



## Assessment of the fishery of a stunted population of the cichlid, *Sarotherodon melanotheron* (Rüppel), in a “closed” lagoon in Ghana

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### Summary

This paper examines the status of the tilapia fishery in Fosu Lagoon at Cape Coast, in the Central Region of Ghana (5°07' N, 1°16' W). The blackchin tilapia, *Sarotherodon melanotheron* (Rüppel), constitutes about 90% by weight of the total fish catch, and the annual yield of 452–664 kg/ha is appreciably higher than those reported for other tropical lagoons. Variations in the CPUE (0.30–0.96 kg/man-h) were related to fluctuations in the water level of the lagoon. Using the ELEFAN method, estimates of the growth and mortality parameters, based on length-frequency data were:  $L_{\infty} = 16.1$  cm TL,  $K = 0.82$ /yr,  $Z = 4.95$ /yr,  $M = 1.90$ /yr and  $F = 3.05$ /yr. The growth estimates and the maturity-length ratio suggest that the population is stunted. The mean length at first capture ( $L_{C50}$ ) was estimated to be 6.2 cm TL. Although the present rate of exploitation ( $E = 0.62$ ) appears high, an analysis of the relative yield-per-recruit ( $Y'/R$ ) and high recruitment shows that this exploitation rate can be maintained by the lagoon population. Recruitment occurs throughout the year with two peaks, and this probably ensures the sustenance of the high yield.

### Introduction

Lagoons and estuaries have a good potential for fisheries development in West Africa. In Ghana, although these fisheries are not highly developed, they play an important role in the economy of some coastal inhabitants (MENSAH 1979), especially during the marine fishery off-season. Very little is known about the state of the fish stocks of lagoons and estuaries in the country and, of the approximately fifty lagoons occurring on the coast, only the fishery of Sakumo Lagoon (1 km<sup>2</sup>) located east of Accra (Ghana) has been assessed (PAULY 1976).

The coastal lagoons in Ghana are dominated by the cichlid fishes, notably *Tilapia* and *Sarotherodon* spp. (MENSAH 1979), of which the blackchin tilapia, *Sarotherodon melanotheron* (Rüppel), is known to be well-adapted to “closed” lagoon systems in West Africa (BOUGHEY 1957).

In the “closed” Fosu Lagoon at Cape Coast (Ghana), *S. melanotheron* is exploited throughout the year by the local fishermen, but there is no information on the state of the stock and its level of exploitation. However, aspects of the biology of the fish in this lagoon have been reported (EYESON 1979; EYESON in Press).

As observed for other fisheries resources, proper management of the fisheries of brackishwaters in Ghana is necessary if they are to make significant impacts on the socio-economic life of the fishing communities in the coastal regions. The purpose of the present study is to assess the status of the tilapia fishery of Fosu Lagoon (Ghana) with the aim of identifying the management requirements for its rational exploitation.

### The fishery

Fosu Lagoon (61 ha) is located at Cape Coast, in the Central Region of Ghana (5°07' N; 1°16' W). It is a shallow lagoon which is separated from the sea by a sandbar. Precipitation and effluents from the Cape Coast municipality are its main sources of water, although at spring

Table 1. Some hydrological features of Fosu Lagoon

Surface area (ha)	61
Maximum depth (m)	2.0
Mean depth (m)	1.5
Air temperature (°C)	28.7 (26.0–31.5)*
Water temperature (°C)	29.7 (27.0–32.0)
Salinity (parts per thousand)	4.6 (1.6–6.2)
Conductivity (µS/cm)	7,565 (2,450–11,500)
pH	9.3 (8.8–11.1)
Oxygen (mg/L)	6.7 (1.8–13.6)
Transparency (cm Secchi disc)	30.1 (20.6–40.0)
Plankton biomass (mg/L)	162.7 (9.0–395.0)
* Range in parentheses	

tides sea water spills over the sandbar into the lagoon. A summary of some hydrological features of the lagoon is presented in Table 1.

The lagoon supports a thriving artisanal fishery for both commercial and subsistence purposes. Cast-nets (25 mm stretched mesh) are the main fishing gear; gill-nets are seldom used in the fishery. Because all sections of the lagoon are accessible on foot, canoes are not used. The lagoon is fished throughout the week, but on Tuesdays fishing commences after 12 h (local time) in strict observance of local tradition. Fishing is prohibited from early August to early September in connection with annual celebrations of a local festival. This means there are approximately 286 fishing days a year. One group of fishermen operate one fishing session a day, while others operate two fishing sessions (unpubl. obs.); each session lasts about 3 h.

