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Assessment of Exploited Population Dynamics of African Butter Catfish (*Schilbe mystus*) in Stratum VII of Lake Volta, Ghana

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ABSTRACT

The current study aimed to assess the population status of *Schilbe mystus* in stratum VII of Volta Lake, Ghana, based on length-frequency data collected throughout 2021. Individual fish samples, ranging from 5.5 to 22.0cm with a mean length of 11.5± 0.17cm, were analyzed using FiSAT II. The study revealed a mean condition factor of 0.36, indicating the fish's overall health. The growth pattern, estimated at 3.1 suggested positive algometric growth. The growth rate (K) was determined as 0.25 per year. Length at infinity (L∞), length at first capture (Lc50), and length at first maturity (Lm50) were calculated as 24.7, 10.27, and 16.47cm, respectively. The growth performance index was recorded at 2.58. The total mortality rate (Z) was calculated as 2.09 per year, with the natural mortality rate (M) at 0.78 per year and the fishing mortality rate (F) at 1.31 per year. The exploitation rate was 0.63, indicating overexploitation of *S. mystus* in Stratum VII. To sustain the stock size of the *S. mystus* fishery in Lake Volta, we recommend reducing fishing efforts, regular status assessments, and enforcement of fisheries regulations.

INTRODUCTION

Ghana's fisheries sector plays an important source of food and nutritional security, contributing about 5% to the annual GDP and supporting the livelihoods of over 2.6 million Ghanaians **(FAO, 2016)**. The sector continues to play an important role in achieving the targets of the sustainable development goals. The African butter catfish (*S. mystus*) is a freshwater demersal and potamodromous fish belonging to the family Schilbeidae **(Garcia *et al.*, 2010; Diouf *et al.*, 2020)**. These species are distributed from the Nile basin and West Africa from the Senegal River eastward to the Cross, Wouri, and Sanaga Rivers, including the Chad basin **(De Vos, 1995)**.

According to **Azeroual *et al.* (2010)**, *S. mystus* adapts to running and stagnant waters, often forming shoals in standing or slowly flowing open water with emergent or submerged vegetation. Additionally, it can be found in sandy streams, rocky streams, standing deep water, abundant in shallow swamps, and occasionally in shallow flood plains. Generally, the *S. mystus* is more active at night or in subdued light and feeds from mid- water and surface waters on a wide variety of foods, including fish larvae, insects, shrimps, snails, plant seeds, and fruit **(Omondi & Ogari, 1994)**. *S. mystus* is oviparous breeding during the rainy season. It may act as either single or multiple spawner in various localities, and it lays eggs on vegetation **(Azeroual *et al.*, 2010)**.

The harvesting of *S. mystus* is mostly for human consumption serving as a delicacy for many low- income earners since it is cherished for its taste, affordable price, and is of a considerable commercial importance **(Ayoade *et al.*, 2008; Diouf *et al.*, 2020)**. Water pollution, overfishing, and drought are some of the threats facing the stock status of *S. mystus*. This has resulted in the declining stock size of *S. mystus* in many lakes globally including Lake Volta, Ghana **(Diouf *et al.* 2020)**. However, *S. mystus* is categorized as 'Least concern (with a lower risk of extinction)' by the International Union of the Conservation of Nature **(Diouf *et al*., 2020)**.

In general, limited research studies and information have been found on the population dynamics of *Schilbe mystus* **(Ayaode, 2007; Lebo *et al.*, 2009)**. **Lebo *et al.* (2009)** studied the breeding seasonality and population dynamics of the catfish *Schilbe mystus* (Schilbeidae) in the Cross River, Nigeria. Nevertheless, the study of **Ayaode (2007)** addressed the age and growth of the African butter catfish, *Schilbe mystus* in Asejire and Oyan Lakes, south-western Nigeria. In data- deficient fisheries such as Ghana, attaining sustainable fisheries management is a huge challenge. Currently, there is paucity of information on the population dynamics of *Schilbe mystus* in Ghana, which is hampering the management of the fishery. Therefore, this study aimed to assess the population status of *Schilbe mystus* from Stratum VII of Lake Volta in Ghana.

