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TROPHIC RELATIONSHIPS AND SPAWNING HABITS OF POST-IMPOUNDMENT FISH STOCKS OF LAKE VOLTA IN GHANA

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Abstract

The forage-carninvore ratio was used to study trophic relations of commercially important fish fauna in Lake Volta (Yeji sector) between 1995 and 1997. The fish community was dominated by benthic omnivorous claroteids *Chrysichthys nigrodigitatus* and *C. auratus*, as well as aufwuchs/detrital feeders *Labeo* spp. The estimated forage-carnivore ratio (F/C = 14.09) was outside the range of 1.4-10.0 observed for balanced populations, indicating unsuitable ecological balance between the piscivores and their prey populations, and possible ecological "imbalance" in the food web of the lake. For *Oreochromis niloticus*, the ratio of the length-at-first maturiy to the theoretical maximum lengh ($L_m/L_\infty = 0.59$) fell below the value of 0.70 known for normal growth of tilapias indicative of stunting. There was generally high recruitment success attributable to continuous spawning behaviour thoughout the year. The adaptive implications of the results for ensuring all-year round recruitment to the fishery are discussed.

Résumé

OFORI-DANSON, P. K.: *Les rapports trophiques et les habitudes de la ponté des espèces de poisson après l'endiguement du las de volta au Ghana.* La proportion de fourrage-carnivore était utilisée pour étudier les rapports trophiques de la faune de poisson d'importance commerciale dans le lac de Volta (le secteur de Yeji) entre 1995 et 1997. La communauté de poisson était dominée par les claroteids omnivores benthiques *Chrysichthys nigrodigitatus* et *C. auratus* ainsi que les mangeurs d'aufwuchs/detritiques *Labeo* spp. La proportion de fourrage-carnivore estimée (F/C = 14.09) était hors de la variation de 1.4-10.0 observée pour les populations équilibres, indiquant un équilibre écologique impropre entre les piscivores et leurs populations de proie et la possibité de déséquilibre écologique dans la trame alimentaire du lac. Pour *Oreochromis niloticus*, la proportion du longueur-à-première-maturité à la longueur maximum théorique ($L_m/L_\infty = 0.59$) tombait au-dessous de la valeur de 0.70 connue pour la croissance normale des tilapies indicatives d'arrêt dans la croissance. Il y avait dans l'ensemble un succès de recrutement élevé attribuable aux habitudes de ponte continue durant l'année. Les implications adaptives des résultats pour assurer un recrutement à la pêcherie de toute l'année sont discutées.

Introduction

During the formative years of Lake Volta in early 1960s, numerous multi-disciplinary investigations were carried out which provided considerable amount of information on the fisheries of major commercially important fish species. Most of these studies benefited from support of the Volta Lake Research and Development Project (VLR&DP), initially through UNDP/FAO assistance which formally came to a halt in 1979 (FAO/UNDP, 1979). During this early life of the lake, it was 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.

According to Petr (1968), 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.

On the basis of their food habits, Evans & Vanderpuye (1973) placed fish in Lake Volta into four categories namely: aufwuchs-detritus and herbivores, semipelagic omnivores, benthic omnivores, and carnivores, which referred to piscivores. Current analysis of food habits of some commercial fishes including *Alestes baremose, Brycinus nurse, Schilbe intermedius, Schilbe mystus, Bagrus bajad, Clarias anguillaris* and *Labeo coubie* indicated that majority of the fishes depend on authochthonous material, especially larvae of chironomidae (Amakye, 1996).

After three and half decades of impoundment of the Volta river and considering the importance of Lake Volta as an inland fishery resource of Ghana, it would be of both ecological and economic importance to investigate the changes in the different trophic levels, reproductive patterns and adaptations of the fish populations which may have occurred over the years. The primary objective of this study is to contribute to the gap of biological information on the commercially important fish species of Lake Volta for sustainable exploitation and development of management strategies.

