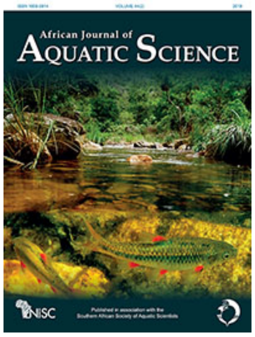

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Growth and mortality parameters of the black-chinned tilapia *Sarotherodon melanotheron melanotheron* (Pisces: Cichlidae) in a small lagoon in the Central Region of Ghana

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This study quantified growth, mortality, and exploitation rate of the black-chinned tilapia (*Sarotherodon melanotheron melanotheron*) population in Etsir Lagoon, a small brackish waterbody at Abandze (5°11′ N, 1°5′ W) in the Central Region of Ghana for management of the stock. Fish samples were collected monthly between April 2014 and March 2015, and specimens measured 3.9–13.8 cm SL with a mode in the 7.0–7.9 cm length class. Analysis of the length-frequency data of 861 specimens using the ELEFAN method indicated a growth constant (*K*) of 0.93 yr^{-1}, and asymptotic length (L_∞) of 14.3 cm SL for the population. The short lifespan (t_{max} = 3.2 years) determined for the species and estimated growth parameters suggest stunting in the population, as in other brackish water populations in Ghana. The total mortality (*Z*), natural mortality (*M*), and fishing mortality (*F*) coefficients: 5.09 yr^{-1}, 2.15 yr^{-1} and 2.95 yr^{-1}, respectively, indicate fishing as a major contributor to total mortality. The calculated exploitation rate (*E* = 0.58) of the population suggests overexploitation of the stock, however, the all-year-round recruitment in the population probably ensures production at levels that compensate for its relatively high exploitation rate.

Keywords: Etsir Lagoon, growth and mortality parameters, population dynamics, recruitment, tilapiine fish

Introduction

The black-chinned tilapia *Sarotherodon melanotheron melanotheron*, an endemic fish in brackish waters of West Africa, constitutes 60–98% of the fish biomass in these waters (Welcomme 1972; Pauly 1976; Blay and Asabere-Ameyaw 1993). The importance of the species for brackish water and freshwater fisheries and aquaculture development in the region has been highlighted by some authors (Ouattara 2005). Estimates of growth and mortality rates of this species in natural habitats have been the subject of earlier studies, including that of Fagade (1973) on the age and growth of the fish in Lagos Lagoon (Nigeria), and Niyonkuru et al. (2007) and Lederoun et al. (2015) on the growth and mortality of the species in Lake *Nokoué* and *Lake Toho* in Republic of Benin, respectively. In Ghana, growth and mortality parameters of the species have been investigated in a number of brackish water systems in the Central Region (Blay and Asabere-Ameyaw 1993; Blay 1998; Koranteng et al. 1997; Koranteng et al. 2000), and the Western Region (Arizi et al. 2015). Many of these earlier studies were on populations inhabiting waterbodies larger than 0.4 km^2 (e.g. Lagos Lagoon: 966 km^2 (FAO 1969); Sakumo Lagoon: 1.0 km^2 (Pauly 1976); Densu Delta: 3.5 km^2 (Ntiamoa-Baidu 1991); Fosu Lagoon: 0.6 km^2 (Blay and Asabere-Ameyaw 1993) and Lake Togo: 64 km^2 (Laë 1997)). In the current study, we focussed on the black-chinned tilapia in a smaller waterbody, Etsir Lagoon, in Ghana, with a surface area of only 0.027 km^2 and maximum depth of about 1.3 m. The only known studies in this lagoon are those of Yankson and Obodai (1999), who categorised it as a 'classical' closed lagoon, and Essumang et al. (2009) who reported pesticide concentrations in the lagoon and tilapia specimens below maximum residue levels.