MATERIALS AND METHODS

Study area

The study focused mainly on four landing communities within Stratum VII of Lake Volta. These sampling locations lie between longitudes 0°10' and 1°05'W and latitudes 8° 8' and 8° 20'N. This area extends 60km south and 50km north Yeji in the South. These communities are Tonka, Vutideke, Brekente, and Fante Akura, which are all landing sites within the Stratum VII of Lake Volta (Fig. 1). Yeji is the capital of Pru District in the Bono East Region, with a population of 29,515 **(GSS, 2014)**. Some livelihoods in these communities are fishing, fish processing, agriculture, livestock rearing, petty trading and cassava dough processing.

Data collection

Fish samples were randomly purchased from fish landing sampling communities within the stratum VII (Yeji) on a monthly basis from January to December 2021. Random sampling was applied to ensure that all fishermen had an equal opportunity to select. Fish samples purchased were sorted to the species level at the landing sites using identification keys, as indicated by **McConnell and Wuddah (1976)**. The weight of the fish was taken to the nearest 0.01g using an electric weighing scale. The sampled fish were kept on ice before the morphometric measurement was taken. Subsequently, a graduated measuring board of 100cm was used to measure the total length of fish species to the nearest 0.1cm at the study site.

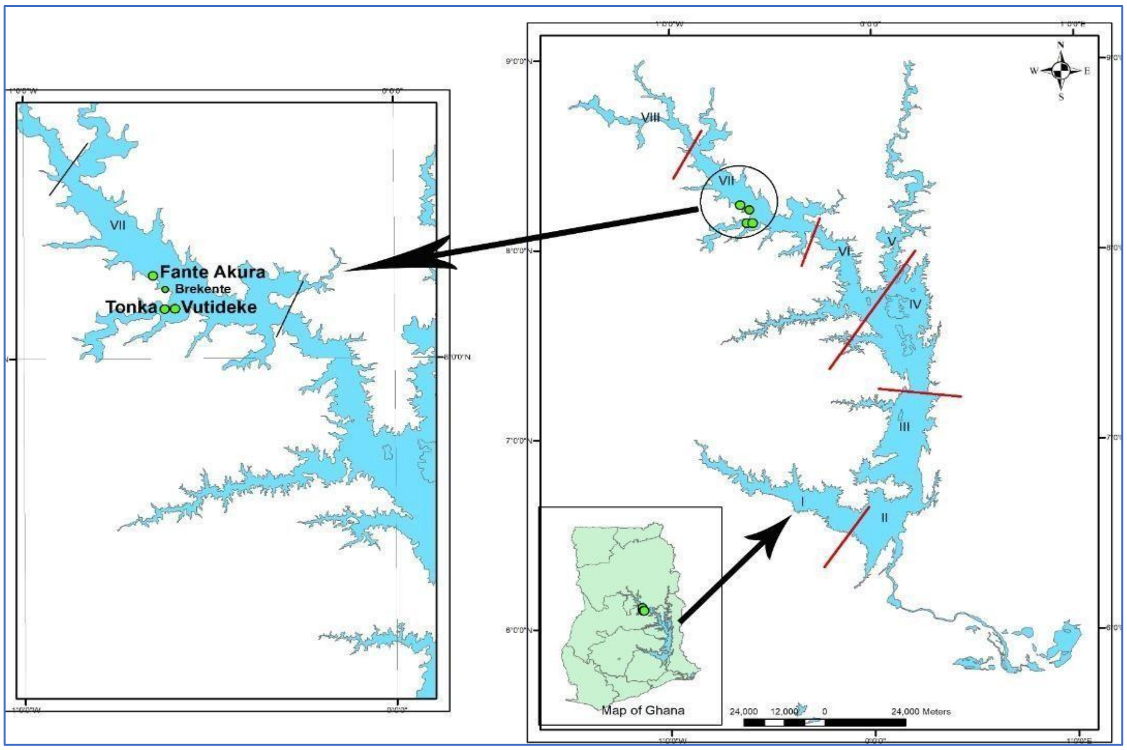

Fig. 1. Map of the study areas showing Stratum VII of the Volta Lake, Ghana

Measurements and estimation of parameters

The following measurements and estimations were carried out; length- frequency distribution, length- weight relationship, condition factor, growth parameters, mortality rates, length at first maturity, probability of capture, relative yield per recruit (Y/ R) and relative biomass per recruit (B/ R).

Length- frequency distribution

The fish were grouped into different size classes of 1cm interval. MS Excel (2016) was used for data treatment and determining the length frequency. During the study, a total of 326 fish specimens of *S. mystus* were measured for the length- frequency data.