Experimental

Study area

The 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°

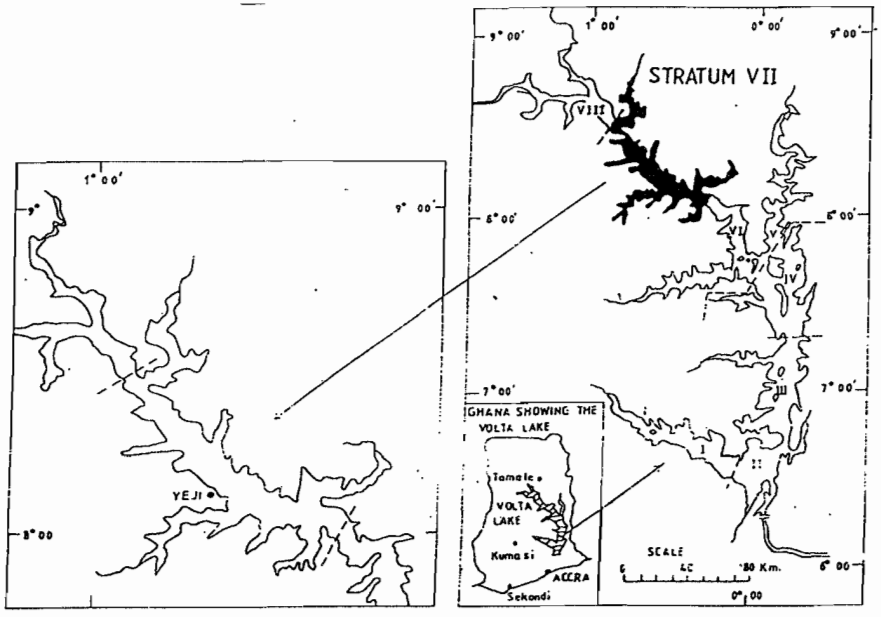

Fig. 1. Map of Lake Volta, Ghana

20' N and extends for about 60 km south and 50 km north of Yeji (Fig. 1). Stratum VII (Yeji sector) 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. Stratum VII is influenced mainly by the Black Volta, White Volta, Daka, Pru and Kalurakun rivers. Thus, by comparison to other sectors of the lake, this area may be regarded as riverine and may be expected to be closest to the community structure of the original Volta river.

Sampling and data source

Monthly sampling for reproductive data on major fish stocks were carried out for 2 years between February 1995 to January 1997. Two-stage stratified sampling approach was adopted for the purpose of sampling the study area. First, the study area was geographically divided into three sub-strata (Fig. 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 were identified, 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 (1971) and Coppola & Agadzi (1976).

Relative abundance

Fish samples from commercial gillnet catches were examined for their species composition using keys provided by Leveque, Paugy & Teugels (1992). The fish were identified to species level whenever possible to enable calculation of the percentage frequency of occurrence of given fish species. The percentage frequency of occurrence for each species was used as input data for the estimation of the relative abundance of the fish species.

TABLE 1
Description of gonad maturity stages (after Bagenal & 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 the 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.

Forage-carnivore (F/C) ratio

On the basis of their food habits 14 major fish species (> 5% frequency of occurrence in gillnet catches) were classified as forage (F) species following the system of categories in Evans & Vanderpuye (1973), which together consisted of aufwuchs-detrital feeders and herbivores, semi-pelagic omnivores and benthic omnivores. A fifth category was classified as carnivorous species (C) which referred to piscivores. The relationship of total weights of forage (F) species to carnivores (C) is defined as the forage-carnivore ratio (Blay, 1985).

Spawning habits

The investigation on the spawning habit focused on five major fish species: *Hemisynodontis membranaceus, Chrysichthys auratus, C. nigrodigitatus, Oreochromis niloticus* and *Schilbe intermedius.* Standard lengths of the fishes were measured to the nearest centimetre. Fish weights were determined to the nearest gramme. Fish sex was determined and gonads weighed to the nearest 0.01 g. Gonad condition was graded visually on a five-point maturity scale (Bagenal & Braum, 1968) and tabulated (Table 1). The gonadosomatic index (*GSI*) was calculated from the relation: $GSI = (GW/W) \times 100$ where GW is the gonad weight and W is the total body weight in grammes. The seasonal variation in the *GSI* was used to define the peak spawning periods, respectively.

Mean length at first sexual maturity (L_m)

The mean length at first sexual maturity (L_m), was defined as the length at which 50 per cent of all individuals were mature. Based on samples obtained during the onset of the peak spawning season (i.e. at about July), the number of females of major species, with advanced stages of gonad development (i.e. Stages II and above), in a range of size classes were determined and used to estimate the mean length at first sexual maturity.

