Ghana J. Sci. **38** (1998), 47-55

GROWTH AND MORTALITY PARAMETERS OF *SAROTHERODON MELANOTHERON MELANOTHERON* (TELEOSTEI: CICHLIDAE) IN TWO BRACKISH WATER SYSTEMS IN GHANA

JOHN BLAY, JR
Department of Zoology, University of Cape Coast, Cape Coast, Ghana

Abstract

Growth and mortality parameters of the black-chinned tilapia, *Sarotherodon melanotheron melanotheron*, populations in Benya Lagoon and Kakum River Estuary (Ghana) were determined by analysis of length-frequency data using the ELEFAN computer method. The study was aimed at obtaining requisite information for the assessment and management of the stocks. The growth parameters indicated a faster growth in the estuarine population (K=1.25/year) than the lagoon population (K=0.61/year) but the former attained a smaller asymptotic length (L_∞=10.0 cm SL) than the latter (16.4 cm SL). Estimated life-span for the estuarine and lagoon populations were 2.4 and 4.7 years, respectively. Both populations were, however, considered stunted when these parameters are compared with those of populations with larger maximum sizes. Stunting in the two populations was further implied by their low maturity-length ratios (< 0.50), and maturity ages of 3 months in the estuary and 5 months in the lagoon. The total mortality rate (Z) was higher in the estuarine population (5.17/year) compared with the lagoon population (3.49/year), and the higher mortality rate in the estuarine fish might possibly be compensated for by its higher recruitment rate.

Introduction

The black-chinned tilapia, *Sarotherodon melanotheron*, is the mainstay of the fishery of many West African lagoons where it constitutes between 59 and 90 per cent of the ichthyomass (Welcomme, 1972; Pauly, 1976; Mensah, 1979; Blay & Asabre-Ameyaw, 1993). Its culture in brush parks ('acadjas') and potential for intensive culture in the region have been highlighted by earlier workers (Welcomme, 1972; Pauly, 1976). Lagoon cage culture of the species has been experimented in La Cote d'Ivoire (Legendre, 1986) and Ghana (Blay, unpublished data).

Aspects of the biology of some lagoon, lake and experimental populations of the species, especially the food, feeding and reproductive habits have been investigated (*see* Fagade, 1971, 1979; Pauly, 1976; Eyeson, 1979, 1983, 1992; Ugwumba & Adebisi, 1992). Trewavas (1983) studied the taxonomy of the species and reported the occurrence of four subspecies in West Africa. In Ghana, populations of the species belong to the subspecies *S. melanotheron melanotheron*. Only a few populations have been studied for their growth and mortality rates (e.g. Pauly, Mureau & Palomares Ma, 1988; Blay & Asabre-Ameyaw, 1993), although such information is of vital importance for the assessment and management of the stocks.

Difficulties associated with the ageing of tropical fish from hard parts such as otoliths, scales, vertebrae, opercular bones, or spines for growth and mortality studies are well-known, and have been attributed to inconsistencies in the periodicities of growth ring formation in these parts (Pannella, 1974; Bagenal & Tesch, 1978). In the light of these drawbacks, length-based methods continue to play a significant role in tropical fish stock assessment (*see* Amarasinghe, 1987; De Silva, Moreau & Senaratne, 1988; Dalzell & Peñaflor, 1989) although there is also an increasing interest in the use of daily growth increments in otoliths for age determination (Pannella, 1971, 1974; Fagade, 1980; Dayaratne & Gjøsaeter, 1986;

Ntiba & Jaccarini, 1988).

The aim of the present study was to determine from length-frequency data, the growth and mortality parameters of populations of *S. m. melanotheron* occurring in an estuary and a lagoon near Cape Coast (Ghana) to provide information for managing the stocks. Results of the present investigation would also act as baseline information to facilitate comparison of these parameters with those assessed in future by otolith microstructure studies.