Estimation of the length- weight relationship

The total length and body weight of fish were used for the length-weight relationship. The length-weight relationship was calculated using the regression equation, as implemented by **Le Cren (1951)**, as follows:

$$W = a * TL^b$$

Where, W = Total body weight of fish (g); TL = Total length of fish (cm); "a" = Regression constant, and "b" = Regression coefficient; it's also allometric growth coefficient. The value of "b" provides information on the fish growth type. The association degree between length–weight variables was calculated by the correlation coefficient (R^2), and its statistical significance level was assessed following the method indicated by **Santos *et al.* (2002)**, as follows:

$$\text{Log } W = \text{Log } a + b \text{ Log } TL$$

If b = 3, it means that the growth is isometric, and when $b \neq 3$, the growth is allometric (negative allometric if $b < 3$ and positive allometric if $b > 3$).

Condition factor

The condition factor (K) of the experimental fish was estimated from the relationship using the method attributed to **Pauly (1983)**, as follows:

$$K = 100 W / L^b$$

Where, W = Weight of the fish in grams; L = The total length of the fish in centimeters, and b = Value obtained from the length-weight equation formula.

Growth parameters

Growth parameters following the von Bertalanffy Growth Function (VBGF) including growth rate (K) and asymptotic length ($L\infty$) were estimated using the electronic length frequency analysis. von Bertalanffy Growth Function (VBGF) was given as follows:

$$L_t = L_\infty\left(1 - e^{-K(t - t_o)}\right)$$

Where, L_t is the expected or average length at time (or age) t; L_∞ is the asymptotic average length; K is the so-called growth rate coefficient (yr^{-1}), and t_o represents the time or age when the average length was zero.

The estimation of longevity (t_{max}) of the species was done following the method indicated by **Anato (1999)**, as follows:

$$t_{max} = 3/ K$$

The growth performance index was calculated using the formula indicated by **Pauly and Munro (1984)**, as follows:

$$\Phi' = 2\log L\infty + \log K$$

The theoretical age at length zero (t_0) followed the equation that is pointed out by **Pauly (1979)**, as follows:

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

Mortality rates

Total mortality (Z) was computed using a linearized length converted catch curve, as shown by **Sparre and Venema (1992)**. It is given as Z = M + F; where Z is the instantaneous rate of total mortality; M is the instantaneous rate of natural mortality, and F is the instantaneous rate of fishing mortality.

The natural mortality rate (M) was calculated using **Pauly's (1980)** empirical formula at a temperature (T) of 29.5 ^oC: $\log_{10}M = -0.0066 - 0.279\log_{10}L\infty + 0.6543\log_{10}K + 0.4634\log_{10}T$

Fishing mortality (F) was calculated as Z – M following the method of **Qamar *et al.* (2016)**.

The exploitation rate (E) was computed using E = F/ Z formula, as indicated by **Georgiev and Kolarov (1962)**.

Length at first maturity

The estimation of length at first maturity (Lm_{50}) is considered a vital tool in the management of fish stock, and it is of great importance in the determination of optimum mesh size for sustainable exploitation of fish stock **(Arizi *et al.*, 2015)**. The length at first sexual maturity (Lm_{50}) was estimated following the formula of **Hoggarth *et al.* (2006)**, as follows:

$$Lm_{50} = 2L\infty / 3$$

Probability of capture

The length at first capture was estimated based on the cumulative probability of capture against mid-length. From the resultant curve, the length at first capture (Lc_{50}) which is defined as the mean total length at which 50% of the fish caught, was taken as corresponding to the cumulative probability at 50%. This procedure followed the methods by **Beverton and Holt (1956)** and **Sparre and Venema (1998)**, as follows:

$$Lc_{50} = [TL - K(TL\infty - TL')]/ Z$$

Where, Lc_{50} is the length at first capture, and TL' is the mean length of fish in the catch sample. In addition, the length at both 75 and 95% capture correlates with the cumulative probability at 75 and 95%, respectively, as indicated by **Pauly (1983)**.

Relative yield per recruit (Y/ R) and relative biomass per recruit (B/ R)

Regarding a function of exploitation rate 'E', relative yield per recruit (Y/ R) and relative biomass per recruit (B/ R) values were estimated using the growth parameters and the probability of capture by length methods used by **Pauly and Soriano (1986)**. As a result, the maximum allowable limit of exploitation (E_{max}) representing the maximum relative yield- per- recruit, the exploitation rate at which the marginal increase in relative yield-per-recruit is $E_{0.1}$ and $E_{0.5}$, the exploitation rate corresponding to 50% of the unexploited stock, were computed.