Recruitment patterns

The length frequency data for the selected fish stocks served as input data for the determination of the recruitment patterns using the FISAT software (Gayanilo, Sparre & Pauly 1994).

Results

Relative abundance

A total of 66 species representing 39 genera and 19 families were recorded from the commercial gillnet catches. The species were dominated by two claroteid species, *Chrysichthys nigrodigitatus* and *Chrysichthys auratus* with a composition of 19.0 per cent and the cyprinid, *Labeo coubie* (19%) (Fig. 2). Following these were the mochokid, *Hemisynodontis membranaceus* (10%) and the schilbeid, *Schilbe intermedius* (7%). The cichlids, *Oreochromis niloticus* and *Sarotherodon galilaeus* together formed 7 per cent of the species composition.

Forage-carnivore (F/C) ratio

The results for the four categories of feeding groups are presented in Table 2. The feeding groups by numbers were in the following order of importance: aufwuchs-detritus and herbivores (57.39%) > benthic omnivores (20.59%) > semipelagic omnivores (15.90%) > piscivores (6.62%) (Table 2). 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 F/C ratio was estimated as 14.09 (Table 2) which is outside the range of 1.4 - 10.0 observed for balanced populations (Blay, 1985). This indicates unsuitable ecological balance between the carnivores and their prey populations.

Spawning habits

Data on maturity stages of males were irregular due to difficulty in staging immature individuals. Therefore, analysis of seasonal variation in maturity considered only females excluding those

TABLE 2
Relative abundance of different tropic types in gill-nets in stratum VII of Lake Volta, 1995-96 (W= total catch in kilograms)

Feeding types	*W*	*% of total catch*
1. Aufwuchs-detritus and Herbivores		
Osteeoglossidae		
Heterotis niloticus	0.12	1.06
Cyprinidae		
Labeo coubie	1.29	10.01
Mochokidae		
Hemisynnodontis 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**
2. Semipelagic Omnivores		
Characidae		
Brycinus Nurse	0.17	1.99
Alestes baremoze	0.38	4.23
Schilbeidae		
Schilbe intermedius	0.65	6.54
Distiochodontidae		
Distichodus rostratus	0.31	2.63
Total	**1.51**	**15.39**
3. Piscivores		
Characidae		
Hydrocynus forskalii	0.27	2.40
Bagridae		
Bagrus bajad	0.38	4.22
Total	**0.65**	**6.62**
4. Benthic Omnivores		
Mormyridae		
Mormyrus rume	0.21	2.82
Bagridae		
Chrysichthys auratus	0.97	9.31
C. nifrodigitatus	0.77	7.31
A. occidenttalis	0.07	0.56
Total	**2.02**	**20.59**

F/C ratio 14.09*

$$*\frac{5.63 + 1.51 + 2.02}{0.65}$$

at maturity stage V. This is because stage V ovaries normally have shed eggs and are mostly 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 Fig. 3a-e.

For *H. membranaceus* (Fig. 3a), almost all species encountered during January to April were immature females (Stage O), which contrasted 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 3 months (July-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.

With regard to *C. nigrodigitatus,* two peaks of relatively high proportion of ripening individuals occurred during the year (Fig. 3b.), a major peak in July and a minor one in September. These two peaks of spawning activity were more clearly illustrated in the case of *C. auratus* (Fig. 3c). The two peaks could be distinguished from a period of rapid decline in percentage of Stage IV individuals in August (Fig. 3b and Fig. 3c). 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.

Except 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* (Fig. 3d), one clear peak of spawning activity was observed similar to what was found for *H. membranaceus* (Fig. 3a). The data for *Oreochromis niloticus* (Fig. 3e) were relatively inconsistent due to their low