### Materials and methods

Weekly counts of fishermen engaged in fishing in the lagoon were made between May 1989 and July 1990, and the daily average for each month was computed. Estimates of the monthly catch per unit effort (CPUE, kg/man-h) were made using the individual catches of 15 fishermen fishing two sessions a day. The total weight of fish landed daily from the lagoon was calculated from the CPUE, on the assumption that one half of the men engaged in fishing did one session (3 h), while the other half did two sessions (6 h).

Table 2. Percentage Composition (by weight) of Fish in Fosu Lagoon

Total weight of fish sampled (kg)	Composition (%)				
	<i>Sarotherodon melantheron</i>	<i>Porogobius schlegelii</i>	<i>Liza</i> spp.	<i>Clarias</i> sp.	Decapods
831.406	90.1	6.6	0.3	0.2	2.8

For the growth and mortality parameter estimates of *S. melantheron* in the lagoon, samples of fish were obtained from the commercial catches in the middle of each month during the study period. Specimens were measured for total length (TL) and body weight (BW) to the nearest 0.1 cm and 0.1 g, respectively. Monthly length-frequency distributions were determined at 1.0 cm length classes. The asymptotic length ( $L_{\infty}$ ) and growth constant ( $K$ ) of the von Bertalanffy growth function were extracted from the length-frequency data using the Compleat ELEFAN version 1.1 computer programmes (GAYANILO et al. 1989). The total mortality coefficient ( $Z$ ) was estimated from the catch curve, and the natural mortality coefficient ( $M$ ) was derived from PAULY's (1980) empirical equation. The fishing mortality coefficient ( $F$ ) was calculated from the equation,  $Z = F + M$  (RICKER 1975). Other

parameters estimated from the programme were the exploitation rate (E), given as  $F/Z$ , the mean length at first capture ( $LC_{50}$ ), the annual recruitment pattern, and the relative yield-per-recruit ( $Y'/R$ ) which was determined at the existing exploitation rate, using different values of  $LC_{50}$ .

## Results

### Fish production

Table 2 gives the percentage composition of the fish species caught in the lagoon. The blackchin tilapia, *Sarotherodon melanotheron* constitutes 90 % by weight of the total catch, and is therefore the dominant species. This is similar to PAULY's (1976) observations on the

Table 3. Estimates of catch and yield per month, and the average number of fishermen engaged in fishing per day in each month in Fosu Lagoon

Month	Fish Production		Number of Fishermen per day
	Total Catch (tonnes)	Yield (kg/ha)	
May 1989	6.0	98.8	62
June	11.6	189.8	109
July	1.0	16.2	22
August	—	—	—
September	2.7	44.2	39
October	1.7	28.6	25
November	3.0	49.4	36
December	1.5	24.3	18
January 1990	2.4	39.0	26
February	3.1	50.4	32
March	5.3	86.4	45
April	2.2	36.4	27
May	2.7	44.2	46
June	2.4	39.0	40
July	0.6	10.4	17

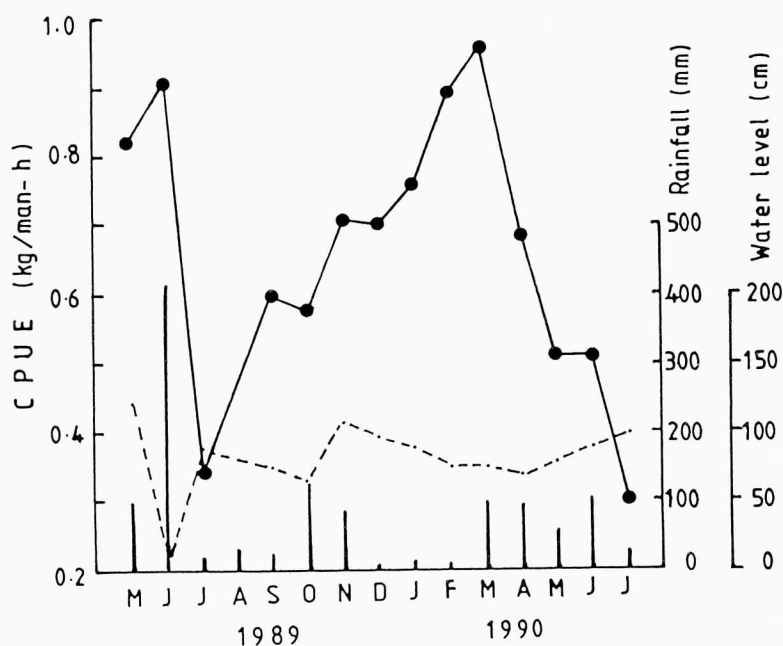


Fig. 1. Monthly variations in catch per unit effort (CPUE, —•—), water level (----), and rainfall (vertical bars) in Fosu Lagoon

