02	0.07
24.00 0.301	20449.81	0.00	0.07
25.00 0.337	16572.92	0.01	0.06
26.00 0.382	,12466.67	0.02	0.05
27.00 0.440	8047.39	0.03	0.04
28.00 0.521	4686,59	0.01	0.02
29.00 0.638	■2736.40	0.01	0.02
30.00 0.822	2000.00	0.01	0.01
Total	2980090.00	0.91	1.93

Table 5.15 VPA output for S. *intermedius (a = .0001; b = 3.1483)*

CM (YEARS)	MEAN N	CATCH (tonnes)	STEADY-STATE BIOMASS
6.00 0.052	250623.25	0.03	0.01
7.00 0.054	213299.09	0.00	0.01
8.00 0.057	204149.94	1.00	0.01
9.00 0.060	134935.30	0.18	0.01
10.00 0.063	82183.05	0.01	0.01
11.00 0.066	74948.96	0.01	0.01
12.00 0.069	63753.59	0.04	0.02
13.00 0.074	51819.79	0.03	0.02
14.00 0.078	43519.73	0.02	0.02
15.00 0.083	37502.80	0.02	0.02
16.00 0.089	32029.60	0.02	0.02
17.00 0.096	26943.12	0.02	0.02
18.00 0.104	23280.31	0.01	0.02
19.00 0.114	20530.89	0.01	0.02
20.00 0.125	17839.13	0.01	0.02
21.00 0.139	15472.60	0.00	0.02
22.00 0.156	12742.23	0.02	0.02
23.00 0.179	.9795.55	0.01	0.02
24.00 0.209	7764.83	0.00	0.02
25.00 0.251	6277.52.	0.00	0.02
26.00 0.314	4486.14'.	0.01	0.01
27.00 0.421	4285.71	0.01	0.01
Total	**1338183.00**	**0.47**	**0.37**

For *H. membranaceus* (Fig.5.30), changes in *F* showed an increase to a maximum of 1.2 yr^{-1} at 23cm which was followed by a decline, and fluctuated around 2.0 at 30 to 37 standard length around 2.0. The average *F* for fully recruited fishes (L > = 13.0) was 0.514 yr^{-1} which was lower than the 1.93 yr^{-1} estimate from catch curve analysis (Table 5.9). The average number recruited to the fishing ground which account for the catches was estimated to be about 2.75 x 10^6 (See survivors at 13.0 cm length in Fig.5.30). The estimated steady-state biomass and average total annual catch for *H. membranaceus* in stratum VII were respectively computed to be around 3.60 and 7.18 tonnes (Table 5.11).

For *C. auratus* (Fig.5.31), *F* values sharply declined from about 1.5yf^{1} to 0.0 at 4.0 cm to 6.0 cm. It then increased to 0.6 yr^{-1} at 11.0 cm length . The average number of recruits into the fishery was about 1.51 x 10^7 (See survivors at 4.0cm length in Figure 5.31).. The estimated steady-state biomass and average total annual catch for *C. auratus* in stratum VII were computed as 1.44 and 3.34 tonnes respectively (Table 5.12). *F* remained relatively stable at this value up to about 20.0cm . The average *F* for fully recruited lengths (L > = 4.0cm) was 1.20 yr^{-1} which is lower than the 1.33 yr '* estimate (Table 5.9) from catch curve analysis.

For C. *nigrodigitatus* (Fig.5.32), *F* values increased with increasing length to 18cm and from there onwards it became unstable. The average *F* for fully recruited fish

(L > = 6.0cm) was 1.22 yr'1 (Fig.5.32) which is lower than the 2.53 yr'! estimate (Table 5.9) from catch curve analysis. The steady-state biomass and annual catch were computed as 0.23 and 0.50 tonnes respectively (Table 5.13). It seems therefore that the bulk of this species might be accounted for by other gears beside the gill nets, notably the bamboo trap which is known to account for more than 90% of the catches.

For *O. niloticus* (Fig.5.33), *F* increased to maximum of 1.45yr"' at 14cm length and then showed decline, after which they were more or less fluctuating around l.Oyr'1. The average *F* (F-array), for fully recruited fish (L > = 7.0cm) was 0.28 yr"1 which is lower dian the 0.31 yr "] estimate (Table 5.9) from catch curve analysis. The steady-state biomass and average total annual catch for *O. niloticus* in stratum VII were computed as 1.93 and 0.91 tonnes respectively (Table 5.14).

For *S. intermedius, F* values increased sharply to peak value of 5.6yr-1 at 9.0cm length (Fig. 5.34) suggesting the gill-nets highly selects this sizes of *Schilbe. F* then declined gradually to minimum value of about O.lyr"1 around 24cm length (Fig. 5.34). The average F for fully recruited *S. intermedius* (L> = 6.0cm) was 2.60 yr"1 which is lower than the 2.90 yr 1 estimate (Table 5.9) from catch-curve analysis. Its steady-state biomass in stratum VII was computed as 0.37 tonnes (Table 5.15).

From the fore-going, estimates of *F* from VPA presented in this section were lower than estimates of average *F* obtained by the linearied length-converted catch-curve analysis. This is possibly because smaller fishes (< 6.0- 7.0 cm standard length) experiencing higher mortality rates were included in the catch-curve analysis.

5.2.6 Relative yield-per-recruit (Y/R)’ and relative biomass-per-recruit (B/R)’ analysis

Following the length-based Beverton and Holt model (Sparre and Venema, 1992) the input parameters used in the relative yield- per- recruit (Y/R)’ and relative biomass-per-recruit (B/R)’ analysis were the growth and mortality parameters, together with the length-weight relationship established for the species. These required input data which have been estimated are presented in Table 5.16.

Table 5.16 Input parameters for (Y/R)' and (B/R)' analysis for the targeted species

Species	L,, (cm)	K (yr^1)	L_C50 (cm) (present)	L_C5</ Loo	F (yr'1) present	M (yr^1)	a (unsexed)	b (unsexed)
H. membranaceus	44.0	0.55	22.60	0.51	1.93	1.12	0.0005	2.54
C. auratus	31.0	0.60	10.70	0.35	1.33	1.30	0.0001	3.02
C. nigrodigitatus	44.5	0.65	13.80	0.31	2.53	1.24	0.0001	2.76
S. intermedius	30.0	0.80	10.60	0.35	0.31	1.59	0.0004	3.15
0. niloticus	33.5	0.55	11.50	0.34	2.90	0.90	0.0001	2.84

Figures 5.35-5.39 show the relative yield-per-recruit (Y/R)' and relative biomass-per-recruit (B/R)' curves for varying exploitation rate (E) for the five species. The maximum relative yield-per-recruit was obtained at the E_{MSY} (Figures 5.35-5.39) which is the expected optimal exploitation level. At the present estimated exploitation rate ($E_{present}$), relatively low (Y/R)' values were obtained for the major species (Figure 5.35 -5.39). The Epresent was higher than the expected optimal exploitation level (E_{MSY}) for the major species indicating over-exploitation.