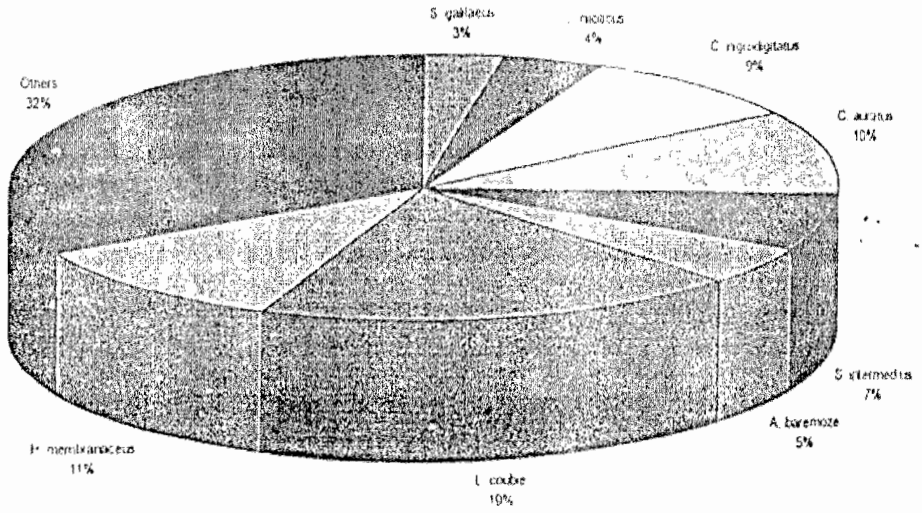

Fig. 2. Species composition (by wt) in gillnet catches of the Yeji sector of Lake Volta during 1996

representation in the samples. However, it appeared that some mature individuals with advanced gonad stages were present during most of the year (Fig. 3e) 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.

Monthly mean GSI values for the females of species studied are presented in Fig. 4. The seasonality pattern in GSI conforms with the timing of the major spawning seasons deduced from earlier observations on seasonal variation in gonad maturity (Fig. 3a-e).

Mean length at first sexual maturity (L_m)

Plots of standard length *versus* cumulative percentage of mature females were generally S-shaped or sigmoid (Fig. 5). From the underlying sigmoid curves in Fig. 5, the 50 per cent line suggested that the average standard length for a first time spawner (L_m) was 26.7 cm, 8.5 cm, 10.5 cm, 13.5 cm, and 16.8 cm, respectively, for *H. membranaceus, C. auratus, C. nigrodigitatus, O. niloticus* and *S. intermedius*. The calculated values of L_m/L_∞ ratios for the five targeted species are presented in Table 3. The calculated value of L_m/L_∞ ratio = 0.59 for *Oreochromis niloticus* was lower than known average value of 0.70 estimated for tilapias having normal growth (Iles, 1970), suggesting possible stunting in this stock of tilapia in the lake.

Recruitment patterns

The annual recruitment patterns for the major species are respectively provided in Figures 6a-e. The figures show that recruitment occurs throughout the year, with conspicuous major and minor peaks.

Discussion

Over 100 fish species were identified for the whole of Lake Volta during its early life (Roberts, 1967; Vanderpuye, 1991), with *Tilapia* alone accounting for 50 per cent of the catch. In this study, 66 species were encounterd indicating that

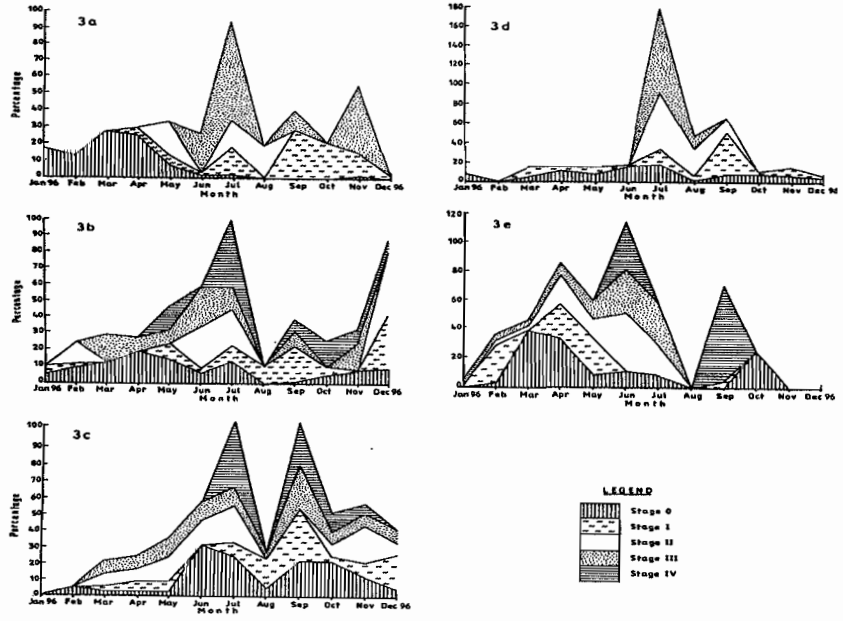

Fig. 3. Percentage of different development stages in females of five major species in the landings during 1995-96