Although the tilapia and other fish in the lagoon are exploited by the local inhabitants, there is no information on the biology and magnitude of exploitation of the stock. Our study was therefore undertaken to investigate aspects of the population dynamics of *S. m. melanotheron*, the dominant fish in the lagoon using length-based methods to obtain baseline information for management of its fishery, information that may have relevance to other *S. m. melanotheron* fisheries in small waterbodies

Materials and methods

Study Area

Etsir Lagoon is a closed brackish waterbody in the Central Region of Ghana, located at 5°11′ N, 1° 5′ W (Figure 1). It is fed by runoff from the surrounding areas, inflows from a seasonal stream, and occasional spills of seawater over the sand bar. The lagoon occasionally opens up and connects to the sea when the sand bar is breached by rising water levels at the peak of the major rainy season in May–June. The following physico-chemical conditions were recorded in the lagoon using

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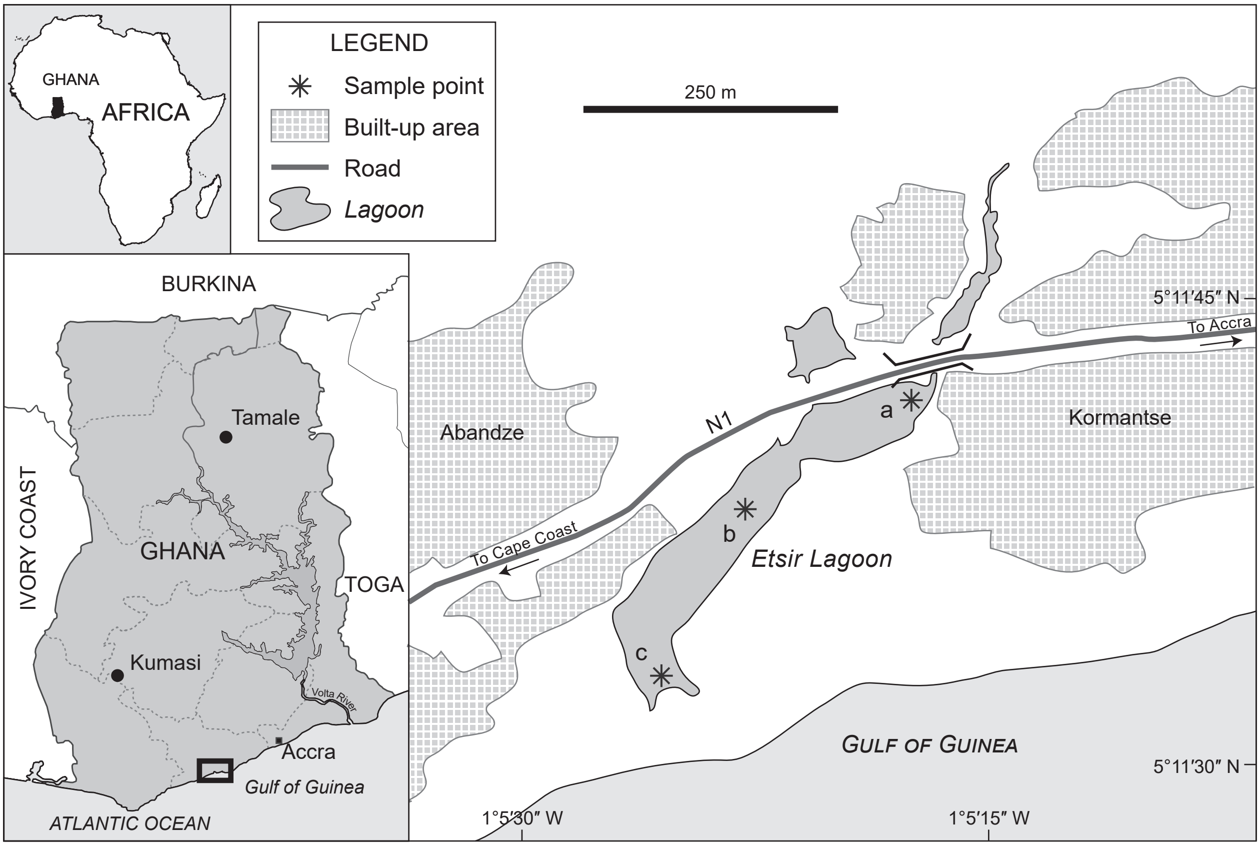