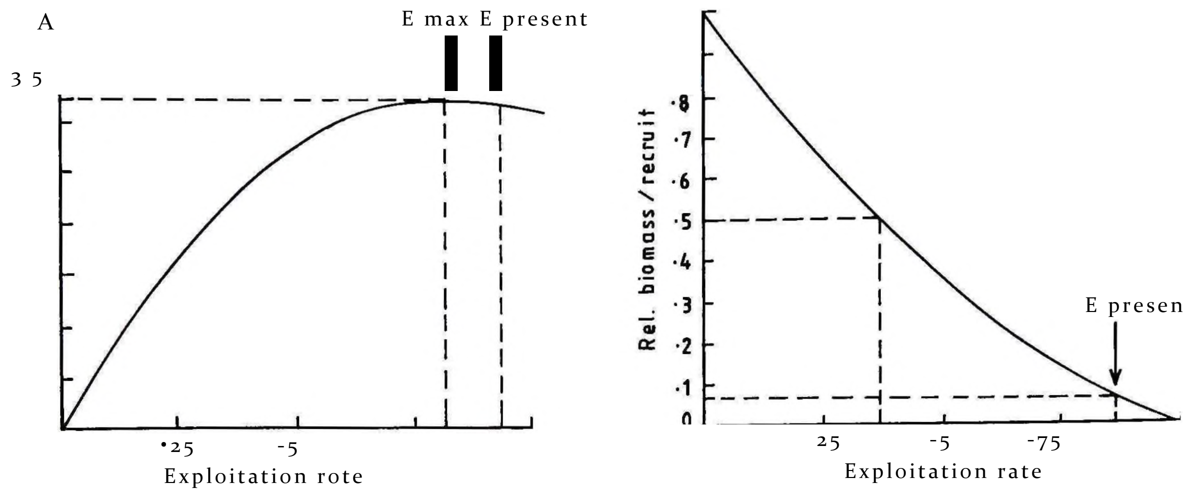


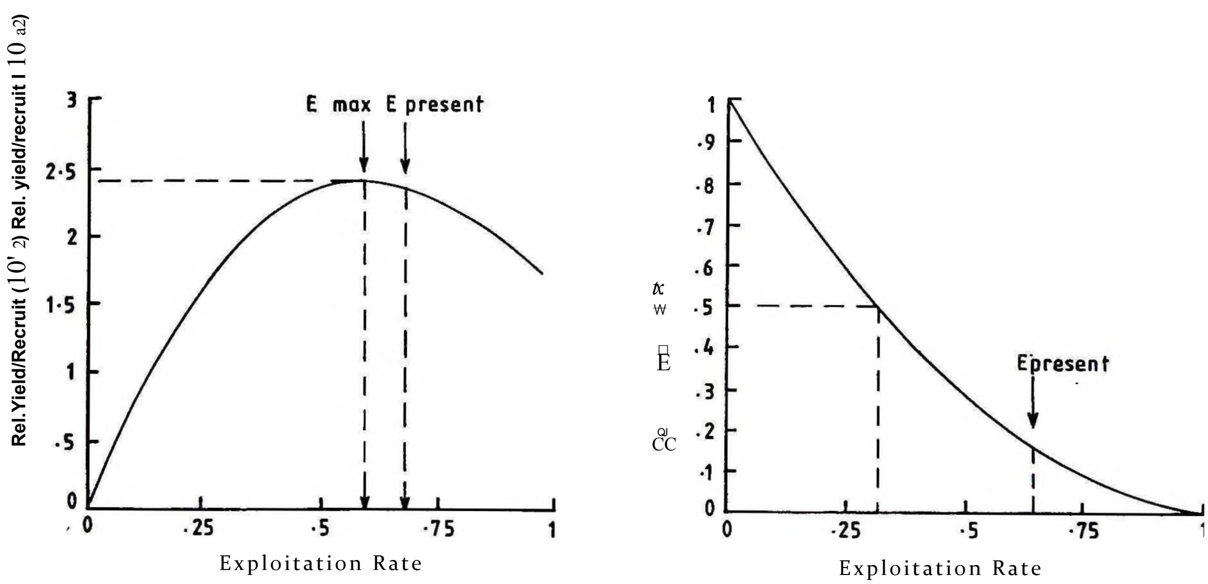
Figure 5.35 Relative yield-per-recruit (Y/R)' and relative biomass-per-recruit (B/R)' curves for ***H. membranaceus*** at varying rates of exploitation (E)

E max : 0 8180

E present : 0-87

Lc/ Loo = 0-51

M/K = 2'04



E max : 0-5940

E present: 0-67

L c /oo 0 3 5

M/K 2-17

Rel. yield / rec rui t

Figure 5.36 Relative yield-per-recruit (Y/R)' and relative biomass-per-recruit (B/R)' curves for *C. auratus* at varying rates of exploitation (E)

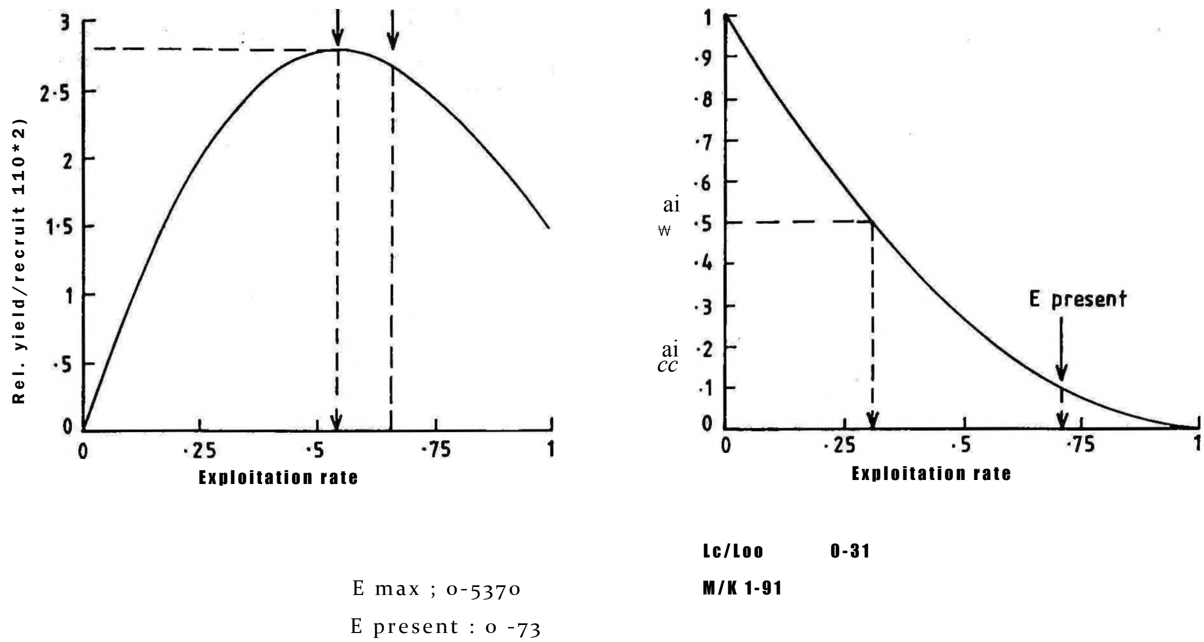


Figure 5.37 Relative yield-per-recruit (Y/R)’ and relative biomass-per -recruit (B/R)’ curves for *C. nigrodigitatus* at varying rates of exploitation (E)