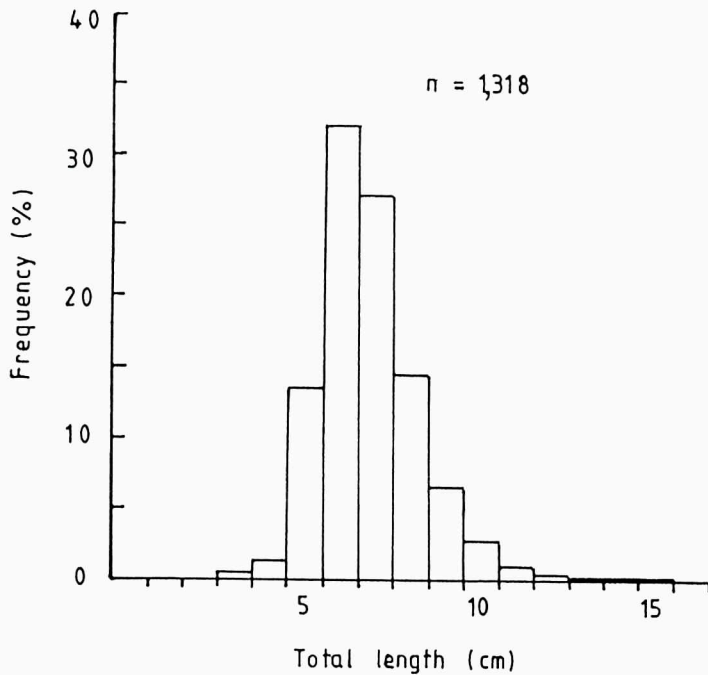


Fig. 2. Overall length-frequency distribution of *Sarotherodon melanotheron* in Fosu Lagoon. n = sample size

fishery of Sakumo Lagoon. This fishery can therefore be assessed by the single-species methods (MUNRO 1983). Estimates of the monthly total fish production and the daily number of fishermen engaged in the fishery during the study period are provided in Table 3. Totals for twelve monthly yields indicate that the annual yields range from 452 to 664 kg/ha. CPUE varied from 0.30 to 0.96 kg/man-h; a negative relationship existed between its fluctuation and water level, except in November (Fig. 1). Maximum CPUE values were recorded in June 1989 and March 1990 when water levels were low, while minimum values were obtained in July each year which coincided with high water levels in the lagoon. No clear relationship existed between CPUE and rainfall.

### Growth parameters

Samples of *S. melanotheron* in the commercial catches measured 3.6 to 15.9 cm TL, and the overall length-frequency distribution showed a modal length of 6.0–6.9 cm (Fig. 2). The growth parameter estimates, according to the ELEFAN programme, were  $L_{\infty} = 16.1$  cm TL, and  $K = 0.82/\text{yr}$ . Illustrated in Fig. 3 are the resultant growth curves fitted to the monthly length-frequency distributions. Using PAULY's (1983) empirical equation,  $\log_{10}(-t_0) = -0.3922 - 0.2752 \log_{10} L_{\infty} - 1.038 \log_{10} K$ ,  $t_0$  was calculated to be  $-0.23$  yr. Hence, on an annual basis, the growth of the population can be described by the von Bertalanffy equation,

$$L_t = 16.1 \{1 - \exp[-0.82(t + 0.23)]\} \text{ cm TL.}$$

The growth curve derived from this equation is shown in Fig. 4. The longevity ( $t_{\text{max}}$ ) of the fish estimated from its maximum observed length ( $L_{\text{max}} = 15.9$  cm TL), and the equation  $t_{\text{max}} = 3/K$  (PAULY 1983a) approximates 4 years, which portrays the population as a short-lived species.

The length-weight relationship of the *S. melanotheron* population is described by the equation  $BW = 0.0405 \text{ TL}^{2.6549}$  ( $r = 0.97$ ), where BW = body weight in grams, and TL = total length in centimetres (Fig. 5). Substitution of the estimated  $L_{\infty}$  in this equation shows that the asymptotic weight ( $W_{\infty}$ ) of the fish is 64.8 g.