Figure 1: Map of Etsir Lagoon showing approximate fish sampling locations (a, b and c). (Source: Centre for Coastal Management, University of Cape Coast)

a multiparameter water quality checker (Oakton PCD 650): salinity 1.8‰ to 20.1‰; conductivity 11.1 μS cm^{-1} to 38.4 μS cm^{-1}; water temperature 25.8 °C to 32.4 °C; dissolved oxygen 3.2 mg l^{-1} to 6.8 mg l^{-1}, and pH 6.5 to 8.5 (Tibu, 2017). Pesticide concentrations of 1.3626 mg l^{-1} in the water and 0.0088 mg kg^{-1} in muscle tissues of the black-chinned tilapia have been reported by Essumang et al. (2009), values below maximum residue limits. The lagoon is fringed by the red mangrove (*Rhizophora* sp.), white mangrove (*Avicennia* sp.), and black mangrove (*Laguncularia* sp.), all of which are exploited as wood for fuel by the local inhabitants, and patches of the creeping herbaceous plant *Sesuvium* sp. on the sand bar. Fifteen finfish species from nine families, and three shellfish species from two families occur in the lagoon, the dominant fish being the black-chinned tilapia (*Sarotherodon melanotheron melanotheron*) with a numerical composition of 74% (Tibu 2017). This species is exploited for both commercial and subsistence purposes.

Fish sampling and data collection

Black-chinned tilapia samples were taken monthly from the catch of fishers who used cast nets of stretched mesh size 2.5 cm and 3.0 cm, from April 2014 to March 2015. The standard length (SL) of fish was measured to the nearest 0.1 cm using a fish measuring board, and body mass (BW) determined to the nearest 0.01 g with an electronic balance. The length-weight relationship and the length-frequency distribution of the sample and the length-frequency distribution of the fish sampled was determined.

Using the ELEFAN II program in the FiSAT software (Gayanilo and Pauly 1997), the asymptotic length (L_∞, cm) and growth constant (K; yr^{-1}) were determined. The fish age at length zero (t_0) was computed using the equation from Pauly (1983a):

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

The growth parameters (L_∞, K and t_0) were used to fit the von Bertalanffy growth function (VBGF) for the population. The total mortality coefficient (Z) was determined from the length-converted catch curve (Pauly 1983b) and natural mortality coefficient (M) from Pauly's (1980) equation:

$$\log_{10} M = -0.0066 - 0.279\log_{10} L_\infty + 0.6543\log_{10} K + 0.4634\log_{10}T$$

where T is the average temperature (°C) of the aquatic environment. The fishing mortality coefficient (F) and exploitation rate (E) of the stock were computed from the equations of Ricker (1975) as $Z = F + M$ and the $E = F/Z$, respectively.

The longevity or lifespan (t_{max}) of the fish was estimated from the equation $t_{max} = 3/K$ (Pauly, 1984), and the growth performance index (ϕ') computed from the equation (Munro and Pauly 1983; Moreau et al. 1986): $\phi' = \log_{10}K + 2\log_{10}L_\infty$

Results

Fish size distribution

A total of 861 black-chinned tilapia specimens was sampled from the catch of fishers during the study period. The standard length (SL) of the fish ranged from 3.9 cm to 13.8 cm, and body mass ranged from 2.41 g to 91.74 g. The overall length-frequency distribution of the population shown in Figure 2 indicates a mode in the 7.0–7.9 cm SL class.

Length-weight relationship

Figure 3 shows the relationship between the logarithmic transformed length and weight data for *Sarotherodon melanotheron melanotheron* in the lagoon, which is described by the following linear equation:

$$\log BW = 2.87 \times \log_{10}SL - 1.34$$

where BW is body weight (g), and SL is standard length (cm). Fish weight was then related to length using the following power function:

$$BW = 0.046SL^{2.87} \text{ g}$$

The exponent (b = 2.87) was not significantly different from 3.0 (t = 4.5; $p > 0.05$), which suggests isometric growth of this tilapia population.

Growth and mortality parameters

Analysis of the length-frequency data from the 861 specimens using the ELEFAN I program provided estimates of the asymptotic length (L_∞) as 14.3 cm SL, and growth constant (K) as 0.93 yr^{-1}. Substitution of the L_∞ and K values into Pauly's (1983a) equation gave t_0 as −0.21 yr. On an annual basis, the growth of the tilapia population in Etsir Lagoon was described by the von Bertalanffy growth equation:

$$L_t = 14.3\,[1 - \exp(-0.93(t + 0.21)]\text{ cm SL}$$

where L_t is length of the fish at age t. The monthly length frequency distribution of the population with the superimposed growth curve is illustrated in Figure 4, which shows irregular shifts in modal length of the fish during the year.