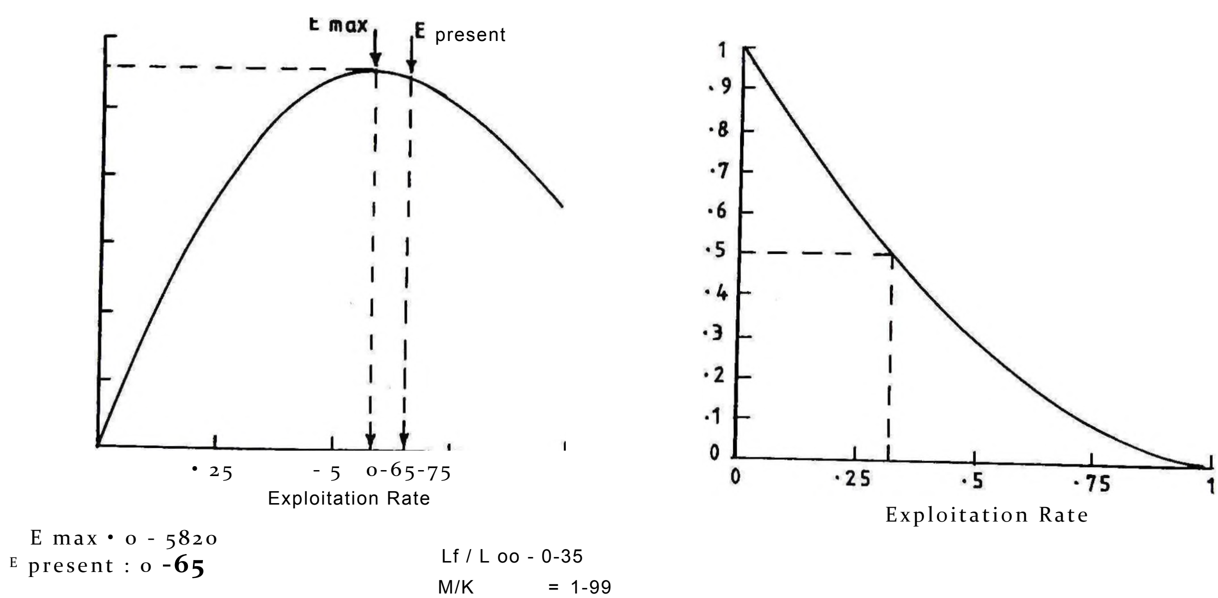
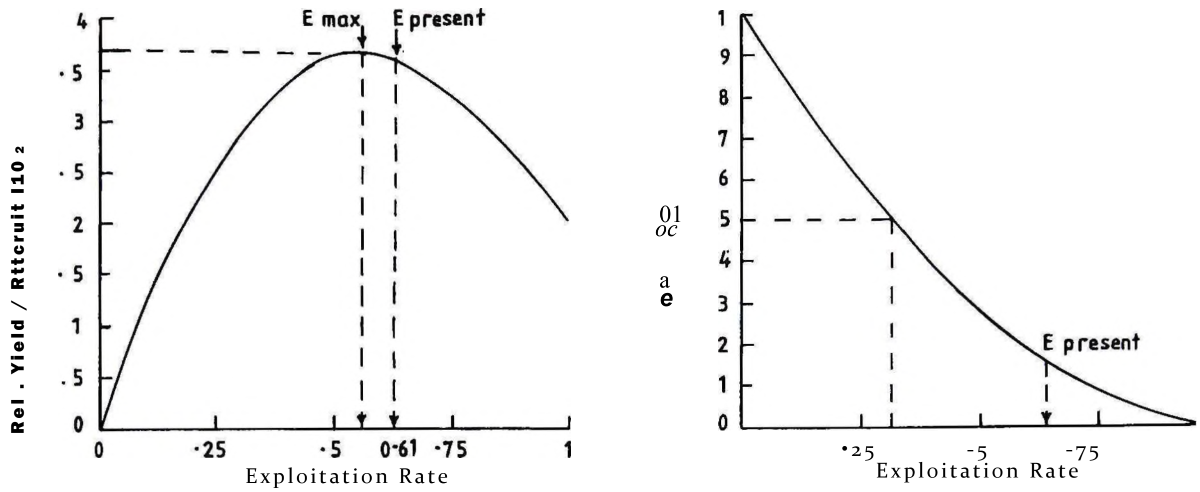


Figure 5.38 Relative yield-per-recruit (Y/R)’ and relative biomass- -recruit (B/R)’ curves for *S. intermedius* at varying rates of exploitation (E)



E max : 0-5540 L c/oo = 0-34

E present: 0-61 M/K = 1-64

Figure 5.39 Relative yield-per-recruit (Y/R)' and relative biomass-per-recruit (B/R)' curves for *O. niloticus* at varying rates of exploitation (E)

Based on Pauly's **(1984)** E_{opt}= **0.5** optimization criterion the present higher range of exploitation rates **(E $_{prese}$nt= 0.61** to **0.8J)** imply over-exploitation of the major species. In addition, relatively very low relative biomass-per-recruit (B/R)' was achieved at (E **present) f°r** the major species (Figures **5.35-39)** indicating that higher biomass-per-recruit would be achieved if the current exploitation level is reduced.

CHAPTER 6: DISCUSSION

The fish populations or fish community in the Volta River before impoundment were studied by Irvine (1947) and Roberts (1967). Both workers were mainly concerned with the taxonomy rather than the quantitative aspects of the fish populations. From their studies a check-list of some 150 fish species were documented for the Volta River before impoundment. The former riverine community was dominated by mormyrids (Petr, 1969). When the Lake finally formed, the increased fish population led to the migration of additional fishermen from below the dam and the formation of numerous villages along the lakeshores. Consequently, the fisheries of the Volta Lake showed an explosive development within the four years after its formation in 1968. Since then, the fisheries in the Volta basin have become the main source of employment for the fisherfolk as well as those dependent on fisheries related activities in the area.

With particular reference to the limnology of the lake, the results indicate that tremendous changes have occurred since its creation in 1964. At the time of its formation, the Volta Lake was described as oligotrophic (Entz, 1969; Ewer, 1966). Studies carried out in the 1970s , early 1980s and early 1990s in the Akosombo gorge area of the lake (Ofori-Danson and Antwi, 1994) also revealed same, i.e. near neutral pH, low solute and high dissolved oxygen (DO) concentrations. However, by comparison with World and African fresh water bodies, the respective concentrations of Ca^{++} and Mg^{++} in the water during 1995/96 were relatively low. From these results, it can be surmised that chemically, the waters in stratum VII of Lake Volta generally have low ionic content. From the results of 1995/96, transparency of the lake has narrowed since its creation; or that visibility with depth (as measured by Secchi disc disappearance) has decreased. The transparency in Lake Volta is influenced by colloidal suspended particles, colloidal ferric iron and phytoplankton (Biswas, 1968; Nauman, 1969; FAO/UNDP, 1971). The inorganic turbidity, caused by these suspended particles of colloidal nature, prevent solar radiation from penetrating all but the surface waters and could thereby, effectively reduce the trophogenic zone. Hence the already low photosynthetic activity and primary production may be restricted to a relatively shallow zone just below the air-water interface. This situation obviously reduces primary production in the lake.