Data analysis

The FiSAT II tool was used to assess the population parameters, such as asymptotic length ($L\infty$), growth rate (K), growth performance index (Φ'), natural mortality rate (M), fishing mortality rate (F), exploitation rate (E), and relative yield per recruit indicators of samples from the assessed fish species encountered during the study period **(Gayanilo *et al.*, 1996)**.

RESULTS

Length- frequency distribution

The total length *of S. mystus* (N = 326) ranged from 5.5 to 22.6cm with a mean total length of 11.5± 0.17cm. The length- frequency distribution showed a bimodal distribution (Fig. 2).

The graphical representation of the estimated length-weight relationship (Fig. 3) shows a good fit for *S. mystus* data: $W = 0.0025TL^{3.147}$ ($R^2 = 0.99$). This study's results showed that the slope of the regression equation (b = 3.147) for this species was significantly different ($P < 0.05$) from the isometric value of 3, depicting a positive allometric growth (Fig. 3). The condition factor of the species was 0.36.

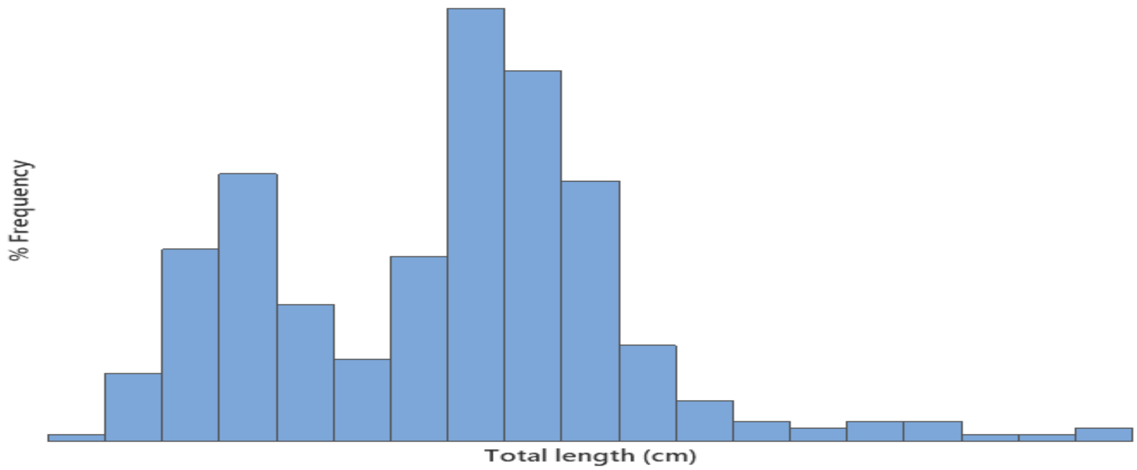

Fig. 2. Length- frequency of *S. mystus* from Volta Lake, Ghana

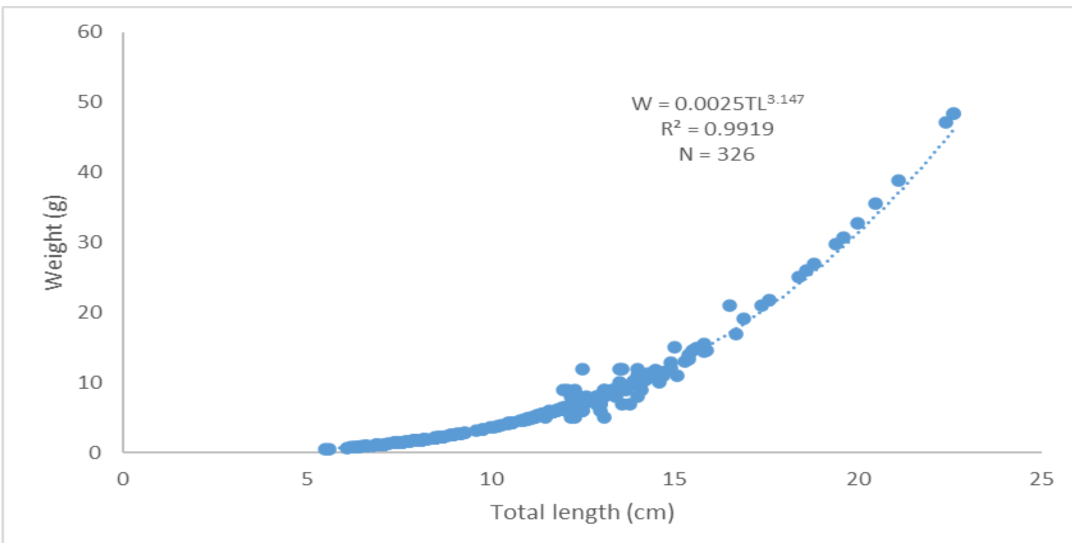

Fig. 3. Linearized length-weight relationship of *S. mystus* from Volta Lake, Ghana