The VBGF of the Etsir lagoon tilapia (Figure 5) shows that growth of the fish was rapid during the first year, but slowed down thereafter up to the fourth year. The growth performance index of the population was computed as 2.28, and longevity (t_{max}) of the species as 3.2 years. The latter result indicates a relatively short lifespan of the tilapia in the lagoon.

Figure 6 illustrates the length-converted catch curve for the lagoon tilapia population. The slope of the regression equation derived from the data on the descending part of the curve (Pauly 1983b) gave a total mortality coefficient (Z) of 5.09 yr^{-1} for the population.

Substituting the annual mean temperature of the lagoon (29.4°C) and estimated growth parameters of the fish in the empirical equation of Pauly (1980) gave a natural mortality coefficient (M) of 2.15 yr^{-1} for the species, hence the fishing mortality coefficient (F) of the population was derived as 2.94 yr^{-1}, and the exploitation rate (E) as 0.58.

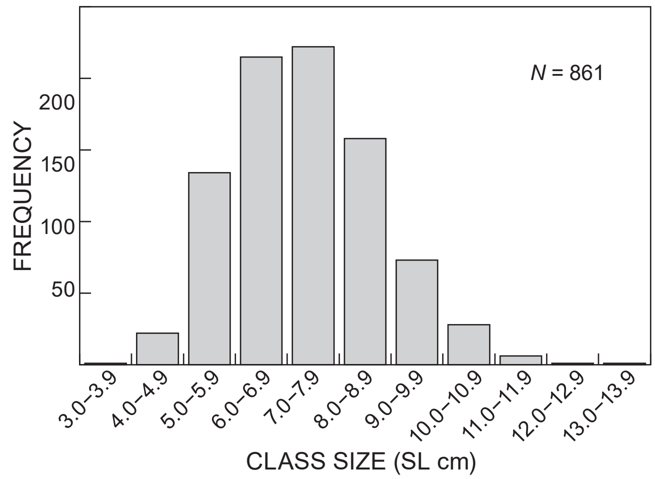

Figure 2: Length-frequency distribution of *Sarotherodon melanotheron melanotheron* from Etsir Lagoon

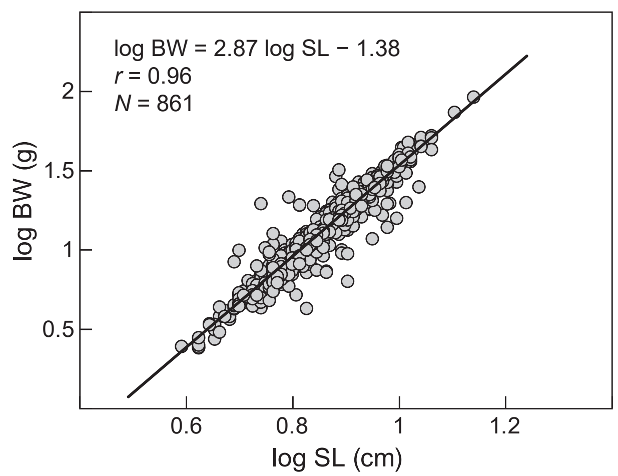

Figure 3: Length-weight relationship of *Sarotherodon melanotheron melanotheron* from Etsir Lagoon. BW = body weight (g), SL = standard length (cm)

Recruitment pattern

The recruitment pattern of the population indicates all-year-round recruitment of individuals into the population with a major peak in April and a minor peak in September (Figure 7).