The increase in turbidity could be attributed to the introduction of sediment arising from anthropogenic activities such as farming, industrial and cultural activities; and erosion within the Volta basin which contribute to changes in the physical and chemical conditions of the lake.

The pH levels 7.2 at the surface to 6.7 at the bottom were however, considered suitable for fish growth and productivity because the survival of fish has been reported to range between 5.0 and 9.0 (Jobling, 1995). This is also supported by the current oxygen condition in the lake at stratum VII which was found to be satisfactory all year round and sufficient enough to support fish life right to the bottom.

OECD (1970) reported that the limit of nitrate, nitrite and phosphate values for oligotrophic lakes were 1.0, 0.05, and 1.0 mg I'1 respectively. On this basis, Lake Volta, as in its early life, may still be said to be oligotrophic as the values ranged between

0.51-0.82 mg L'1 for nitrates, 0.02-0.05 mg I"1 for nitrites and 0.34 -0.41 mg 1'^ for. phosphates.

During the formative years of the lake, over 100 fish species were identified for the whole of Lake Volta (Roberts, 1967; Vanderpuye, 1991). Of these, *Tilapia* alone accounted for 50% of the catch. Other important elements comprised *Labeo* and *Synodontis*. The present studies show that at least 60% of the total number of species encountered in the lake before impoundment are still present in stratum VII of the lake. Unlike the early year of the lake, the tilapias notably *Oreochromis niloticus* and *Sarotherodon galilaeus* were together found to represent only 7% of the gillnet catches. Thus, the predominance of cichlids no longer holds for the gill-net fishery. Currently, the species composition is predominated by *Chrysichthys* spp., *Labeo* spp., mochokids and schilbeids in this order of importance. However, survey at Yeji fish market clearly shows that the cichlids form a major fish product. It could be that they might not be on the main fishing ground of either the gill-net or winch-net which normally operate in the main channel of the lake in the offshore water. This implies that these species may spend most of their time in the littoral floating/submergent vegetation. This is supported by the fact that tilapias constitute the bulk (> 80%) of the catches of *nifa-nifa* gear which operates in this littoral vegetated areas.

The most obvious difference in species representation compared to that of 1960s was the representation of the Nile perch, *Lates niloticus* which proved to be one of the most important species in the lake ten years after impoundment (FAO,1979) but had relatively poor representation in the gill-net landings during 1995-96 . It is apparent that the fishery of *Lates niloticus* has drastically declined in catches during the past thirty years and its fishery needs immediate management attention.

A variety of mormyrids such as *Mormyrus rume* (Valenciennes, 1846); *Mormyrus hasselquistii* (Cuvier & Valenciennes, 1846); *Mormyrus macropthalmus* (Gunther, 1856); *Mormyrus anguloides* (Leach, 1818) were encoutered. This indicates current improvement in the importance of mormyrids in the lake because the proportion of mormyrids in catches from the lake was negligibly small during the first sixteen months of its creation (Petr, 1966).

The forage-camivore ratio (F/C) was estimated as 14.09 and was found to be outside the range of 1.4-10.0 observed for balanced populations (Blay, 1985). This indicated unsuitable ecological balance between the piscivores and their prey populations implying ecological “imbalance” among fish populations in the lake. It is possible that if this situation persists for long, low predation by existing carnivorous fishes could be expected which could lead to over-crowding by forage fish. Such a situation could promote stunting in some of the fish stocks.

Pre-impoundment estimate of fish catch from the Volta River was 3,000 tonnes (Bazigos, 1970a). The present estimated annual catch of about 25,000 tonnes for stratum VII alone suggest possibly higher annual catch than the optimum catch of 40,000 metric tonnes for the whole lake as suggested for the late sixties (Vanderpuye, 1984). This needs verification from catch assessment surveys in all the eight sub-strata of the lake.

The MEI model predicted the potential fish yield as 15.55 kg ha "* yr'1 compared to the estimate of 32.77 kg ha'1 yr'1 by Henderson and Welcomme in 1974. The currently lower estimate is not very clear but could be attributed to the changes in the limnological factors of the lake. If the area of Lake Volta is taken as 4,840 km^2 (Anon, 1974) or 484,000 hectares, then total potential yield per year may be estimated as 15.55 kg ha'1 yr'1 x 484,000 = 7,526,200 tonnes. This is far lower than the annual catch estimate of about 25,000 tonnes for stratum VII. This difference could be explained by the possibility that some of the criteria for the application of MEI (e.g. reasonably constant proportionality of ions, a flushing regime roughly proportional to the lake volume, and moderately intensive fishing effort on most abundant species over a period of years) as a tool for predicting fish yield might not have been satisfied because these are by no means easy to find for the lake. It is needless to say therefore, that predictions using the MEI as fish yield estimator needs caution as suggested by Vanderpuye (1984). For instance, only 2 out of the 7 empirical annual yields fell within the predicted interval from catch statistics in 1970 to 1976 (Vanderpuye, 1984).

The mean CPUEs as defined by the studies in 1995 and 1996 were 14.28 ± 4.02 and

11.33 ± 3.45 kg canoe ‘‘d’^{1} respectively. The declining mean CPUE values indicate decreasing stock size of the major fish stocks. This may largely be attributed to too many fishermen chasing few fish. For instance, a number of frame surveys conducted in stratum VH (Agyenim-Boateng, 1989; Maembe, 1990, 1992) indicated that the number of fishermen operating in the area increased by at least 300% since the mid 1970s.

In the midst of the increasing fishing effort, two major results found in the life history of of the major fish species which could sustain the fisheries are reproduction and recruitment. For instance, fluctuations in the gonadosomatic index (GSI) indicate continuous spawning behaviour by of the major stocks with one or two peak spawning periods. With regard to recruitment, the study showed that there was generally high recruitment success annually.

The major species are generally short-lived because their longevity (t,,, — 3/K) were between 4 and 6 years. This is expected because tropical fish are known to be fast growing and short-lived (Lowe-McConnell, 1987). An increase in growth rate accompanied by a decrease in size appeares to be the way by which the major species have adapted to withstand the increasing fishing pressure in the lake. Rapid growth and early recruitment of individuals to the spawning stock ensures an increase in reproductive rate which facilitate restoration of population size at mean equilibrium level.

Like almost all the stock assessment models used in the population dynamics studies (Sparre and Venema, 1992; Hilbom and Walters, 1992), it was assumed that the fishery was in equilibrium. This means that all the important demographic parameters are not influenced by the fishery, they are constant. There is therefore a tendency to assume that nature, without human interference, is static and ordered. Yet, it is a known phenomenon that populations of animals are not static. They can and do fluctuate very considerably even in absence of exploitation. Thus, it is noteworthy that the estimated growth and mortality parameters are subject to change in time and space.

lies (1970) reported that lake tilapias having normal growth are usually known to attain L _ of approximately 35 cm and an average L_m *!h*~ ratio of 0.70, which are higher than those estimated for *O. niloticus*. Thus, it could be possible that some stunting is occuring in the population of this tilapia stock in Lake Volta and needs to be verified in future studies.