TABLE 3

Comparison of length at maturity (L_m) and L_m/L_∞ ratio for five commercially important fish species in Lake Volta *

Species	*Estimated L_∞ (cm)*	*Estimated L_m (cm)*	*L_m/L_∞ ratio*
H. membranaceus	44.0	25.25	0.57
C. auratus	31.0	17.28	0.56
C. nigrodigitatus	44.5	21.08	0.47
O. niloticus	33.5	19.73	0.59
S. intermedius	30.0	20.75	0.69
Mean	36.6	20.81	0.58

* *Source*: Ofori-Danson (1999)

at least 66 per cent of the earlier species occur in the Yeji sector of the lake. The cichlids *Oreochromis niloticus* and *Sarotherodon galilaeus* together represented only 7 per cent of the gillnet catches. This implies that the dominance of tilapiine species in gillnet catches has now given way to the claroteids *Chrysichthys nigrodigitatus* and *C. auratus* (19% altogether) and *Labeo* spp. (also 19%), followed by mochokids and schilbeids in this order of importance. On the other hand, a market survey at Yeji clearly shows that the cichlids still formed a major fish component. The cichlids also constituted the bulk (> 80%) of *nifa-nifa* gear which operates in this littoral area. This implies that these cichlids may spend most of their time in the littoral floating/submergent vegetation. It could also be that they might not have been on the main fishing ground of the gillnet which were normally operated in the main channel of the lake in the offshore water due to obstructive tree stumps in the lake.

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 the most important species in the lake 10 years after impoundment (FAO/ UNDP, 1979) but had relatively poor

representation in the gillnet landings during this study. It is apparent that *Lates niloticus* catches have declined considerably during the past 30 years.

The estimated forage-carnivore ratio (F/C) of 14.09 was outside the range of 1.4-10.0 observed for balanced populations (Blay, 1985). This indicates unsuitable ecological balance between the piscivores and their prey populations, and suggests ecological "imbalance" in the food web of the lake. If this situation persists for long, low predation by existing carnivorous fishes could be expected which could lead to overcrowding by forage fish. Such a situation could promote stunting in some of the fish stocks which was found to be occurring in the population of the nile tilapia *Oreochromis niloticus*. This is because lake tilapias having normal growth are usually known to attain L_∞ of approximately 35 cm and an average L_m/L_∞ ratio of 0.70 (Iles, 1970). In this study, lower L_m/L_∞ ratio of 0.59 was estimated for *O. niloticus*. It has been observed that stunted tilapia populations breed precocially (Chimits, 1955; Blay & Asabere-Ameyaw, 1993). It is likely that similar breeding habits occur in Lake Volta's tilapia populations, and this characteristic might