Growth parameters

Fig. (4) shows the restructured length frequency of *S. mystus* growth curves. The asymptotic length ($L\infty$), and the annual growth coefficient (K) assessed through the K-scan technique ELEFAN I routine were 24.7cm and 0.25 year^{-1}, respectively. The growth performance index (Φ') was 2.58; the age at zero length was estimated as - 0.71, and the longevity (t_{max}) was 6 years. The von Bertalanffy equation for growth in length of *S. mystus* derived from the parameters obtained in the present study is written as follows: $TL_t = 24.7* (1– e^{-0.25\ (t+0.71)})$.

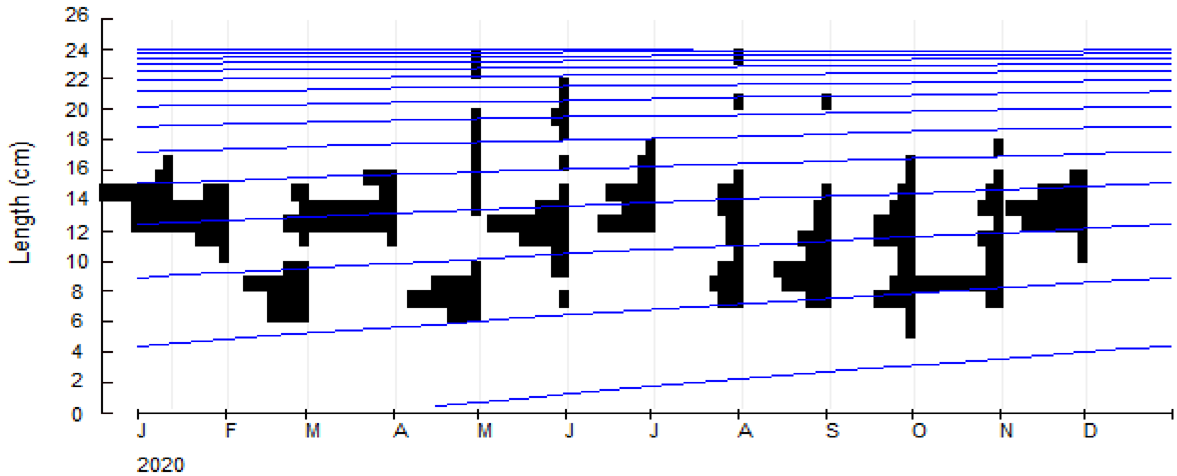

Fig. 4. vBGF plot of *S. mystus* from Volta Lake, Ghana

Length at first capture and maturity

The length at first capture (Lc_{50}) was 10.27cm. The lengths at 25% (Lc_{25}) and 75% (Lc_{75}) of catch probability were estimated as 9.43 and 11.11cm, respectively (Fig. 5). The length at first maturity (Lm_{50}) of *S. mystus* was estimated as 16.47cm.

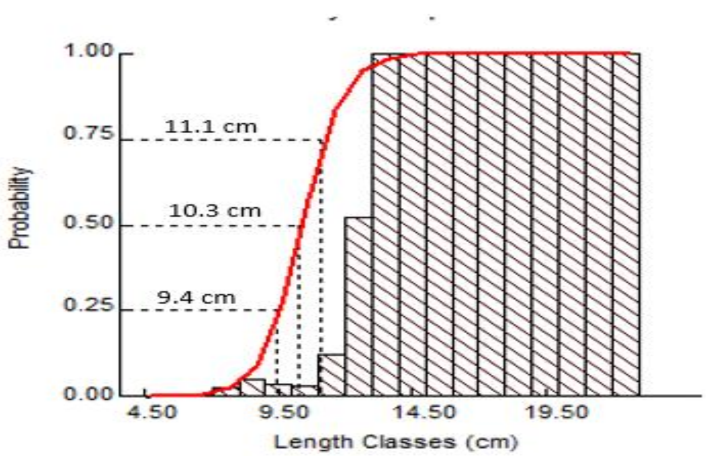

Fig. 5. Length at first capture of *S. mystus* from Volta Lake, Ghana

Mortality rate

The total mortality rate (Z), natural mortality rate (M) at 29.5^{o}C and fishing mortality rate (F) were estimated as 2.09, 0.78, and 1.31year^{-1}, respectively (Fig. 6). The exploitation rate (E) was 0.63.