Based on the Beverton and Holt (1966) relative yield-per-recruit (Y/R)' analysis, the current levels of exploitation ($E_{present}$) for the major species are higher than the maximum expected levels of exploitation (E_{max}) suggesting that most of the stocks are being over-fished and inappropriate to the life history strategy of the species. The fish were normally caught before one year old and have less chance of growing into large sizes to substantially contribute to the stock biomass; this is indicative of growth-overfishing. This result is in contrast with findings from the Fish Stock Assessment program which was carried out from 1969 till 1977 by the Volta Lake Research and Development Project (VLRDP) which reported at that period in the life of the lake that there was no sign of over-fishing of the stocks and that increased fishing effort could be encouraged. It is apparent from the present results that this situation may no longer be recommended for the fishery and that the monitoring, control, surveillance and enforcement as enshrined in the Fisheries Law (1991) need to be applied to Lake Volta.

In order to ensure rational exploitation of fish stocks in Lake Volta, some recommendations have been provided in the next chapter.

CHAPTER 7: RECOMMENDATIONS

Ghana ratified the United Nations Convention Law of the Sea (UNCLOS) in 1983 (Lauziere, 1997). Since then, major elements of the fisheries' management strategy are yet to be implemented in Ghanaian waters. The resultant open access to the fisheries of Ghana has led to increased fishing pressure on the both marine and inland fish stocks. In order to sustainably exploit the fisheries, the following measures are recommended to help operationalise fisheries policy and management plan for Lake Volta.

7.1 ENFORCEMENT OF MESH SIZE REGULATIONS

The first and most obvious feature of the stocks in Lake Volta is the multitude of species occurring on the fishing grounds. In this study, for example, at least 66 fish species were encountered. Most of the component species are small-sized (not greater than 30 cm standard length). The predominance of small-sized fishes on the fishing grounds forces the fishermen to use very fine-meshed gear so as to catch both the large valuable fishes as well as the less valuable small fishes which contribute to the value of the catch by sheer bulk.

According to this study, the minimum L_m /SF ratio (i.e. estimated mesh size to ensure 50% retention) for the major species is 6.52 cm (or 2.57 inches). It is therefore necessary to increase the mesh size of gill-nets to at least 6.5cm (about 2.5 inches) in order to allow escapes of fish at first maturity to sustain the fishery through spawning. In this regard, there is an urgent need to vigorously enforce existing mesh size regulations as enshrined in the Fisheries Law (1991), to avoid the inshore habitats of juveniles, and discard live juveniles in the catch.

7.2 CONTROL OVER CHANGING FISHERY TECHNOLOGY

Technological change in the fishery with increased competitiveness within the community impose threat to successful management strategies. For instance, the emerging popularity of bamboo pipe fishing is currently enabling the exploitation of the deeper inshore waters, tree stumps or no tree stumps. The technique has been developed for harvesting fish in the bottom of the water. Furthermore, the bamboo pipe **fishing** is species specific and largely targets gravid *Chrysichthys* spp. This type of **fishing** is now highly commercialized and the gains reaped by fishers seem to attract other fishers not already engaged in it. If this trend continues, more gravid fish will be harvested as the practice spreads throughout the lake. This could affect recruitment and so it is recommended that bamboo pipe fishing should be prohibited from Lake Volta.

There is also the problem of beach seining in Lake Volta. Water banks are cleared of vegetation for beach seining, thereby removing vegetation cover for inshore spawners. The beach seines catch all categories and species at less than their juvenile stages. The Acadja (atidja) is another fishing'~Jrractice that may provoke several problems for environment (deforestation, pollution) and social inequity between fishers (territorial rights). It is also recommended that the beach-seine should be banned from Lake Volta.

7.3 LIMITATION OF ENTRY INTO THE FISHERY

The forces of poverty, population growth, migration and urbanization have profound effect on increasing trend in fishing effort. In particular, the general exploding population growth in the country fueled by high fertility place increasing pressure on the fisheries resources. The increased population pressure lead to further deterioration of the resource. Also improved marketing facilities incite fishermen to expand (instead of limiting) production.

In view of the need to reduce fishing effort and to allow recovery of declining stocks, fishers and canoes should be licensed to avoid the unlimited access into the fishery.

7.4 ESTABLISHMENT OF "LAKE RESERVES" THROUGH CLOSURE OF FISHING IN SELECTED AREAS

Probably the more practical means to arrest over-exploitation of large species and contribute to the protection of the fishery as a whole would be the periodic prohibition of fishing from certain areas. This might be achieved through the establishment of "lake reservoirs" and monitoring of their effects as a management strategy. The areas to be delineated as "lake reserves" should be based on sound research and fishermen collaboration.

7.5 TOWARDS COMMON PROPERY RIGHTS-BASED MANAGEMENT SYTEM

The problems facing the fisheries of Lake Volta manifest themselves as biological over-exploitation and economic over-capitalisation. There are simply too many canoes to catch the yield available. That which is owned by no one is no one's responsibility to maintain. Thus, the current model or system of fisheries management where access and other development measures are regulated by the state has now become disastrously inadequate. There is therefore the need to devolve fisheries management to the local level to compel fishers to take greater responsibility for the sustainability and conservation of the fisheries resource as is reflected in common property rights-based management. Common propery regimes are forms of resource management grounded in a set of individuall accepted rights and rules for the sustainable and interdependent use of collective goods. In this regard, Studies that will elucidate the possibilities for adopting aspects of rights-based management system should be commissioned for Lake Volta.

7.6 INDUCED SOCIAL CHANGE

There is the serious problem of poverty and illiteracy in the fishing community which need to be addressed. Furthermore, some local chiefs who are not really fishers charge exorbitant fees from migrant fishers many of whom have migrated from coastal areas. There is the need to resolve this system so as to avoid conflicts between migrant fishers and traditional authorities. This will make the fishers feel more at home in the Volta basin to facilitate their operations.

7.7 ENVIRONMENTAL PROTECTION AND LEGISLATION BY LOCAL ASSEMBLIES

The use of poisonous chemicals, explosives and herbs for fishing are often practiced by some fishermen on Lake Volta. These chemicals and herbs as well as explosives kill not only adult fish targeted but also non-targeted juveniles and other living organisms including plankton. The ecosystem is thereby damaged. Education of fishers and community participation in controlling the use of these methods by the Fisheries Administration (e.g. Department of Fisheries) need to be rigorously pursued.

It is recommended that a programme for planting of suitable trees (with advice from the Department of Forestry) should more vigorously be put in place as has been started in the Akosombo Gorge and the Yeji area under the FAO/IDAF Project. This has been demonstrated in the Akosombo Gorge area with support from the VRA.

7.8 IMPROVEMENT IN COLLECTION OF FISHERY STATISTICS

In order to update and review information on the fisheries there is need to expand existing fishery statistics database so as to provide grounds for an adequate stock assessment for the whole of the lake.

The complex and interacting activities in the lake basin could be better understood and evaluated with the use of Geographical Information System (GIS) possibly by liaising with the Remote Sensing Applications Unit, Department of Geography, University of Ghana. Such a tool should enhance the effective formulation and implementation of integrated management plan in the lake area.

CHAPTER 8: CONCLUSIONS

During the formative years of Lake Volta, numerous lines of work were carried out which provided considerable amount of information on the fisheries of major commercially important fish species. Most of these studies benefited from the support of the Volta Lake Research and Development Project (VLR&DP), initially through UNDP/FAO assistance which formally came to a halt in 1979. Since then, no systematic studies have been undertaken for the whole of Lake Volta.