### Mortality parameters

Figure 6 shows the length-converted catch curve for the lagoon samples of *S. melanotheron*. The total mortality rate ( $Z$ ) was determined only for fish that were fully exploited; the slope of the regression line indicates that  $Z = 4.95/\text{yr}$ . The regression analysis excluded the points on the ascending part of the curve for specimens not fully recruited to the fishery, and those on the descending arm corresponding to fish in the older age groups with lengths very close to the asymptotic size (PAULY 1983b). Also precluded from the analysis were the backward-projected points indicating the number of small size fish that would have been caught in the absence of gear selection and/or incomplete recruitment. As shown by the inflexion at the point of projection, these fish have a lower total mortality rate than that of the fully exploited stock because of reduced fishing mortality.

The annual mean water temperature of the lagoon during the study period was  $29^\circ\text{C}$ ; by substituting this value and the values of the growth parameters ( $L_{\infty} = 16.1$  cm TL and  $K = 0.82/\text{yr}$ ) in the empirical equation of PAULY (1980), the natural mortality rate ( $M$ ) is calculated to be  $1.90/\text{yr}$ . The fishing mortality ( $F$ ) is therefore estimated as  $3.05/\text{yr}$ .

### Mean length at first capture

The selection curve generated by the ascending part of the length-converted catch curve for *S. melanotheron* is shown in Fig. 7. From the curve, the mean length at first capture ( $L_{C50}$ ) is extrapolated as 6.2 cm TL, which incidentally falls within the modal size group of the population.

### Exploitation rate

The exploitation rate ( $E = F/Z$ ), also referred to as the exploitation ratio, is a

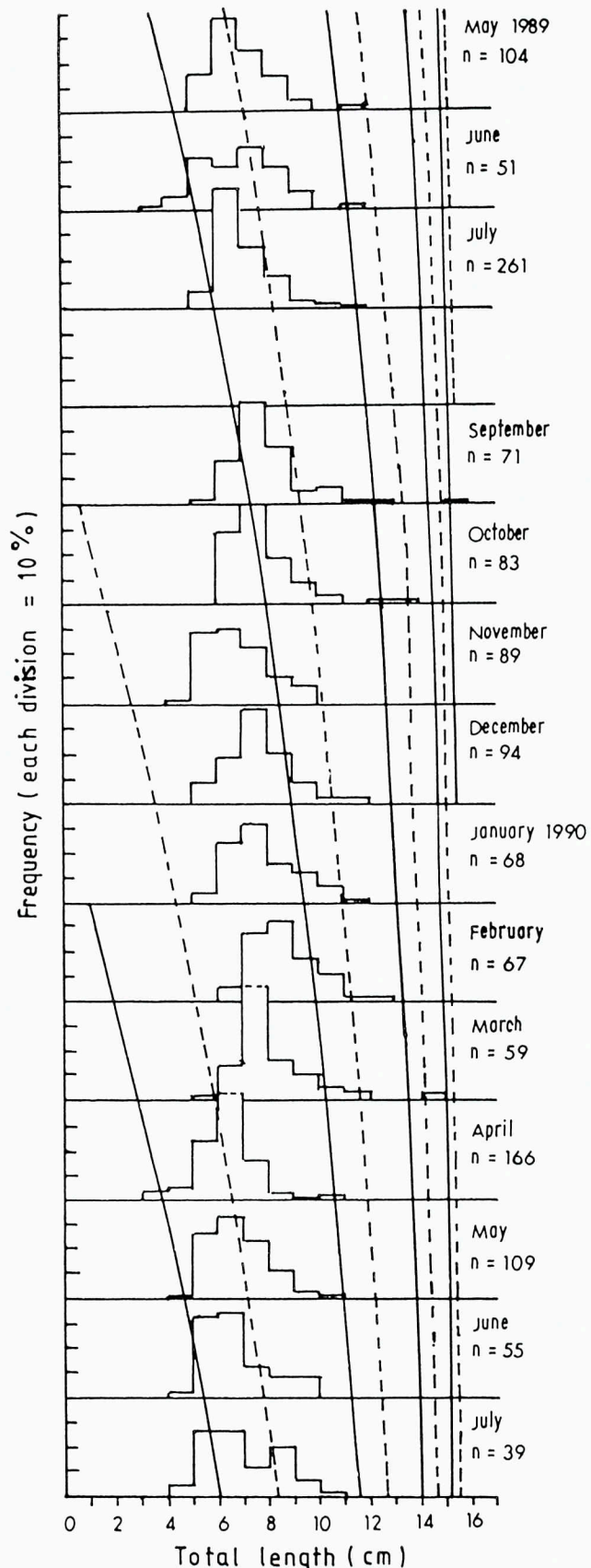


Fig. 3. Monthly length-frequency data of *Sarotherodon melanotheron* fitted with growth curves obtained by ELEFAN I.  $n$  = sample size