Discussion

Results obtained from the current study indicate a fast growth rate (K = 0.93 yr^{-1}) and a small maximum theoretical length (L_∞ = 14.3 cm SL) for the black-chinned tilapia (*Sarotherodon melanotheron melanotheron*) in Etsir Lagoon. Estimates of these parameters are within the ranges (K = 0.61 to 1.25 yr^{-1}, and L_∞ = 10 to 16.4 cm SL) reported for some brackish water populations in the Central Region of Ghana (e.g. Blay and

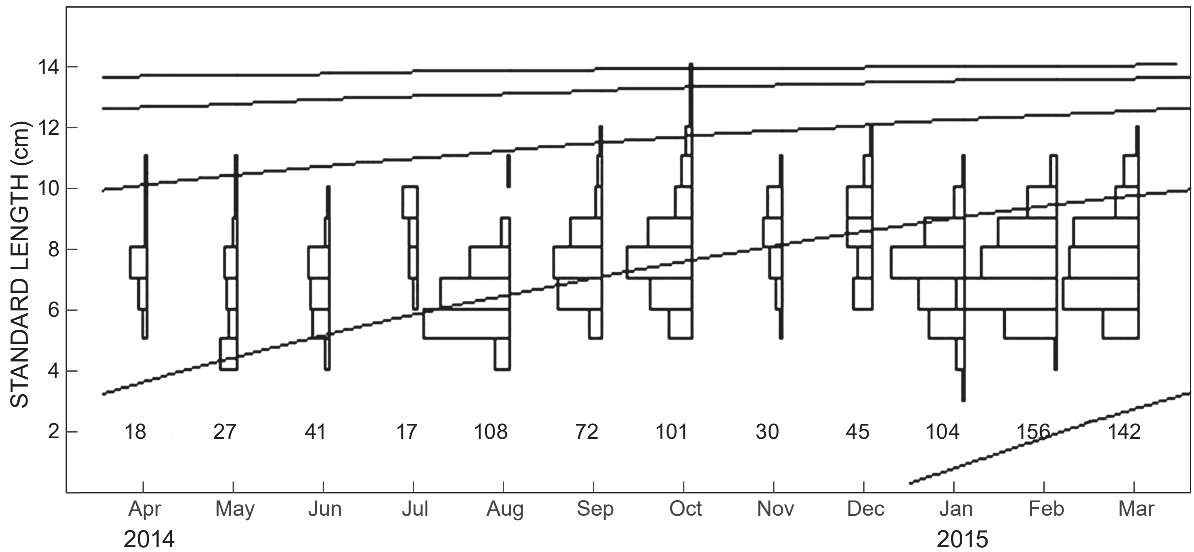

Figure 4: Monthly length-frequency distribution of *Sarotherodon melanotheron melanotheron* population in Etsir Lagoon with a superimposed growth curve. The growth curve lines constitute segments of a single growth curve. Numbers indicate monthly sample sizes

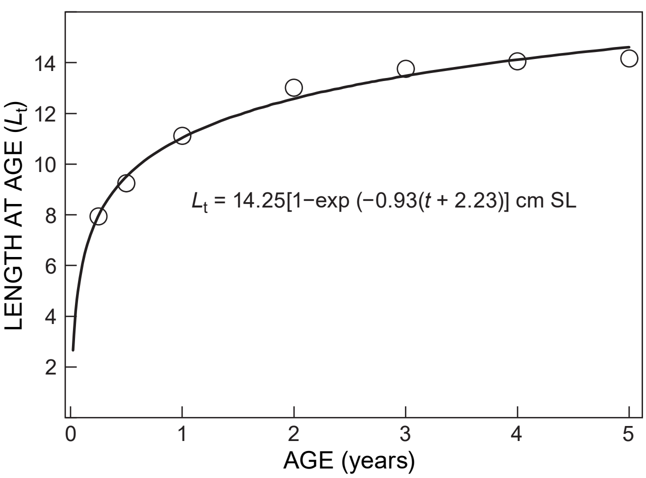

Figure 5: Derived growth curve of *Sarotherodon melanotheorn melanotheron* in Etsir Lagoon