Currently, the productivity and catch-per-unit of effort of canoes utilizing gill-nets in the lake at Yeji area has declined due to increased fishing effort as measured by the number of canoes or fishermen. The total annual mean catch is estimated as 25,000 metric tonnes. In order to improve productivity, there is an urgent need to adopt measures to restrict unlimited entry into fishing.

The limnological conditions of the lake have remained unchanged as the lake is still oligrotrophic as reported by scientists in its early life. The water is therefore suitable for fish life. The dominant species in gill-net catches by weight are *Chrysichthys auratus* and *Chrysichthys nigrodigitatus* which indicate a shift from earlier dominance by the cichlid, *Oreochromis niloticus* and the nile perch *Lates niloticus*. There has also been development of a strong fish population of forage feeding habit suggesting unsuitable ecological balance between piscivores and their prey populations.

For *Ot-eocftromis niloticus,* there is a clear decline in size (or age) at first maturity. It is anticipated that stunting could occur in the population of this tilapia stock if this trend is not reversed or halted.

The length at first capture (L_{C50}) occurs at ages lower than one year for the major species It can be concluded that that there is growth over-fishing of the fisheries.

The study shows that a length-based stock-assessment programme can be applied in Lake Volta, and can provide the needed information on the status of the stocks within a relatively short period compared to the comprehensive long-time series of catch and effort data (currently lacking for Lake Volta) needed for the Surplus Production Models.

The length frequency analyses show that the major fisheries operate on at least three pseudo-cohorts with longevity between 4 and 6 years which indicate fast growth. It can be concluded that fast growth rate accompanied by the decreasing sizes could be adaptation for survival by most species in the midst of the increasing fishing effort.

The current exploitation rate for the major species in the Yeji area is far beyond the expected level for harvesting maximum yield. It can be concluded that the major fisheries in the Yeji sector of the lake is being over-exploited, and controls have to be applied on expansion of the fishing activities.

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Appendix I. Major characteristics of the sampled landing sites in stratum VII of Lake Volta.

Name	Sub-stratum	No of canoes	Village Class
Gbevukpo	Northern	82	Large
Blackiekope	Northern	20	Medium
Kejawu	Northern	120	Large
Fanti Town	Central	13	Medium
Jaklai	Central	37	Medium
Salt Town	Central	10	Small
Site Area	Central	16	Medium
Abodwese Akura	Southern	34	Medium
PedjaiNo 1	Southern	9	Small
Avorkope	Southern	120	Large

Appendix It: Species composition (by numbers) of glll-nets meshed 12.7 to 165.1mm In startum VII of Lake Volta during 1995 and 1996.

Month	J.autratu	;.nlgrodigitu	-L membranaceus	S.schall	S.occellfer	S.lntermedlus	B.bajad	H.forskalll	M.rume	C.cltharus	D.rostratus	A.baremoze	A.occldentalls	L.couble	O.nlloticu	B.nurse	O.mento	Others
4/95	113	8	0	3	42	100	4	0	0	0	0	1	0	2	0	4	0	3
5/95	709	45	2192	49	18	142	37	25	4	0	5	9	0	93	131	118	69	1
6/95																		
7/95	178	207	1633	88	45	265	16	89	4	6	16	34	7	28	92	5	167	0
8/95	79	56	267	244	23	929	1	4	14	1	57	48	1	87	70	0	0	0
9/95	140	67	321	96	48	231	83	10	20	0	8	83	1	138	9	0	23	8
10/95	249	79	359	172	34	1078	55	39	14	3	19	26	3	75	74	131	0	1
11/95	220	45	229	53	78	552	51	11	2	1	6	18	0	86	46	26	0	15
12/95	382	148	822	92	45	475	42	18	16	1	13	22	4	238	14	297	0	0
1/96	112	120	323	81	61	77	19	17	7	8	52	444	1	421	80	35	0	2
2/96	922	2462	317	178	3532	228	139	70	23	8	625	511	11	966	389	1100	0	2
3/96	527	176	32122	150	7685	231	139	25	3	4	159	247	1	542	15	161	3	1
4/96	982	606	246	240	95	339	54	56	32	7	164	415	16	536	296	231	0	0
5/96	2296	1480	614	441	3334	340	93	29	22	61	96	765	33	495	150	0	0	8
6/96	934	592	73	713	186	3492	230	24	22	3	122	71	18	459	1171	0	0	3
7/96	239	399	278	278	156	801	51	19	31	3	110	107	5	173	35	0	374	6
8/96	895	322	3677	489	132	1013	69	22	48	11	175	34	4	182	445	20	44	4
9/96	186	144	319	291	157	777	25	21	23	5	154	7	1	336	26	0	4	1
10/96	692	446	196	244	9475	3872	59	63	10	8	326	152	7	234	322	7	9	1
11/96	535	275	171	121	47	204	57	47	2	26	80	32	2	122	78	8	0	5
12/96	968	417	320	239	128	370	133	78	27	69	72	72	37	669	272	1137	0	I 3

Appendix III. Species composition (by weight in kgs) of gill-nets meshed 12.7 to 165.1mm in stratum VII of Lake Volta during 1995 and 1996

Month	S.galilaeus	C.autratus	C.nigrodigitatus	H.membranaceus	S.schali	S.oceilifer	S.intermedius	B.balad	H.forskalii	M.rume	C.citharus	D.rostratus	A.baremoze	A.occidentaiis	L.couble	O. niloticus	B. nurse	O.mento
4/95		14.01	2.1	0	0.03	38.4	33.05	47.55	14.4	3.3	4	19.31	20.8	1	83.35	2.3	13.85	0
5/95	0	60.4	6.65	365.49	9.3	8.09	29.57	17.74	21	10.52	4.3	17.76	48.1	3.3	99.39	46.5	23.5	0
6/95	_	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
7/95	3.4	38.33	39.02"	267.27	25.45	12.3	53.47	43.8	7.05	10.9	3	17.5	24.25	7.3	149.6	254.35	0	0
8/95	10.35	8.3	13.3	59.55	28.9	19.75	47.5	28.8	41	39.13	11.25	21.65	28.15	6.2	49.8	8.75	0	7.6
9/95	2	2.5	10.6	13.7	15.3	14.15	43.33	32.21	20.01	24.35	11.39	36.94	8.65	0	109.34	0	0	0
10/95	19.87	30.62	11.95	76.15	21.22	4.85	1.9	9.85	5.25	1.5	0.26	3.85	4.6	0	47.99	4.75	0	0
11/95	19.3	13.25	11	93.9	6.1	6.29	26.86	15.04	21.72	18.9	2.6	21.2	26.7	9.1	100.27	69.55	0.5	0.25
12/95	16.9	28.65	18.8	17.32	5.84	4.02	12.01	16.3	11.35	0.55	5.01	14.85	6.1	0.9	38.36	1446	0.6	0
1/96	16.37	13.9	11.35	84.1	6.55	0	0	1.75	0	2.3	0	0	0	0	6	0	0	0
2/96	26.75	57.9	34.61	72.1	11.03	10.37	32.68	41.5	25.54	19.6	12.21	50.81	6.1	4.6	77.97	44.25	41.51	0
3/96	2.9	37.5	27.95	820.32	21.65	19.05	21.1	38.58	16.35	10.5	2.2	36.55	50	1.3	96.05	53.85	62.38	0
4/96	31.36	122.23	99.6	58.92	23.71	1.06	1.45	0.45	0	0	0	0	0.01	0	0.04	0	4.45	0.7
5/96	3.3	189.73	159.92	223.97	39.96	0.8	7.1	7.1	3.2	1.4	0	0.91	3.3	3.3	37.45	32.92	0	1.16
6/96	143.7	107.95	75.37	30.05	69.9	10.49	30.88	51.05	13.3	18.75	56.8	19.4	100	14.5	95.45	35.7	0	0
7/96	1.52	30.59	57.83	185.75	37.4	4.8	20.8	6.5	38.4	0.8	18.5	15.6	27.3	4.1	47.25	32.55	0.31	2.71
8/96	39.4	65.21	83.97	174.65	59.97	2.45	66.4	0.2	2.5	18.35	1.4	13.6	5.65	0.95	37.95	15.56	0	0
9/96	3.4	20.2	20.6	227.15	78.13	4.65	103.55	0.6	4.5	9.7	0	8.5	6.45	5.45	108.71	0.3	2.6	0.47
10/96	16.02	30.25	21.9	110.77	39.1	4.85	56.75	13.1	13.9	15.55	3.8	4.07	6.6	1.6	47.99	15.62	9.15	0
11/96	6.82	32.8	23.9	81.81	9.8	3.7	43.85	9.45	3.7	5.6	1.4	0.7	4.2	0	16.25	6.5	1.8	0.8
12/96	51.6	69.73	38.39	97.51	25.84	2.72	15.22	3.6	4.75	0.5	0.25	1.95	0.8	2.3	38.36	11.25	14	