Experimental

Monthly samples of the blackchin tilapia were obtained from two brackish water bodies located in the Central Region of Ghana, viz. Benya Lagoon (approximately 1° 27' W, 5° 05' N) and Kakum River Estuary (about 1° 23' W, 5° 05' N) from January 1996 to December 1996. The mouths of the estuary and the lagoon are roughly 3 km apart. Cast-nets of 25 mm stretched mesh were used; this is the minimum mesh size permissible in Ghanaian waters and commonly used in the brackish water fisheries. The standard length (SL) of the fish was measured to the nearest 0.1 cm and the body weight (BW) was determined to the nearest 0.1 g. Gonads were also examined to determine the maturity size of the populations. The length-frequency distribution of the montly samples was determined at intervals of 1.0 cm from which the asymptotic length (L_∞) and growth constant (K) of the von Bertalanffy growth function, and total mortality were extracted by means of the Compleat ELEFAN version 1.1 computer programmes (Gayanilo, Soriano & Pauly, 1989).

An estimate of the total mortality coefficient (Z) of the populations was obtained from the catch curve which is a plot of the natural logarithm of the proportion of the number of fish caught in the different ages against their corresponding relative ages. The natural mortality (M) was calculated from Pauly's (1980) empirical equation,

$$\log M = -0.2107 - 0.0824 \log W_\infty + 0.6757 \log K + 0.4627 \log T$$

where K is the annual growth rate, W_∞ is the the asymptotic weight and T is the mean annual water temperature; the fishing mortality coefficient (F) was derived from the equation, Z = F + M (Ricker, 1975). Information concerning the annual pattern of recruitment of the populations was also provided by the programme.

Results

Length-frequency distribution and growth parameters

Samples of the fish from the Benya Lagoon measured 3.6-15.0 cm standard length (SL), and the Kakum River Estuary specimens ranged from 3.1 to 9.5 cm SL. At 1.0 cm class intervals, the overall length-frequency distribution (Fig. 1) showed

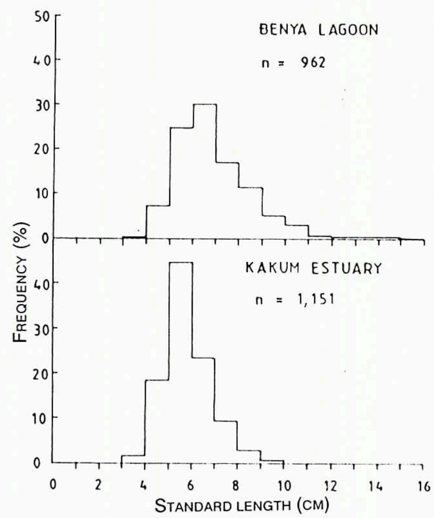

Fig. 1. Overall length-frequency distributions of *S. m. melanotheron* in Benya Lagoon and Kakum River Estuary; n = total number of fish.

modal lengths at 6.0-6.9 cm and 5.0-5.9 cm for the lagoon and estuarine populations, respectively. Estimates of the growth parameters from the length-frequency data obtained by the ELEFAN I