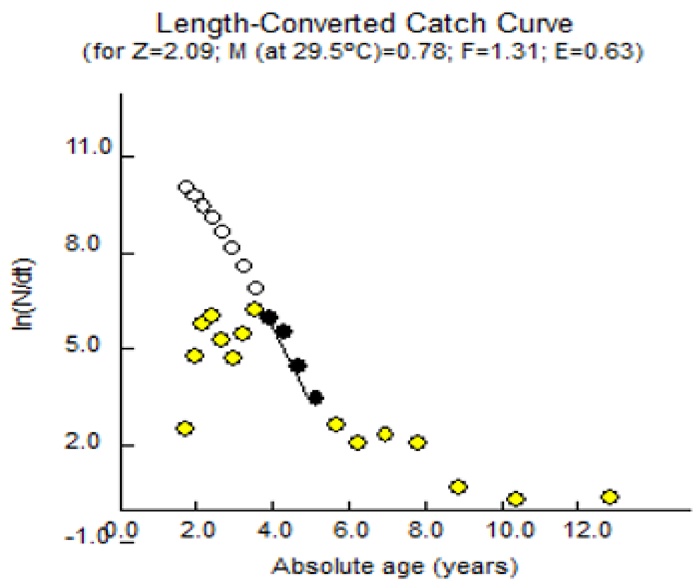

Fig. 6. Length- converted catch curve of *S. mystus* from Volta Lake, Ghana

Relative yield and relative biomass per recruit

Fig. (7) displays the relative Y'/ R and B'/ R analysis estimated using $Lc_{50}/ L\infty$ = 0.42 and M/ K = 3.12 as input for the knife- edge selection procedure. The maximum allowable limit of exploitation level (E_{max}) that gives the maximum relative Y'/ R was 0.81. The exploitation level ($E_{0.1}$) at which the marginal increase in relative yield per recruit is 10% of its value was 0.67; whereas, the exploitation level ($E_{0.5}$) which corresponds to 50% of the relative B'/ R of an unexploited stock was 0.35.

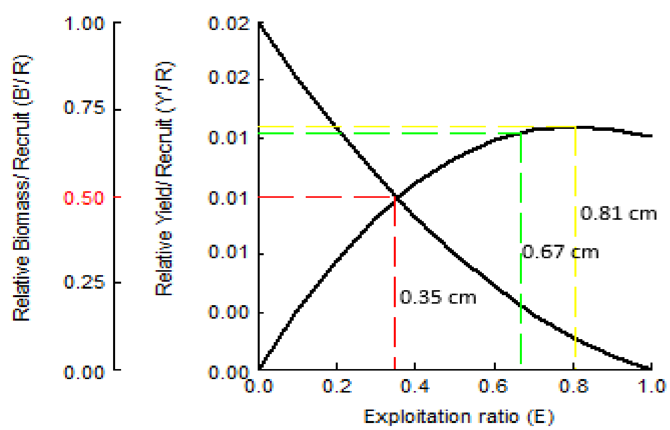

Fig. 7. Relative yield per recruit of *S. mystus* from Volta Lake, Ghana

DISCUSSION

Length frequency

The length range of the *S. mystus* from the current study was 5.5- 22.6cm, with a mean value of 11.5± 0.7cm. The descriptive statistics of the length measurement of the assessed fish species were at variance with other studies carried out in other geographical locations. For instance, the range of size for *S. mystus* from the Lekki Lagoon, Nigeria was 10.1– 20.7cm with a mean value of 16.7cm **(Taiwo, 2010)**. **Adesoun (2019)** from the River Ogun, Nigeria recorded the length range for *S. mystus* to be 11.0- 28.9cm using total length. Furthermore, **Ayoade (2011)** recorded the total length range for *S. mystus* to be 10.0- 18.7cm and 10.8– 18.0cm for Oyan Lake and Asejire Lake, respectively. The difference in sizes could be due to numerous factors, viz. the type of length measurement used (i.e. whether standard or total length), the fishing pressure, and the mesh sizes available. For instance, using standard length instead of total length leads to relatively smaller length sizes than using the total length. Continued high fishing pressure removes large-sized fish species from the ecosystem leading to small-sized fish species in a phenomenon called fishing down the food web.