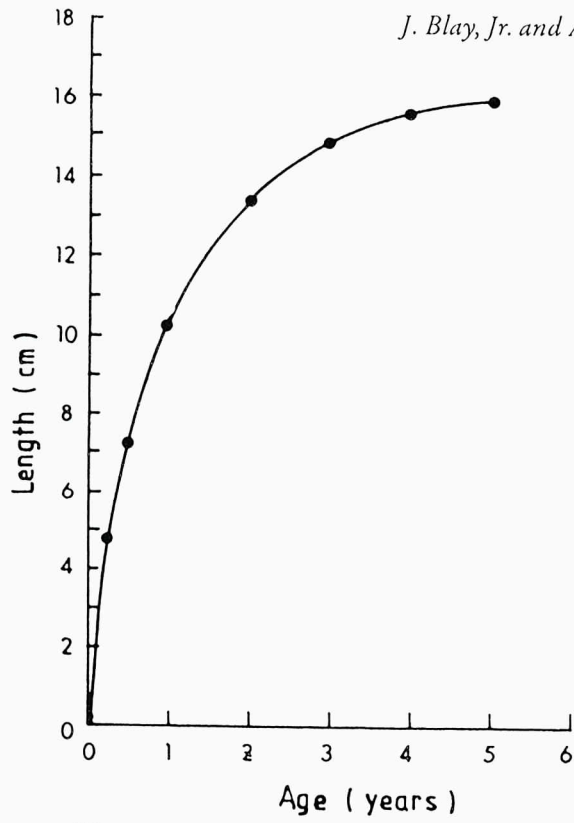


Fig. 4. Derived growth curve of *Sarotherodon melanotheron* in Fosu Lagoon

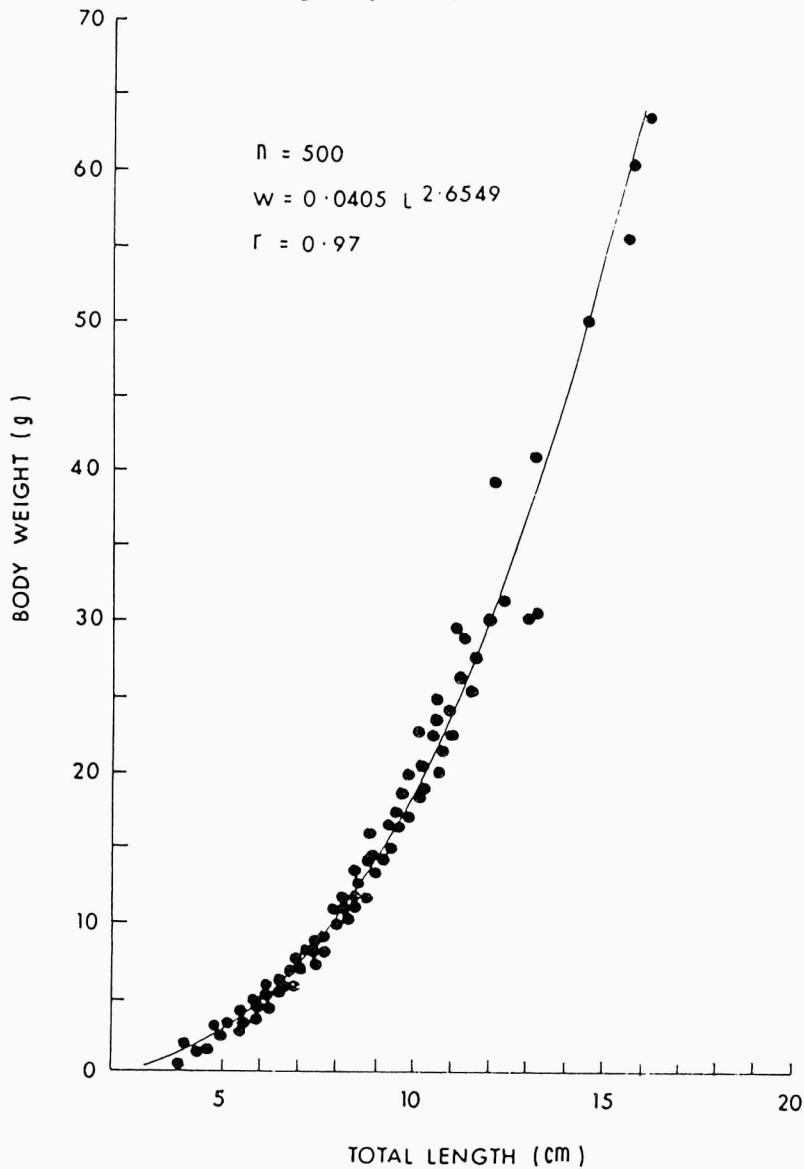


Fig. 5. Length-weight relationship of *Sarotherodon melanotheron* in Fosu Lagoon.  $W$  = body weight in g,  $L$  = total length in cm;  $n$  = number of fish