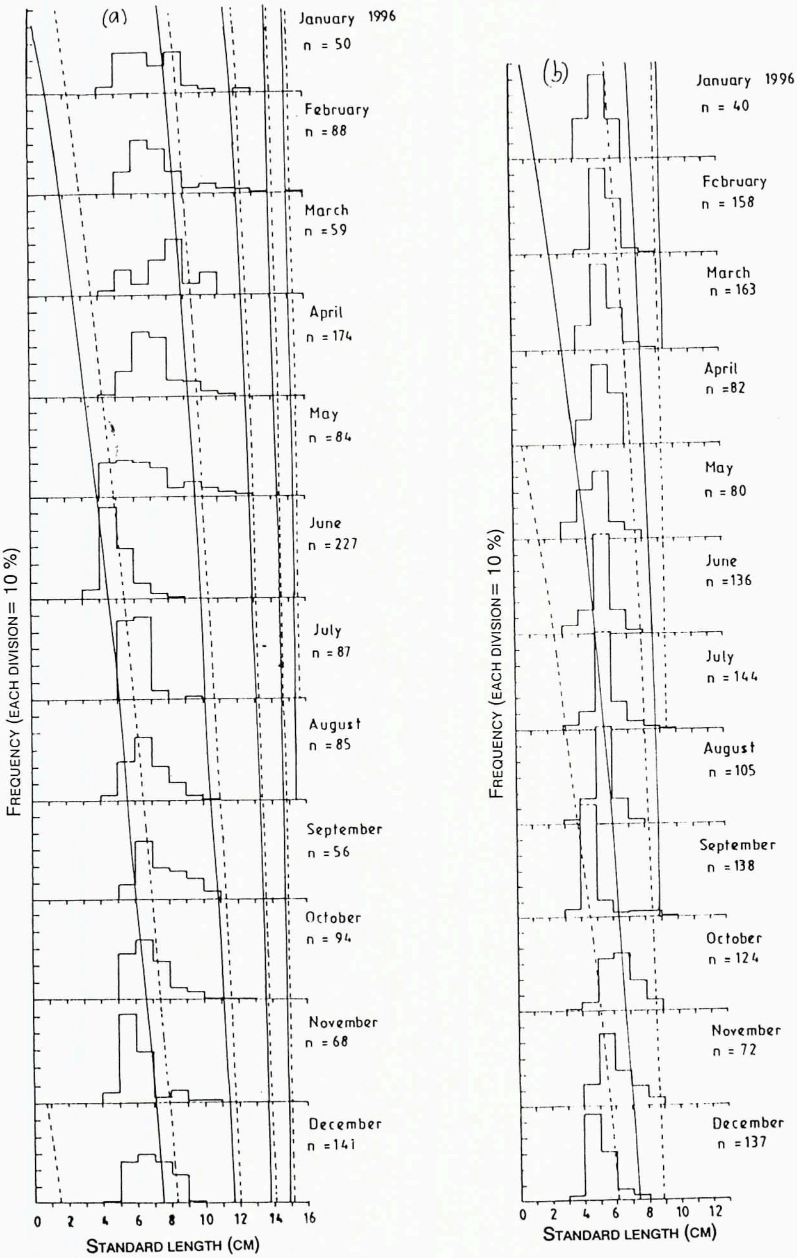

Fig. 2. Monthly length-frequency distributions of *S. m. melanotheron* in (a) Benya Lagoon and (b) Kakum River Estuary. Both are fitted with growth curves obtained by ELEFAN I; n = sample size.

programme gave an asymptotic length (L_∞) of 16.4 cm SL and growth constant (K) of 0.61/yr for the Benya Lagoon population; L_∞ of the Kakum River

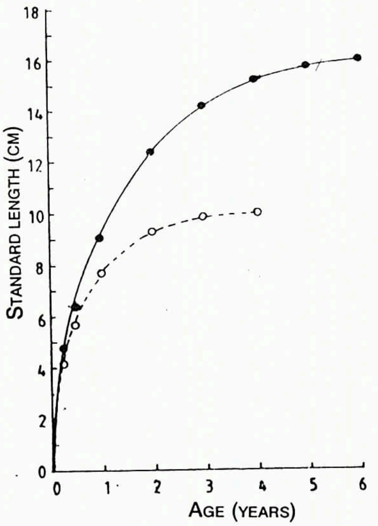

Fig. 3. von Bertalannfy growth curves of *S. m. melanotheron* in (●) Benya Lagoon and (O) Kakum River Estuary.

Estuary population was determined as 10.0 cm SL and K at 1.25/yr. Fig. 2 illustrates the resultant growth curves fitted to the monthly length-frequency distributions of the two populations. Through substitution of the estimated values of L_∞ and K into Pauly's (1983a) empirical equation,

$$\log_{10} t_0 = -0.3922 - 0.2752 \log_{10} L_\infty - 1.038 \log_{10} K$$

the growth parameter t_0, which refers to the age at which the length of the fish is zero (Gulland, 1983) was calculated as -0.31 yr for the lagoon fish, and -0.18 yr for the fish from the estuary. On a yearly basis, therefore, the growth of the two populations could be described by the von Bertalanffy equations,

$L_t = 16.4[1-e^{-0.61 (t+0.31)}]$ cm SL for Benya Lagoon and

$L_t = 10.0[1-e^{-1.25 (t+0.18)}]$ cm SL for Kakum River Estuary, where L_t is the length of fish at age t. Fig. 3 shows the growth pattern of the populations up to the asymptotic length. From the figure, it is evident that the Kakum River Estuary tilapia attained L_∞ at an earlier age than the Benya Lagoon specimens. The longevity (t_{max}) of the lagoon and estuarine populations, determined from their maximum observed lengths and the equation $t_{max} = 3/K$ (Pauly, 1983a), were about 4.7 years and 2.4 years, respectively.