Condition factor

The condition factor (K) of a fish reflects physical and biological circumstances and fluctuations by interaction among feeding conditions, parasitic infections, and physiological factors **(Le Cren, 1951)**. This correspondingly indicates the changes in food reserves, serving as an essential indicator of the general fish condition **(Datta *et al.*, 2013)**. Good growth condition of the fish is deduced when K> 1, while fish is considered to be in poor growth condition when K< 1 **(Jisr *et al.*, 2018)**. Moreover, **Bagenal and Tesch (1978)** posited that the condition factor 'K'≥ 0.5 indicates the proper well- being of the fish. The mean condition factor estimated for this study was 0.36 which is lower than the estimate calculated by **Olagbemide (2010)** from the Lekki lagoon which was 0.72. The current result is an indication of poor growing conditions. This finding suggests that the species might be physiologically stressed. The observed changes in mean condition factors, when compared to **Olagbemide (2010)**, may be due to seasonality, as well as other biological factors, such as the sexes, spawning period, and environmental factors like water temperature.

Length- weight relationship

The estimate for the growth pattern of *S. mystus* for the current study was significantly more than 3.0, implying a positive allometric growth pattern (i.e. the growth rate of length was slower than that of weight). This shows that the species become fatter as they grow, an indication that there is a change along with their ontogenetic growth **(Olagbemide, 2010)**. The growth pattern (b) estimated for the current study was lower than the estimates recorded from Lake Asejire (3.240) and Lake Oyan (3.384), as reported by **Ayaode (2011)**. However, it is slightly higher than the estimate by **Olagbemide (2010)**, who reported 2.94 for *S. mystus* from the Lekki lagoon, Nigeria. The difference in estimates could be attributed to seasonal fluctuations of the environmental parameters, physiological conditions of the fish at the time of collection, sex, gonad development, and nutritive conditions **(Froese, 2006)**. Additionally, **Tesch (1971)** ascribed changes in the growth pattern of fish species to the geographical location, degree of stomach fullness, preservation techniques, and differences in the observed length ranges of the specimen caught might also affect the length- weight relationship in the fish.

Growth parameters

The estimated growth rate (K) from the current study (K = 0.25 per year) was relatively lower than the estimates obtained by **Ayaode (2007)** and **Lebo *et al.* (2009)**. The growth rate obtained from the current study was lower than 0.5, an indication that the species is exhibiting signs of a slow- growth **(Kienzle, 2005)**. In terms of implications, the outcome or consequence of any heavy exploitation of the species will be more of biological than economical since the rebuilding of this species is likely to be at a slow rate **(Forson & Amponsah, 2020)**. The asymptotic length ($L\infty$) from the current study (24.7cm) was lower than the estimates from Cross River, Nigeria (38cm), Lake Asejire (28.5cm) and Lake Oyan (28.7cm) **(Ayaode, 2007)**. The reasons for the variation in growth rate (K) and asymptotic length ($L\infty$) could be due to geographical locations, the data analysis method used and the size classes obtained **(Amponsah *et al.*, 2016)**. Furthermore, the level of fishing activity may be a contributing factor to the lower asymptotic length ($L\infty$) obtained from the current study. The growth performance index of *S. mystus* from the study (i.e. 2.58) was relatively lower than the estimates obtained from Lake Asejire (2.62) but comparable with the estimate from Lake Oyan (2.51) **(Ayaode, 2007)**. The disparity in the growth performance index for the assessed species could be attributed to the changes in the chemistry and biological component of the aquatic environment **(Ofori-Danson *et al.*, 2011)**, facilitated possibly by climate change. Furthermore, the presence of competition for food resources and predation among species could also contribute to the observed difference in the growth performance index. According to **Baijot and Moreau (1991)**, the mean values of the growth performance index for important fish species in Africa range between 2.32 and 2.65, and are considered to be low. The estimate of the growth performance index from the current study (2.58) fell within this range, thus buttressing the claim that the assessed fish species is showing signs of slow- growth.