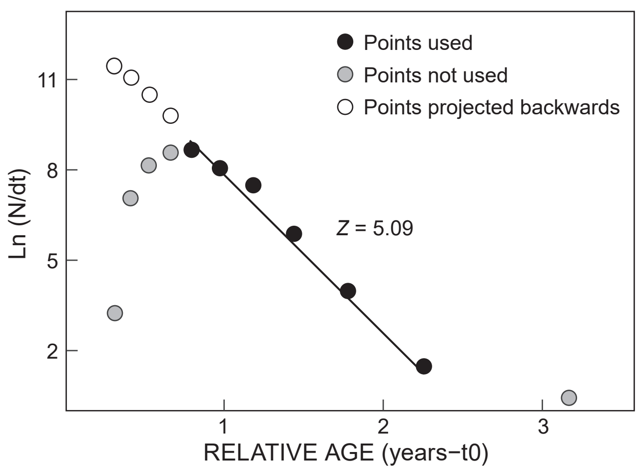

Figure 6: Length-converted catch curve of *Sarotherodon melanotheron melanotheron* from Etsir Lagoon

Asabere-Ameyaw 1993; Koranteng et al. 1997; Blay 1998; Entsua-Mensah 1998; Koranteng et al. 2000). However, the growth characteristics of the black-chinned tilapia in Ghana clearly differ from the species in larger brackish water systems, such as Lagos Lagoon (Nigeria), where K was determined as 0.16 yr^{-1} and L_∞ as 33 cm (Pauly et al. 1988), and the Togo Lagoon where K was 0.44 yr^{-1} and L_∞ as 32.6 cm (Laë 1997).

The fast growth rate, small asymptotic length and short lifespan of the Etsir Lagoon tilapia are indications of accelerated growth and life cycle of the fish, which corresponds with an 'altricial' mode of life shown by populations inhabiting stressful environments (Gunderson 1980; Noakes and Balon 1982). Species with such characteristics tend to mature early and complete their life cycle over a short period of time before they die from prevailing unfavourable conditions. Other factors, such as high population density and intraspecific competition, may also contribute to this condition; however, the high exploitation rate (E = 0.58) of the fish in the lagoon may be a key factor. Because of its small surface area 0.027 km^2 and shallowness (1.3 m maximum depth), Etsir Lagoon may be subject to rapid fluctuations in environmental conditions that could exert stress on fish. Furthermore, the fish population may be exposed to high predation pressure by birds and reptiles and high fishing pressure, as a result of the fish aggregating in the much smaller environment. In Etsir Lagoon, the current maximum fishing effort of 10 fishers per day is equivalent to a fishing intensity of approximately 4 fishers ha^{-1}. This seems very high compared with the average effort of 39 fishers and fishing intensity of 0.6 fishers ha^{-1} determined for Fosu Lagoon (Blay and Asabere-Ameyaw 1993).

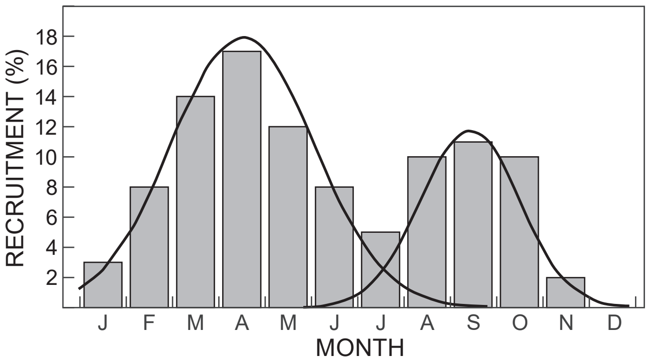

Figure 7: Annual recruitment pattern of *Sarotherodon melanotheron melanotheron* from Etsir Lagoon

The estimated growth performance index (ϕ') of 2.28 for the population in Etsir Lagoon is not appreciably different from 2.14 and 2.05 determined for the Benya Lagoon and Kakum River estuary populations, respectively (Blay 1998). However, a higher growth performance (2.6) was estimated for the fish in the Dominli Lagoon (Arizi et al. 2015) and this might explain the greater modal length (10 cm SL) and maximum theoretical length (20.5 cm SL) of this population, compared with other lagoon populations in Ghana.

Estimates of the fishing and natural mortality coefficients of *S. m. melanotheron* in Etsir Lagoon indicated that the former contributed about 60% of the total mortality of the fish. Although the current exploitation rate (E) of 0.58 of the stock in Etsir Lagoon suggests that it is overexploited, this rate does not differ significantly from the optimum fishery exploitation level (E = 0.5) (Gulland 1971), and might be suggestive of active utilisation of the stock. Similar exploitation rates were reported in the cast net fishery of other lagoons in Ghana, such as the Fosu Lagoon (E = 0.62; Blay and Asabere-Ameyaw 1993), Sakumo Lagoon (E = 0.61; Koranteng et al. 1997), and Abrubi Lagoon (E = 0.64; Entsua-Mensah 1998).