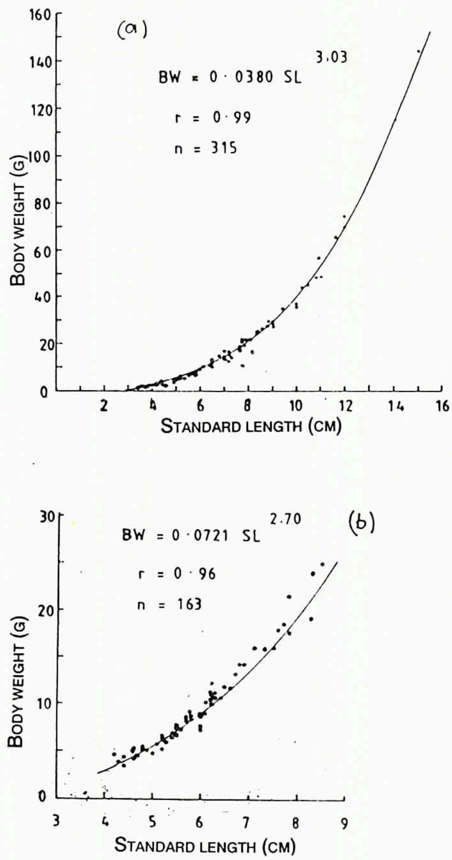

Fig. 4. Length-weight relationships of *S. m. melanotheron* in (a) Benya Lagoon and (b) Kakum River Estuary. BW = body weight in grams; SL = standard length in cm; n= number of fish.

Length-weight relationship

The relationship between standard length and body weight for the *S. m. melanotheron* populations (Fig. 4) was exponential, described by the equations,

$BW = 0.0380\ SL^{3.03}$ ($r = 0.99$) for Elmina Lagoon and

$BW = 0.0721\ SL^{2.70}$ ($r = 0.96$) for Kakum River Estuary, where BW is the body weight in grams and SL is the standard length in centimetres. By substituting the asymptotic length for the two populations in their respective equations, the maximum theoretical weight (W_∞) of the lagoon and estuarine fish was calculated as 182.3 g and 36.1 g respectively.

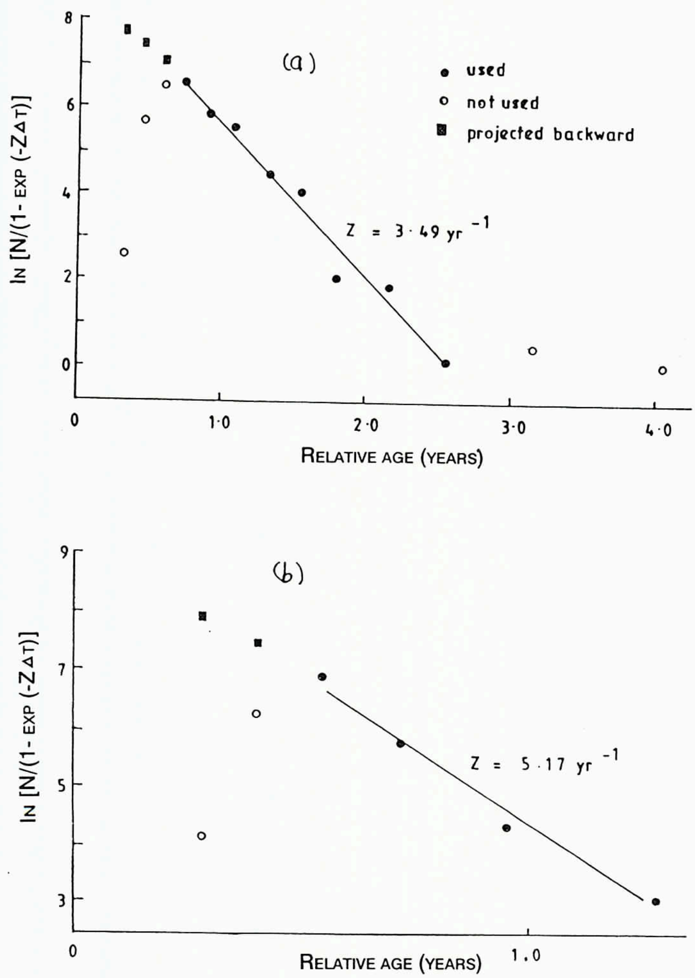

Fig. 5. Length-converted catch curves for *S. m. melanotheron* from (a) Benya Lagoon and (b) Kakum River Estuary (January 1996 - December 1996) based on length-frequency data presented in Fig. 2. Points used for regression analysis (●); points not used for analysis (○); points projected backward to estimate probability of capture (■) (see text).