Appendix HI: (cont'd)

Month	S.galilaeus	C.autratus	C.nigrodigitatus	H. membranaceus	S.schall	S.ocellifer	S. intermedius	B.balad	H.forskalii	M.rume	C.citharus	D.rostratus	A.baremoze	A.occidentalis	L.couble	O. niloticus	B.nurse	O.mento
4/95		14.01	2.1	0	0.03	38.4	33.05	47.55	14.4	3.3	4	19.31	20.8	j I	83.35	2.3	13.85	0
5/95	0	60.4	6.65	365.49	9.3	8.09	29.57	17.74	21	10.52	4.3	17.76	48.1	3.3	99.39	46.5	23.5	0
6/95	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
7/95	3.4	38.33	39.02	267,27	25.45	12.3	53.47	43.8	7.05	10.9	3	17.5	24.25	7.3	149.6	254.35	0	0
8/95	10.35	8.3	13.3	59.55	28.9	19.75	47.5	28.8	41	39.13	11.25	21.65	28.15	6.2	49.8	8.75	0	7.6
9/95	2	2.5	10.6	13.7	15.3	14.15	43.33	32.21	20.01	24.35	11.39	36.94	8.65	0	109.34	0	0	0
10/95	19.87	30.62	11.95	76.15	21.22	4.85	1.9	9.85	5.25	1.5	0.26	3.85	4.6	0	47.99	4.75	0	0
11/95	19.3	13.25	11	93.9	6.1	6.29	26.86	15.04	21.72	18.9	2.6	21.2	26.7	9.1	100.27	69.55	0.5	0.25
12/95	16.9	28.65	18.8	17.32	5.84	4.02	12.01	16.3	11.35	0.55	5.01	14.85	6.1	0.9	38.36	1446	0.6	0
1/96	16.37	13.9	11.35	84.1	6.55	0	0	1.75	0	2.3	0	0	0	0	6	0	0	0
2/96	26.75	57.9	34.61	72.1	11.03	10.37	32.68	41.5	25.54	19.6	12.21	50.81	6.1	4.6	77.97	44.25	41.51	0
3/96	2.9	37.5	27.95	820.32	21.65	19.05	21.1	38.58	16.35	10.5	2.2	36.55	50	1.3	96.05	53.85	62.38	0
4/96	31.36	122.23	99.6	58.92	23.71	1.06	1.45	0.45	0	0	0	0	0.01	0	0.04	0	4.45	0.7
5/96	3.3	189.73	159.92	223.97	39.96	0.8	7.1	7.1	3.2	1.4	0	0.91	3.3	3.3	37.45	32.92	0	1.16
6/96	143.7	107.95	75.37	30.05	69.9	10.49	30.88	51.05	13.3	18.75	56.8	19.4	100	14.5	95.45	35.7	0	0
7/96	1.52	30.59	57.83	185.75	37.4	4.8	20.8	6.5	38.4	0.8	18.5	15.6	27.3	4.1	47.25	32.55	0.31	2.71
8/96	39.4	65.21	83.97	174.65	59.97	2.45	66.4	0.2	2.5	18.35	1.4	13.6	5.65	0.95	37.95	15.56	0	0
9/96	3.4	20.2	20.6	227.15	78.13	4.65	103.55	0.6	4.5	9.7	0	8.5	6.45	5.45	108.71	0.3	2.6	0.47
10/96	16.02	30.25	21.9	110.77	39.1	4.85	56.75	13.1	13.9	15.55	3.8	4.07	6.6	1.6	47.99	15.62	9.15	0
11/96	6.82	32.8	23.9	81.81	9.8	3.7	43.85	9.45	3.7	5.6	1.4	0.7	4.2	0	16.25	6.5	1.8	0.8
12/96	51.6	69.73	38.39	97.51	25.84	2.72	15.22	3.6	4.75	0.5	0.25	1.95	0.8	2.3	38.36	11.25	14	

Appendix IV: Monthly length frequency distributions for *H. membranaceus* caught by winch-nets in Stratum VII during 1995/9(5

Mid-length (cm)	Apr-95	May-95	Jun-95	Jul-95	Aug-95	Sep-95	Oct-95	Nov-95	Dec-95	Jan-96	Feb-96	Mar-96	Apr-96	May-96	Jun-96	Jul-96	Aug-96	Sep-96	Oct-96	Nov-96	Dec-96
9	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	2	7	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0
11	9	27	2	4	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
12	67	522	14	6	0	0	0	15	0	0	0	1	1	1	0	0	0	0	0	0	0
13	232	124	106	20	4	0	0	13	0	2	1	6	0	1	0	0	0	0	0	0	0
14	256	278	137	100	5	1	0	3	0	8	1	23	0	2	0	0	0	0	0	0	0
15	85	306	100	286	13	7	1	1	7	13	6	163	6	1	0	0	0	0	0	0	0
*6	11	238	19	81	14	16	0	0	12	8	14	554	15	18	0	0	0	0	0	0	0
17	2	49	5	18	19	37	1	0	10	3	0	712	25	58	0	0	0	0	0	0	0
18	0	10	1	4	13	34	9	5	4	4	2	387	9	114	1	0	0	3	0	0	0
19	0	0	0	1	10	433	38	10	0	U	0	37	1	95	3	0	0	4	0	0	0
20	0	0	0	0	2	32	47	66	0	15	5	16	9	17	1	0	0	7	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
23			0	0	1	9	1	45	9	73	18	58	1	49	4	25	4	26	5	16	
24			0	3	0	6	0	15	37	38	6	26	0	17	2	26	7	28	12	21	
25			0	0	1	2	4	9	40	4	2	6	0	5	3	10	3	16	16	25	
26			0	1	0	2	2	4	4	3	0	1	1	2	0	5	4	23	26	18	
27			0	2	1	1	1	0	0	5	0	0	0	0	0	3	2	10	15	10	
28			0	0	0	1	0	1	1	1	2	0	0	1	0	1	1	7	6	9	
29			0	0	1	2	0	0	0	0	1	0	0	1	1	1	1	4 _	3	2	
30			1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	5	3	2	
31					1	0	0	0	0	0	0	0	0	0	0	1	0	-1	0	2	
32					1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	
33					0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	