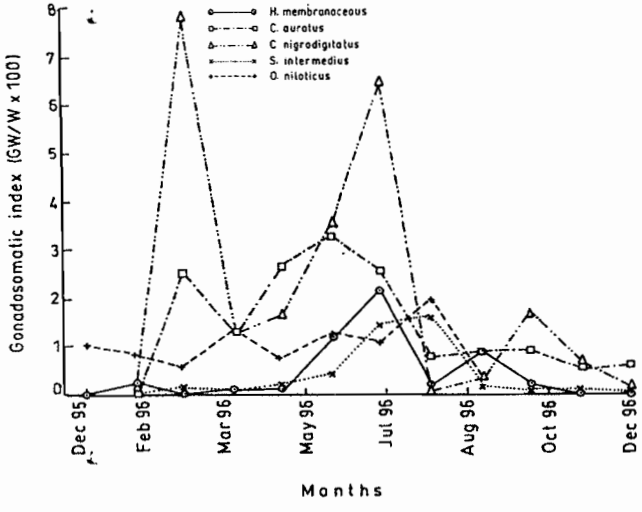

Fig. 4. Monthly variation in gonadosomatic indices for the major species

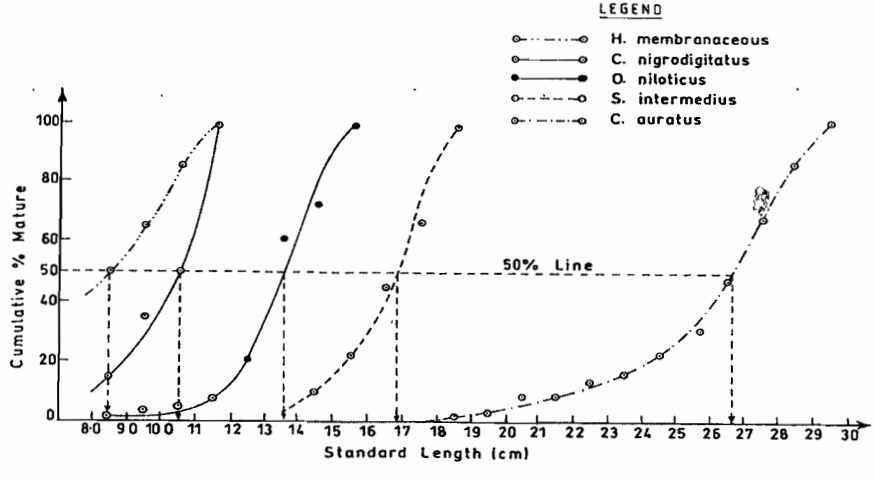

Fig. 5. Mean size at first sexual maturity (L_m) as defined from underlying sigmoid curves for five major species

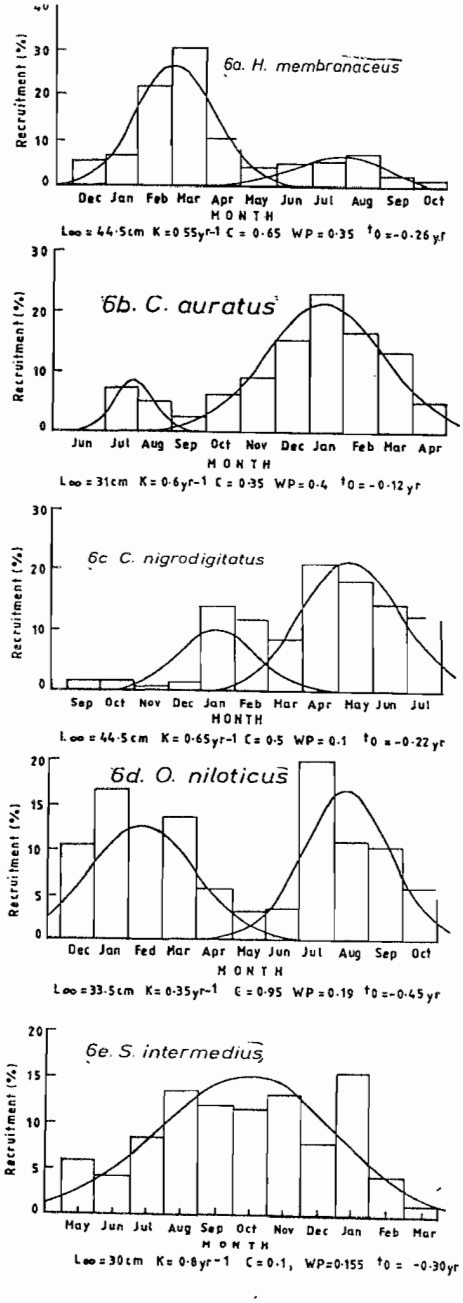

Fig. 6. Recruitment patterns of five major species in the Yeji sector of Lake Volta

guarantee an all-year-round recruitment to the fishery.

In spite of the increased fishing effort by at least 300 per cent in stratum VII since the mid 1970s (Agyenim-Boateng, 1989; Maembe, 1990, 1992; de Graaf & Ofori-Danson, 1996), there was, therefore, generally high recruitment success annually. This may partly be attributed to the continuous spawning behaviour of the major stocks monitored, which demonstrated either one or two peak spawning period(s). Rapid growth and early recruitment of individuals to the spawning stock also improve reproductive rates for sustenance of the stock population sizes.

The major fish species are generally short-lived with longevity ranging between 4 and 6 years (Ofori-Danson, 1999). This is expected because tropical fish are known to be fast growing and short-lived (Lowe-McConnel, 1987). The fast growth and reduced body size coupled with regular spawning are among the observed adaptations which favour survival in the environment of increasing fishing pressure in the lake.

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