Growth performance

The growth performance of the two populations was assessed using Moreau, Bambino & Pauly (1986) index (ϕ') defined as

$$\phi' = \log_{10} K + 2 \log_{10} L_{\infty}$$

where K is the growth constant and L_{∞} is the asymptotic length (SL in centimetres. The growth performance index was calculated as 2.14 for the Benya Lagoon population and 2.05 for the Kakum River Estuary samples.

Maturity-length ratio

In the Benya lagoon, the minimum length at maturity (Lm) was 5.0 cm SL and the length at which 50 per cent of the population matured (Lm50) was found to be 5.5 cm SL. In the Kakum River Estuary, the smallest fish was mature at a length o' 4.0 cm SL with 50 per cent maturing at 4.6 cm SL. The maturity-length ratio (Lm/L_{∞}) was, therefore, calculated as 0.34 and 0.40 respectively for the lagoon and estuarine populations.

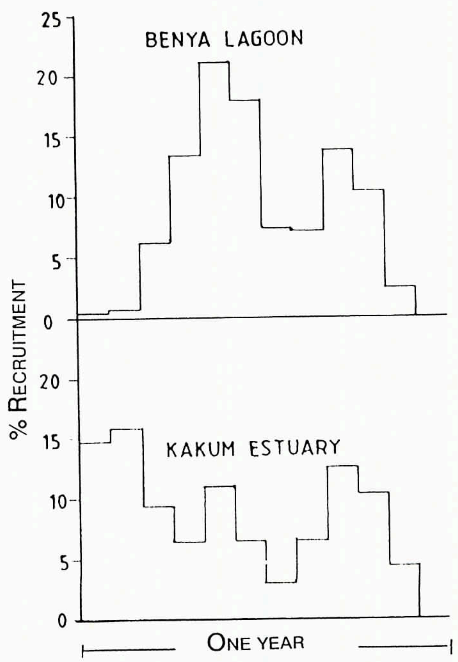

Fig. 6. Recruitment patterns for *S. m. melanotheron* in Benya Lagoon and Kakum River Estuary.

Mortality parameters

Fig. 5 shows the length-converted catch curves for the two *S. m. melanotheron* populations generated by the ELEFAN II programme. The total mortality rate (Z) was determined only for fish that were fully recruited to the catch samples; the smallest recruited fish measured 6.0 cm SL in Benya Lagoon and 5.0 cm SL in Kakum River Estuary. The regression analysis on the descending part of the curve, therefore, excluded the backward projected points referring to fish not fully recruited to the catches and the points representing older fish with lengths near the asymptote (Pauly, 1983b). According to the slope of the regressions, the total mortality rates were 3.49/yr for the Elmina Lagoon population, and 5.17/yr for the Kakum River Estary population.

The natural mortality coefficient (M) of the specimens in Benya Lagoon and Kakum River Estuary was determined as 1.51 and 2.83, respectively, by substituting the annual mean water temperature (Benya Lagoon = 27.3 °C, Kakum River Estuary = 28.4 °C) and growth parameters for each population in the empirical equation of Pauly (1980). Hence the fishing mortality coefficient (F) of the lagoon and estuarine populations was calculated as 1.98 and 2.83, respectively.

Recruitment pattern

As shown in Fig. 6, recruitment of the tilapia populations occurred throughout the year with two major recruitment seasons in the Benya Lagoon and three seasons in the Kakum River Estuary. In the absence of information about the actual age at which the length of the fish is zero (i.e. t_0), the months corresponding to these seasons could not be precisely determined, but it is possible that these periods coincided with the major rainy season (April-June) and the minor rainy season (October-November) when tilapias are known to have enhanced breeding activity.

Discussion

The modal length of 6.0 cm SL observed for the Benya Lagoon *S. m. melanotheron* is slightly longer than that of the Kakum River Estuary population (5.0 cm SL). However, their maximum lengths differed appreciably, being 15.0 cm SL (=19.0 cm TL) in the lagoon, and 9.5 cm SL (=12.1 cm TL) in the estuary. A maximum total length of 19.0 cm was sampled by Pauly (1976) in Sakumo Lagoon and in Fosu Lagoon. Blay & Asabere-Ameyaw (1993) encountered a maximum length of 15.9 cm. These lengths are comparatively smaller than the maximum lengths (25.0-27.0 cm TL) reported for some lagoon and freshwater *S. m. melanotheron* populations in West Africa (Daget & Iltis, 1965; Fagade, 1979; Ugwumba & Adebisi, 1992; Blay, personal observation reported in Blay & Asabere-Ameyaw, 1993). It is, however, not certain whether the populations studied by other authors belong to the same subspecies as that in Ghana, so that these comparisons need to be treated cautiously.