Fig. 6. Length-converted catch curve for *Sarotherodon melanotheron* from Fosu Lagoon (May 1989 – July 1990) based on length frequency data presented in Fig. 3, with  $L_{\infty} = 16.1$  cm and  $K = 0.82$ /yr. Points used for regression analysis (●); points not used for analysis (○); points projected backward to estimate probability of capture (■) (see text)

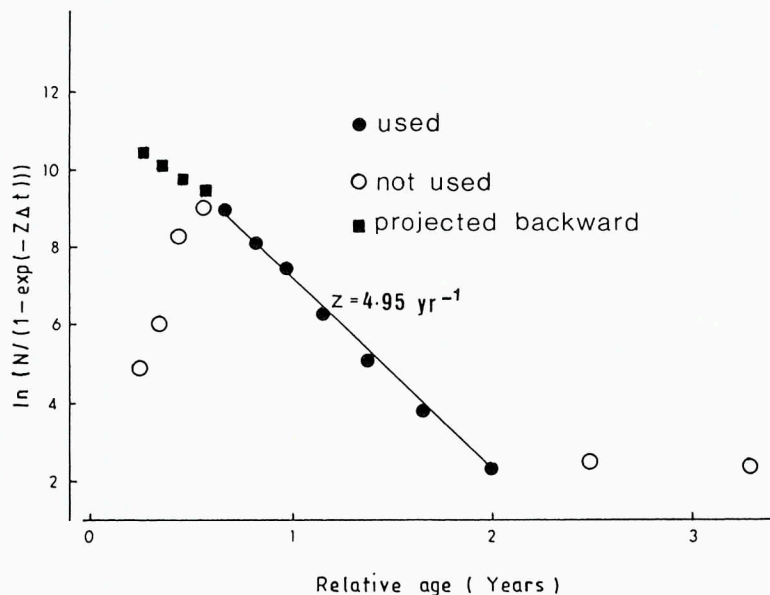


Fig. 7. Selection curve for *Sarotherodon melanotheron* in Fosu Lagoon.  $L_{C50}$  = mean length at first capture

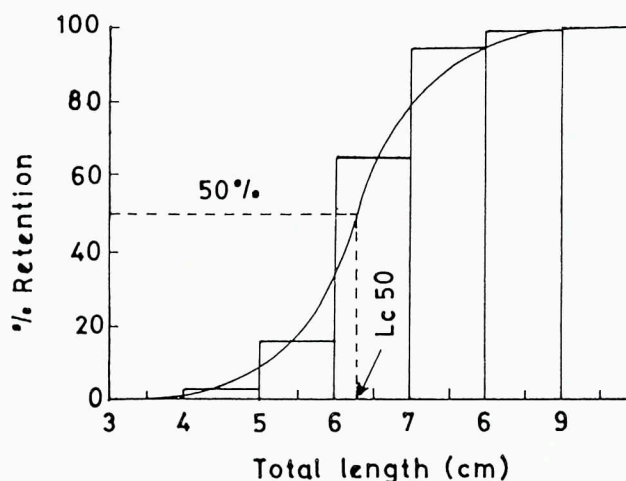
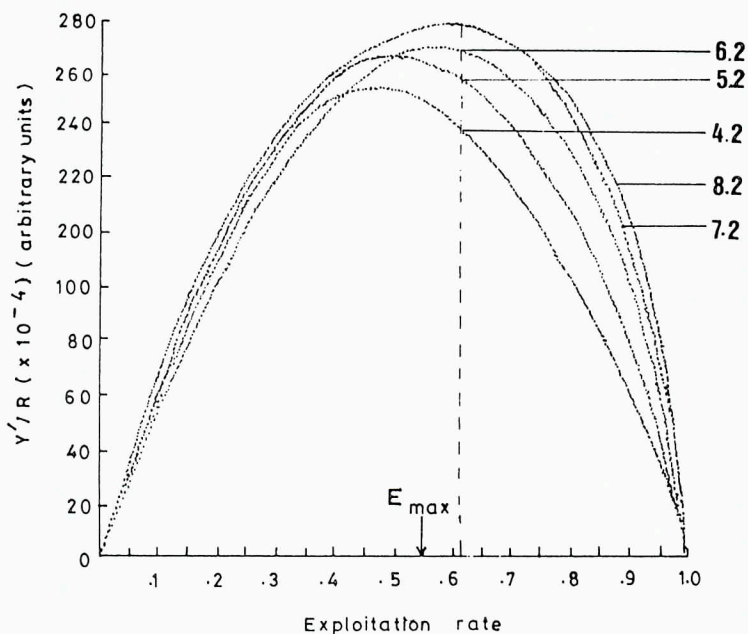