The all-year-round recruitment in the population for the black-chinned tilapia in Etsir Lagoon suggests that the species breeds throughout the year, consistent with observations on populations in other West African lagoons (Legendre and Ecoutin 1989; Blay and Asabere-Ameyaw 1993; Blay 1998; Koné and Teugels, 2003; Arizi et al. 2015). This habit probably sustains recruitment of the population, despite the relatively high fishing mortality. In this regard, it would be prudent to maintain the number of fishers operating in the lagoon at the current maximum of 10 per day to keep the exploitation level near the optimum (E = 0.5), and therefore avert possible collapse of the stock.

Conclusions

The results of the current study revealed that the black-chinned tilapia *S. m. melanotheron* in Etsir Lagoon is stunted. The population is characterised by a fast growth rate (K = 0.93 yr^{-1}), short maximum theoretical length (L_∞ = 14.3 cm SL), and short lifespan (t_{max} = 3.2 years). Fishing pressure is the main source of mortality in the population. The current exploitation level though slightly above the optimum level may not adversely impact productivity of the stock, because of the continuous recruitment activity. It is therefore recommended that the current maximum fishing effort of 10 fishers per day be maintained, or the effort be reduced to allow the fish to grow to a larger size. Although some parameters determined in this study support occurrence of stunting in the population, the reproductive biology of the fish requires detailed investigations to determine its size at maturity and maturity-length ratio, important indices for confirmation of stunted growth in the fish.

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References

Arizi EK, Aggrey-Fynn J, Obodai EA. 2015. Growth, Mortality and Exploitation Rates of *Sarotherodon melanotheron* in the Dominli Lagoon of Ghana. *Momona Ethiopian Journal of Science* 7(2): 258–274.

Blay J. 1998. Growth and mortality parameters of *Sarotherodon melanotheron melanotheron* (Teleostei: Cichlidae) in two brackish water systems in Ghana. *Ghana Journal of Science* 38: 47–55.

Blay J , Asabere-Ameyaw A. 1993. Assessment of the fishery of a stunted population of the cichlid, *Sarotherodon melanotheron* (Ruppell), in a closed lagoon in Ghana. *Journal of Applied Ichthyology* 9: 1–11.

Entsua-Mensah M. 1998. *Comparative studies of the dynamics and management of fish populations in an open and closed lagoon in Ghana*. PhD thesis, University of Ghana.

Essumang DK, Togoh GK, Chokky L. 2009. Pesticide residues in the water and fish (lagoon tilapia) samples from lagoons in Ghana. *Bulletin of the Chemical Society of Ethiopia* 23(1): 19–27.

Fagade SO. 1973. *Age determination in Tilapia melanotheron* (*Ruppell*) *in the Lagos lagoon, Lagos, Nigeria*, In: Bagenal TB (Ed.), *Ageing of fishes.* (pp. 71–77). Old Working, England: Unwin Brothers Ltd.

FAO. 1969 *Fisheries survey in the western and mid-westem regions*. Nigeria. Final Report. Rome, Italy: FAO/SF: 74/NIK/6: 142 pp

Gayanilo FC, Pauly D. 1997. *The FAO-ICLARM Stock Assessment Tools* (*FiSAT*). Reference Manual (No. 8). FAO Computerised Information Series (Fisheries) (262). Rome, Italy: FAO.

Gulland JA. 1971. The fish resources of the ocean. Revised edition of FAO Fisheries Technical Paper (97): (1970). 425 p. West Byfleet, Surrey: Fishing News (Books).

Gunderson DR. 1980. Using r-K selection theory to predict natural mortality. *Canadian Journal of Fisheries and Aquatic Sciences* 37: 2266–2271

Koné T, Teugels GG. 2003. Food habits of brackish water tilapia *Sarotherodon melanotheron* in riverine and lacustrine environments of a West African coastal basin. *Hydrobiologia* 490: 75–85.