Appendix V: Monthly length frequency distributions for *C.nigrodigitatuscaught* by winch-nets in Stratum VII during 1995/96

Mid-length (cm)	Apr-95	Jul-95	Aug-95	Sep-95	Oct-95	Nov-95	Dec-95	Jan-96	Mar-96	Apr-96	May-96	Jul-96	Aug-96	Sep-96	Nov-96	Dec-96
6	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0
9	0	0	1	1	2	3	0	0	0	0	0	0	0	0	0	0
10	0	2	1	3	5	7	0	0	0	0	0	0	0	0	0	0
11	0	0	1	7	3	1	0	0	0	0	0	0	0	0	0	0
12	0	0	0	1	0	5	2	0	0	0	0	0	0	0	0	0
13	0	7	1	4	2	2	2	0	0	0	0	0	0	0	0	0
14	1	6	2	9	0	2	7	0	0	0	0	0	0	0	0	0
15	0	9	4	9	11	8	13	0	0	0	0	0	0	0	0	0
16	3	14	1	6	8	9	14	0	0	0	0	0	0	0	0	0
17	3	13	6	0	8	25	30	0	0	0	0	0	0	0	0	0
18	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	8	0	3	0	5	8	26	0	9	12	1	0	1	5	2
21	1	13	3	1	0	6	2	7	0	13	9	5	1	0	4	1
22	1	2	0	2	0	2	3	6	1	1	10	2	0	1	0	0
23	1	4	1	2	0	0	0	5	1	1	12	0	0	1	1	0
24		1	4	3	0	0	0	1	0	0	8	1	1	1	3	1
25		0	0	2	0	0	0	2	0	0	3	1	0	0	6	0
26		1	1	0	0	0	2	3	0	1	1	0	1	0	3	0
27		0	2	0	0	1	0	2	0	2	2	0	0	0	3	0
28			0	2	0	0	0	1	0	0	3	0	0	0	2	0
29			0	0	0	1	0	0	0	0	1	0	0	0	2	0
30				1					0		1				0	

Appendix VI: Monthly length frequency distributions for *C. auratus* caught by winch-nets in Stratum VII during 1995/96

Mid-length (cm)	Apr-95	May-95	Jul-95	Aug-95	Sep-95	Oct-95	Nov-95	Dec-95	Jan-96	Mar-96	Apr-96	May-96	Jun-96	Jul-96	Aug-96	Sep-96	Oct-96	Nov-96	Dec-96
7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
8	0	6	1	1	1	0	0	0	0	0	0	0	0	2	0	6	0	0	0
9	0	11	0	1	2	0	0	0	0	1	0	1	0	4	1	5	0	0	0
10	0	15	*fi*	0	2	2	0	0	1	0	1	0	0	3	3	14	1	0	0
11	0	14	*2*	6	2	1	1	0	0	0	0	1	2	8	2	10	0	2	0
12	2	8	*2*	3	3	2	5	0	0	0	0	4	0	12	5	12	2	5	0
13	6	2	5	4	8	8	2	0	0	0	0	1	0	2	5	8	0	5	0
14	3	10	2	4	2	0	2	1	2	1	0	2	2	12	4	6	1	7	2
15	9	5	4	5	9	3	4	0	0	0	1	3	0	9	5	3	0	7	1
16	11	7	22	6	1	5	4	8	3	1	4	3	0	13	6	7	1	14	6
17	2	14	16	6	5	2	7	3	3	3	0	12	1	8	1	5	0	6	9
18	0	13	16	2	2	2	6	3	3	2	1	3	0	4	0	3	2	8	2
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0		0	1	1	0	0	0	1	0	0	0	2	0
21		0	5	1	2	0	0	0	0	0	0	1	0	0	0	0	0	1	0
22		2	2	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0
23			0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0
24			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25			0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
26			1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27			1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix VII: Monthly length frequency distributions for *0. niloticus* caught by winch-nets in Stratum VII during 1995

id-Iength (cm	Mar-95	Apr-95	May-95	Jun-95	Jul-95	Aug-95
11	1	6	1	0	0 '	0
12	0	23	1	0	2	2
13	3	79	3	0	0	0
14	3	147	8	1	0	2
15	5	54	21	1	2	0
16	7	23	8	1	0	1
17	8	10	5	2	1	4
18	11	4	4	0	4	3
19	23	1	0	0	3	2
20	9	1	0	0	2	3 1
21	10	5	0	0	2	1
22	5	1	0	0	0	0
23	0	0	0	0	0	0

Appendix VDI: Monthly length frequency distributions for *S. intermedius* caught by winch-nets in Stratum VII during 1995/96

Mid-length (cm)	Apr-95	Jul-95	Aug-95	Sep-95	Oct-95	Nov-95	Dec-95	Jan-96	Feb-96	Mar-96	Apr-96	May-96	Jun-96	Jul-96	Aug-96	Sep-96	Oct-96	Nov-96	Dec-96
5	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	5	0	7	8	0	0	0	0	0	0	0	0	0	0
8	0	1	0	0	1	5	0	7	14	5	0	2	0	0	0	0	0	1	I
9	0	3	0	1	0	1	0	6	3	7	0	1	0	1	0	0	0	0	0
10	0	2	0	0	0	1	0	1	1	1	0	1	0	4	0	0	0	1	1
11	0	3	0	1	0	1	1	1	1	2	1	2	0	2	2	0	0	0	0
12	0	6	1	2	1	3	1	1	0	3	0	3	1	4	1	1	0	3	0
13	0	5	3	0	1	7	0	5	1	1	0	5	1	2	2	1	1	4	1
14	0	5	2	0	4	12	1	2	2	2	I	1	I	4	3	1	0	4	2
15	1	11	0	1	9	18	1	1	0	1	0	5	3	5	4	5	0	4	1
16	4	10	1	3	9	48	6	1	2	8	0	5	2	8	3	7	5	6	0
17	2	11	4	3	4	48	3	7	2	9	1	6	2	9	7	10	3	5	0
18	4	12	4	10	3	68	3	7	4	8	0	6	1	16	6	11	1	13	0
19	3	7	3	10	1	72	3	12	3	8	1	3	0	18	1	11	I	11	1
20	2	9	0	1	1	57	4	3	2	9	0	1	1	6	1	5	0	3	0
21	0	6	2	0	1	21	3	4	5	2	0	3	1	4	1	7	1	6	0
22	0	4	4	0	0	8	0	2	0	0	0	0	0	1	0	0	0	1	0
23		6	0	0	0	2	0	4	0	1	0	0	0	1	2	1	0	0	0
24		1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
25				0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
26					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27					0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
28					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0