Fig. 8. Relative yield-per-recruit ( $Y'/R$ ) as functions of exploitation rate. The  $L_{C50}$  value is also indicated for each curve



measure of the intensity by which a fish stock is exploited. For the fish population in Fosu Lagoon,  $E$  was estimated at 0.62, which is higher than the optimum rate of 0.5 suggested for exploited stocks (GULLAND 1971; PAULY 1983a).

### Relative yield-per recruit

Fig. 8 shows the estimated relative yield-per-recruit ( $Y'/R$ ) for different  $L_{C50}$  values at the current level of exploitation. As might be seen, only a slight increase in  $Y'/R$  is obtained by increasing the  $L_{C50}$  from the present estimate of 6.2 to 7.2 or 8.2 cm TL, but a reduction of  $L_{C50}$  to 5.2 or 4.2 cm results in an appreciable decline in  $Y'/R$ . The figure also indicates that at the present estimate of  $L_{C50} = 6.2$  cm for the population, maximum  $Y'/R$  is obtained when  $E = 0.54$ , which is very close to the present exploitation ratio.

### Recruitment pattern

The annual recruitment pattern of *S. melanotheron* in the Fosu Lagoon is provided in Fig. 9. It shows that recruitment occurs throughout the year, with a conspicuous peak and a minor secondary peak.

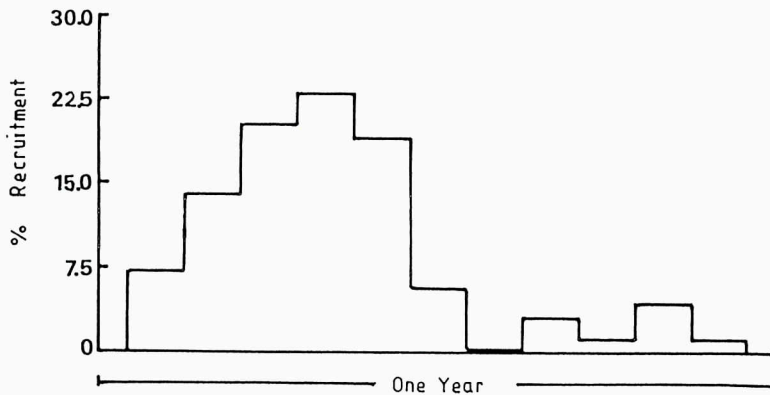


Fig. 9. Recruitment pattern of *Sarotherodon melanotheron* in Fosu Lagoon

### Discussion

The estimated annual yield (452–664 kg/ha) of the tilapia fishery of Fosu Lagoon (Ghana) is much higher than estimates for lagoons elsewhere. Reports on the fisheries of some other West African lagoons (Republics of Benin and Togo) indicate annual yields of 127 and 82 kg/ha, respectively (WELCOMME 1972), while that of the Sakumo Lagoon (Ghana) was estimated as 120 kg/ha (PAULY 1976). WIJEYARATNE and COSTA (1987) have reported an estimate of about 15 kg/ha for Negombo Lagoon in Sri Lanka.

In the present study, the high CPUE associated with low water levels of the lagoon could be attributed partly to increased vulnerability of the fish to netting in a smaller volume of water, and also improved efficiency in operating the nets at low water levels. On the other hand, the low CPUE recorded during periods of high water levels may be attributed to a wider dispersion of the fishes, and the difficulty in operating the nets at shoulder level impairing the fishing efficiency. Water level fluctuations have been observed to have a similar influence on changes in CPUE in Sri Lankan reservoirs (AMARASINGHE & PITCHER 1986; AMARASINGHE 1987).