Length at first capture

The length at first capture estimated from the study was 10.27cm, similar to the findings by **Etim *et al*. (1995)** from Cross River, Nigeria who reported that the length at first capture for *S. mystus* to be 10.9cm. This similarity may be due to the use of related fishing methods or mesh sizes of the fishing gears. The ratio of the length at first capture (10.27cm), and the asymptotic length (24.7cm) which is known as the critical length at capture (Lc) for the current study was 0.42. According to **Pauly and Soriano (1986)**, when Lc is less than 0.5, it implies more juveniles, and when Lc is more than 0.5, it suggests more matured individuals in the catches. From the study, the length at critical capture was relatively lower than 0.5, which indicates the presence of more juveniles than matured individuals. This implies the occurrence of growth overfishing within the fishery of the assessed fish species, which is mostly characterized by the presence of more juveniles. Unlike the marine fishes, there is no minimum required length at first capture for freshwater species in Ghana, and this has implications for the nourishment of these species. Study by **Pauly and Soriano (1986)** has shown that fishing levels based on the critical size ratio (Lc/ L∞) and current exploitation rate (E) can be grouped into four categories (quadrants) each with its distinct properties, with Lc/ L∞= 0.42 and E= 0.63, the fishing level of the assessed fish species falls into quadrant D. This implies that the fishery of *S. mystus* is well- developed and the fishing is eumetric with small- sized individuals caught at a-high fishing effort level.

Length at first maturity

The length at first maturity for the current study was estimated at 16.47cm compared to a lower estimate from **Froese and Pauly (2019)** which was 13.1cm. This disparity may be due to seasonal changes, especially during dry seasons where there is habitat shrinking that could lead to lower amounts of dissolved oxygen, competition, and other factors that stress the fish. Compared to the length at first capture estimated from the current study (10.27cm), the estimated length at first maturity was higher (16.47cm) which suggests that *S. mystus* in Lake Volta becomes vulnerable to fishing gears before they reach-maturity and have the opportunity to spawn at least once. Consequentially, this finding suggests that there is the potential for recruitment overfishing occurring within the stock of *S. mystus* in the future if management measures are not made available.

Mortality parameters

The total mortality for the species in the current study was 2.09 per year. From the study, the natural mortality rate (0.78 per year) was lower than the fishing mortality rate (1.31 per year), which suggests that the assessed fish species is more prone to fishing activities than naturally induced mortality situations such as predation, competition, and diseases (**Ofori-Danson *et al.*, 2021)**. Furthermore, the high fishing mortality rate estimated from the current study may be attributed to the slow movement of the species, which makes them vulnerable to fishing gear **(Etim *et al.*, 1999)**. The total mortality rate for this study was at variance with estimates for Lake Oyan (1.83 per year) and Lake Asejire (5.14 per year). **Pauly (1980)** reported that the optimal exploitation level of fish species is mostly 0.5. Based on the current study, the exploitation rate was estimated to be 0.63, which is relatively higher than the estimates for Lake Oyan (0.50) but lower than the estimate for Lake Asejire (0.78) **(Ayaode, 2007)**. Nonetheless, the exploitation rate of *S. mystus* was lower than the maximum exploitation rate. This finding might suggest that despite the overexploitation of *S. mystus* in Lake Volta, the stock of this species is far from collapse. To address this issue, urgent measures are required, including reducing the number of active canoes, eliminating harmful fishing subsidies, and institutionalizing the closed season.

CONCLUSION

This study sought to assess the stock status of *Schilbe mystus* in the Volta Lake of Ghana. The *S. mystus* had a growth rate (K) of 0.25 per year indicating signs of slow growth, with a condition factor of 0.36. Given this, it can be concluded that *S. mystus* from the Stratum VII of Lake Volta in Ghana is not physiologically sound. The relationship between the lengths at first maturity (Lm_{50} = 16.47cm) and first capture (Lc_{50} = 10.27cm) revealed the presence of growth overfishing. The fishing mortality rate (F = 1.31 per year) was higher than the natural mortality rate (M = 0.78 per year), which indicates a high exploitation rate of the assessed fish species. The exploitation ratio (E= 0.63) was approximately higher than the optimum level of 0.5, suggesting that this species is over-exploited in Lake Volta. From the results, it is recommended that: i) Fishing pressure should be reduced through measures such as reducing the number of fishing vessels and fishermen; ii) Regular assessment of the status of these species should be undertaken to monitor the rebuilding of the stock; and iii) Enforcement of fisheries regulations (mesh size use to ensure that the exploitation of the assessed fish species is sustainable.

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