Estimates of the growth parameters indicate that although *S. m. melanotheron* in the Kakum River Estuary grew at a faster rate (K=1.25/yr) than the lagoon specimens (0.61/yr), it attained a smaller L_∞ (10.0 cm SL) compared to the latter (16.4 cm SL). This reflects in the shorter life-span (2.4 years) estimated for the population in the estuary compared to that for the lagoon specimens (4.7 years). A slightly better growth pefermance was also observed in the lagoon specimens; nevertheless, both exhibited a lower growth performance in comparison with other *S. m. melanotheron* populations (*see* Pauly, Mureau & Palomores Ma, 1988). The present growth parameter estimates do not differ appreciably from the growth parameters assessed for the population in Fosu Lagoon, Ghana, where L_∞ =16.1 cm TL or 12.6 cm SL, K=0.82/yr and longevity ≅ 4 years (Blay & Asabere-Ameyaw, 1993).

A comparison of the growth parameters of the Ghanaian populations with those of the population in the Lagos Lagoon (Nigeria) where L_∞ =33.0 cm TL and K = 0.16/yr (Pauly, Mureau & Palomares Ma, 1988), suggests the possibility of stunting in the short-lived populations in Ghana's lagoons which have faster growth rates and a smaller L_∞. These findings complement those reported by Iles (1970, 1973) on stunted tilapia populations. Similar characteristics associated with stunting have also been observed in the clupeid, *Limnothrissa miodon*, in Lake Kariba (Marshall, 1987).

Information about the population maturity length (Lm50) and the minimum length at which the fish matures (Lm) has been used to assess the occurrence or absence of stunting in tilapia populations (Blühdorn & Arthington, 1990). Low ratios of Lm/L_∞ (0.50 and below) are associated with populations which mature at a small size and early age while a ratio of 0.70 has been noted as characteristic of normal growing talipias which attain L_∞ of around 35 cm (Iles, 1970). The estimated ratios of 0.34 for the lagoon and 0.40 for the estuarine fishes might, therefore, imply stunted growth in the Benya Lagoon and Kakum River Estuary *S. m. melanotheron* populations, and this is still apparent even if Lm50 is substituted for Lm. Furthermore, the estimated maturity ages of approximately 5 months for the Benya Lagoon tilapia and about 3 months for the tilapia in the Kakum River Estuary are not very different from the maturity age of 3 months reported for some stunted tilapia populations (Chimits, 1955) and 4.8 months computed for the specimens in the Fosu Lagoon (Blay & Asabere-Ameyaw, 1993).

From the foregoing, it is evident that as observed for the blackchin tilapia population in the Fosu Lagoon (Blay & Asabere-Ameyaw, 1993), the populations in the Benya Lagoon and Kakum River Estuary might also have accelerated growth and life cycle similar to that exhibited by 'altricial' or 'r-selected' populations under unstable environmental conditions (Pianka, 1970; Gunderson, 1980; Noakes & Balon, 1982). Unstable conditions in the two brackishwaters may be manifested through wide fluctuations in the salinity, temperature, tides and flood waters. Pollution could also contribute to the development of these characteristics as these water bodies receive effluents from the nearby dwellings.

Although both populations investigated portrayed stunted features, this phenomenon appeared more intense in the estuary as demonstrated by the faster growth rate, smaller asymptotic length, smaller maturity size/age, and shorter life-span of the fish. Evidence from the pattern of recruitment of the populations suggests the possibility of a greater reproductive capacity in the Kakum River Estuary specimens which, presumably, compensates for the higher total mortality rate in this population. Iles (1970) pointed out that the ability of stunted tilapia populations to withstand extremely high mortalities is due to their possessing specialized reproductive and growth strategies.