A greater proportion of the *S. melanotheron* samples caught from the lagoon during the study period were of small sizes, and these did not differ from the sizes of the fish sampled in 1973–1974 (Blay, unpubl. data). As the present study shows, the fish were fully recruited to the fishery at a size of 6.2 cm TL. The maximum length of 15.9 cm TL is relatively smaller than lengths reported elsewhere. DAGET and ILTIS (1965) observed a maximum length of



25.0 cm TL in lagoons in the Ivory Coast, and FAGADE (1974) reported a maximum size of 27.0 cm TL in the Lagos Lagoon, Nigeria. In Ghana, specimens measuring nearly 27.0 cm TL occur in the fish landings from the Weiija reservoir (3,362 ha) near Accra (Blay, pers. obs.).

A comparison of the growth parameters of *S. melanotheron* from the Fosu Lagoon ( $L_{\infty} = 16.1$  cm TL;  $K = 0.82/\text{yr}$ ) and the Lagos Lagoon ( $L_{\infty} = 33.0$  cm TL;  $K = 0.16/\text{yr}$ ) (PAULY et al. 1988; based on FAGADE 1974) shows that specimens in the former population grow five times faster, but attain an asymptotic length which is about half that of the latter. Because the tilapia in Fosu Lagoon have a shorter life span (about 4 years) they would be expected to reach  $L_{\infty}$  at a faster rate. ILES (1973) has reported that stunted tilapia populations characteristically display higher relative growth rates and attain a smaller  $L_{\infty}$  than normal populations. It could therefore be deduced from the above comparison that the tilapia in Fosu Lagoon are possibly stunted. In this lagoon, the size at first maturity of the species is about 6.0 cm TL (Blay, pers. obs.); this corresponds to a maturity age of approximately 4.8 months which is close to the maturity age of 3 months assessed for stunted tilapia populations (CHIMITS 1955). The maturity-length ratio ( $L_m/L_{\infty}$ ) of 0.37 estimated for this population further suggests stunted growth of the species in the lagoon. According to ILES (1970), lake tilapias having normal growth usually attain  $L_{\infty}$  of approximately 35 cm and an average  $L_m/L_{\infty}$  of 0.70.

The apparent accelerated growth and life cycle of *S. melanotheron* in the Fosu Lagoon might correspond to the "altricial" or "r-selected" mode of life engendered by unstable environmental conditions (PIANKA 1970; GUNDERSON 1980; NOAKES and BALON 1982). Conditions in the lagoon appear unstable due to the shallowness of the water, and wide fluctuations in the hydrological factors (Blay and Asabere-Ameyaw unpubl. data).

Higher rates of mortality resulting from intense bird and reptile predation have been implicated in the stunting of tilapia populations in some water bodies (ILES 1973; AMARASINGHE et al. 1989). In the present study, mortality in the *S. melanotheron* population of Fosu Lagoon was largely due to the fishing activities. The low natural mortality rate probably resulted from the presence of a few piscivorous fishes, and minimal predation by birds. It is suggested that the combined effects of heavy fishing and predation by birds could also have contributed to the adverse environmental conditions, causing stunting in the population.

The present exploitation rate of the *S. melanotheron* stock in the Fosu Lagoon ( $E = 0.62$ ) is indicative of its over-exploitation, but since this value does not differ appreciably from the maximum value (0.54) estimated to give the highest  $Y'/R$  in the population, it might suggest an active exploitation of the fishery. Presumably, the population has the ability to maintain a high annual yield in spite of its high fishery. A high reproductive resilience of tilapia fishes has been reported by various authors (FRYER and ILES 1972; ILES 1973; PAYNE 1975). It has also been observed (CHIMITS 1955) that stunted tilapia populations breed precociously. It is likely that similar breeding habits occur in the Fosu Lagoon population, and this characteristic could guarantee an all-year-round recruitment to the fishery. A possible contributory factor to the recruitment success and high yield of the population is the abundance of food for all stages of development of the fish. BINEY's (1982) studies on this "closed" lagoon show that it is eutrophic, and high phytoplankton densities prevail at most times of the year. It is perhaps this abundance of food which largely accounts for the continuous egg production manifested in the females of the population (EYESON 1979). PAULY (1976), on the other hand, reported low production of *S. melanotheron* in the Sakumo Lagoon and attributed this to inadequate food supplies for the fish larvae.

The  $Y'/R$  analysis shows that the present level of exploitation and  $L_{C50}$  of *S. melanotheron* in the Fosu Lagoon appear adequate for maximal utilization of the stock. An exploitation in excess of this rate is likely to cause a decline in the fish yield. This means that the mesh-size currently in use could be maintained as the minimum for the exploitation of the stock.

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