Koranteng KA, Entsua-Mensah, M, Ofori-Danson PK. 1997. The current status of the fishery of Sakumo II Lagoon in Ghana. *Ghana Journal of Science* 37: 59–66.

Koranteng KA, Ofori-Danson PK, Entsua-Mensah, M. 2000. Fish and fisheries of the Muni Lagoon in Ghana, West Africa. *Biodiversity and Conservation* 9: 487–499.

Laë R. 1997. Does overfishing lead to a decrease in catches and yield? An example of two West African lagoons. *Fisheries Management and Ecology* 4: 149–164.

Lederoun D, Chikou A, Vreven E, Snoeks J, Moreau J, Vandewalle P, Lalèyè P. 2015. Population parameters and exploitation rate of *Sarotherodon melanotheron melanotheron*. Rüppell, 1852 (Cichlidae) in Lake Toho, Benin. *Journal of Biodiversity and Environmental Sciences* 6(2): 259–271.

Legendre M, Ecoutin JM. 1989. Suitability of brackish water tilapia species from the Ivory Coast for lagoon aquaculture. I-Reproduction. *Aquatic Living Resources*. 2: 71–79.

Moreau J, Bambino C, Pauly D. 1986. *Indices of overall growth performance of 100 tilapia* (*Cichlidae*) *populations*, In: Maclean JN, Dizon LB, Hesillas LV (Eds). The First Asian Fisheries Forum. pp 20–206., Manila, Philippines: Asian Fisheries Society.

Munro JL, Pauly D. 1983. A simple method for comparing the growth of fishes and invertebrates. *Fishbyte* 1: 5–6.

Niyonkuru C, Lalèyè P, Villanueva MC, Moreau J, 2007. Population parameters of main fish species of Lake *Nokoué,* Benin, *Journal of Afrotropical Zoology* 3(Special issue): 149–155.

Noakes DLG, Balon EK. 1982. *Life histories of tilapia: an evolutionary perspective.* In: Pullin RSV, Lowe-McConnell RH (Eds). *The Biology and Culture of Tilapias*. pp 61–82. ICLARM Conference Proceedings 7: 432 pp. Manila, Philippines: ICLARM.

Ntiamoa-Baidu Y. 1991. Conservation of coastal lagoons in Ghana: The traditional approach. *Landscape and Urban Planning* 20: 41–46.

Pauly D. 1976. The biology, fishery and potential for aquaculture of *Tilapia melanotheron* in a small West African lagoon. *Aquaculture (Amsterdam, Netherlands)* 7: 33–49

Pauly D. 1979. Theory and management of tropical multispecies: a review with emphasis on the Southeast Asian demersal fisheries. 35 p. ICLARM Studies of Reviews 1. Manila, Philippines: ICLARM.

Pauly D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *Conseil Permanent International pour l'Exploration de la Mer* 39: 175–192.

Pauly D. 1984. Length-converted catch curve: A powerful tool for fisheries research in the tropics. Part (2) *Fishbyte* 2(1): 17–19.

Pauly D. 1983a. Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Technical Paper No. 234. Rome: FAO.

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

Pauly D, Moreau J, Palomares MLD. 1988. Detritus and energy consumption and conversion efficiency of Sarotherodon melanotheron (Cichlidae) in a West African Lagoon. *Journal of Applied Ichthyology* 4: 190–193.

Ricker WE. 1975. Computation and interpretation of statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, Bulletin 191. Ottawa, Canada: Fisheries Research Board of Canada.

Sparre P, Venema SC. 1992. Introduction to tropical fish stock assessment. Part 1. Manual (Fisheries Technical Paper No. 306/1 Rev. 1 FAO). Rome, Italy: FAO.

Tibu GA. 2017. Aspects of the ecology of Etsir Lagoon: implications for small-scale fisheries management at Abandze, Ghana. MPhil thesis, University of Cape Coast, Ghana.

Welcomme RL. 1972. An evaluation of the acadja method of fishing as practiced in the coastal lagoons of Dahomey (West Africa). *Journal of Fish Biology* 4: 39–55.

Yankson K, Obodai EA. 1999. An update of the number, types and distribution of coastal lagoons in Ghana. *Journal of the Ghana Science Association* 2: 26–31.

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