The results of the present study showed that natural mortality contributed slightly more to the total mortality of the black-chinned tilapia in the estuary while in the lagoon, fishing mortality was slightly more important. This observation is attributable to the exploitation of the lagoon fishery by a larger community where a greater fishing pressure could be expected. Unlike the Fosu Lagoon where the level of exploitation of the fishery was assessed, a similar evaluation could not be made for the Benya Lagoon and Kakum River Estuary as the present data were based on experimental samples.

In conclusion, the *S. m. melanotheron* population in Kakum River Estuary grew faster than that in Benya Lagoon, and these observations are consistent with the smaller asymptoptic length and shorter life-span of the former compared to the latter. These and other characteristics such as the smaller maturity size and early age at maturity, and the low maturity-length ratio suggest the occurrence of stunting in both populations. The higher mortality rate of the estuarine population was possibly compensated for by its relatively higher recruitment rate.

Acknowledgement

The author is greatly indebted to the Department of Zoology, University of Cape Coast (Ghana), for partly funding this work.

References

AMARASINGHE, U. S. (1987) Status of the fishery of Pimburettewa wewa, a man-made lake in Sri Lanka. *Aquacult. Fish. Mgmt.* **18**, 375-385.

BAGENAL, T. B. & TESCH, F. W. (1978) Age and growth. In *Methods for the Assessment of Fish Production in Fresh Waters* (ed. T. B. Bagenal), pp.101-130. Oxford: Blackwell Scientific Publications.

BLAY, J. & ASABERE-AMEYAW, A. (1993) Assessment of the fishery of a stunted population of the cichlid, *Sarotherodon melanotheron* (Rüppel), in a "closed" lagoon in Ghana. *J. Appl. Ichthyol.* **9**, 1-11.

BLÜDHORN, D. R. & ARTHINGTON, A. H. (1990) The incidence of stunting in Australian populations of the introduced cichlid *Oreochromis mossambicus* (Peters). In *The Second Asian Fisheries Forum* (ed. R. Hirano and I. Hanyu), pp. 41-44. Manila, Philippines: Asian Fisheries Society.

CHIMITS, P. (1955) Tilapia and its culture. *Fish Bull. F.A.O.* **8**, 1-33.

DAGET, J. & ILTIS, A. (1965) Poisson de Côte d' Ivoire (eaux douces et saumatres). *Mem. I.F.A.N. No.* **74**, 385 pp.

DALZELL, P. & PENAFLOR, G. (1989) The fisheries biology of the big-eye scad, *Selar crumenophthalmus* (Bloch) in the Philippines. *Asian Fish. Sci.* **3**, 115-131.

DAYARATNE, P. & GJØSAETER, J. (1986) Age and growth of four *Sardinella* species from Sri Lanka. *Fish. Res.* **4**, 1-33.

DE SILVA, S. S., MOREAU, J. & SENARATNE, K. A. D. W. (1988) Growth of *Oreochromis mossambicus* (Pisces, Cichlidae) as evidence of its adaptability to Sri Lanka reservoirs. *Asian Fish. Sci.* **1**, 147-156.

EYESON, K. N. (1979) Studies on egg production, spawning and fry development in *Tilapia melanotheron*. *Ghana J. Sci.* **17**, 26-34.

EYESON, K. N. (1983) Stunting and reproduction in pond-reared *Sarotherodon melanotheron*. *Aquaculture*. **31**, 257-267.

EYESON, K. N. (1979) Residual biparental oral-brooding in the blackchin fish, *Sarotherodon melanotheron* Rüppell, *J. Fish. Biol.* **41**, 145-146.

FAGADE, S. O. (1971) The food and feeding habits of *Tilapia* species in the Lagos Lagoon. *J. Fish Biol.* **3**, 151-156.

FAGADE, S. O. (1979) Observations on the biology of two species of *Tilapia* from Lagos Lagoon, Nigeria

Bull. I.F.A.N. **41**, 628-653.

FAGADE, S. O. (1980) The structure of the otoliths of *Tilapia guineensis* (Dumeril) and their use in age determination. *Hydrobiologia* **69**, 169-173.

GAYANILO, F. C. JR., SORIANO, M. & PAULY, D. (1989) *A Draft Guide to the Compleat ELEFAN. ICLARM Software 2*. International Centre for Living Aquatic Resources Management. 67 pp.

GULLAND, J. A. (1983) *Fish Stock Assessment: a manual of basic methods*. Chichester, U.K., Wiley Interscience, FAO/Wiley series on food and agriculture, Vol.1, 223 pp.

GUNDERSON, D. R. (1980) Using r-K selection theory to predict natural mortality. *Can J. Fish. Aquat. Sci.* **37**, 2266-2271.

ILES, T. D. (1970) Ecological aspects of growth in cichlid fishes *J. Cons. int. Explor. Mer.* **33**, 363-385.

ILES, T. D. (1970) Dwarfing or stunting in the genus *Tilapia* (Cichlidae), a possibly unique recruitment mechanism. *Rapp. P. V. Reun. Cons. int. Explor. Mer*. **164**, 247-254.

LEGENDRE, M. (1986) Influence de la densité, de l' élevage monosexe et de l' alimentation sur la croissance de *Tilapia guineensis* et de *Sarotherodon melanotheron* éievés en cage-enclos en lagune Ebrie (Côte d' Ivoire). *Rev. Hydrobiol. Trop.* **19**, 19-29.

MARSHALL, B. E. (1987) Growth and mortality of the introduced Lake Tanganyika clupeid, *Limnothrissa miodon*, in Lake Kariba. *J. Fish Biol.* **31**, 603-615.

MENSAH, M. A. (1979) *The Hydrology and Fisheries of the Lagoons and Estuaries of Ghana*. Marine Fisheries Research Reports, No.7. Fishery Research Unit, Tema, Ghana. 14 pp.

MOREAU, J., BAMBINO, C. & PAULY, D. (1986) Indices of overall growth performance of 100 tilapia (Cichlidae) populations, pp. 201-206. In *The First Asian Fisheries Forum* (ed. J. N. Maclean, L. B. Dizon and L. V. Hesillas), pp. 201-206. Manila, Philippines: Asian Fisheries Society.

NOAKES, D. L. G. & BALON, E. K. (1982) Life histories of tilapias: an evolutionary perspective. In *The Biology and Culture of Tilapias* (ed. R. S. V. Pullin and R. H. Lowe-McConnell), pp. 61-82. *ICLARM Conference Proceedings* **7**, 432 pp.

NTIBA, M. J. & JACCARINI, V. (1988) Age and growth parameters of *Sigamus sutor* in Kenyan marine inshore water, derived from numbers of otolith microbands and fish lengths. *J. Fish Biol.* **33**, 465-470.

PANNELLA, G. (1971) Fish otoliths: daily growth layers and periodical patterns. *Science* **173**, 1124-1127.

PANNELLA, G. (1974) Otolith growth patterns: an aid in age determination in temperate and tropical fishes. *The Ageing of Fish* (ed. T. B. Bagenal), pp. 28-39. Old Working, Surrey: Unwin Brothers Ltd.

PAULY, D. (1976) The biology, fishery and potential for aquaculture of *Tilapia melanotheron* in a small West African Lagoon. *Aquaculture* **7**. 33-49.

PAULY, D. (1980) On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *J. Cons. int. Explor. Mer.* **39**, 175-192.

PAULY, D. (1983a) Some simple methods for assessment of tropical fish stocks. *FAO Fish Tech. Paper* **234**. 52 pp.

PAULY, D. (1983b) Length-converted catch curves: a powerful tool for fisheries research in the tropics (Part 1). *Fishbyte* **1**(2), 9-13.

PAULY, D., MUREAU, J. L. & PALOMARES MA, L. D. (1988) Detritus and energy consumption and conversion efficiency of *Sarotherodon melanotheron* (Cichlidae) in a small West African Lagoon. *J. Appl. Ichthyol.* **4**, 190-193.

PIANKA, E. R. (1970) On r-and k- selection. *Am. Nat.* **104**, 592-597.

RICKER, W. E. (1975) Computation and interpretation of statistics of fish populations *Bull. Fish. Res. Bd. Can.* **191**. 382 pp.

UGWUMBA, A. A. A. & ADEBISI, A. (1992) The food and feeding ecology of *Sarotherondon melanotheron* (RÜPPEL) in a small freshwater reservoir in Ibadan, Nigeria. *Arch. Hydrobiol.* **124**, 367-382.

WELCOMME, R. L. (1972) An evaluation of the acadja method of fishing as practiced in the coastal lagoons of Dahomey (West Africa). *J. Fish Biol.* **4**, 39-55.

Received 29 May 97; revised 16 Mar 98.