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Original Article

Assessing the stock status of Atlantic bumper, *Chloroscombrus chrysurus*, Linnaeus 1766, from the coastal waters of Ghana

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Abstract: The main objective of this study was to examine the growth, mortality, and exploitation rate of *Chloroscombrus chrysurus* from the continental shelf of Ghana, West Africa between July 2018 and June 2019. This study provided results on fishery dynamics parameters to contribute to estimating the stock assessment of these fish species. Monthly length-frequency data were collected from 697 samples and analyzed using fisheries models fitted in TropFish R. The von Bertalanffy growth parameters were utilized to analyze the population dynamics of these species using ELEFAN Simulating Annealing. The estimated asymptotic total length (L_∞), coefficient of growth (K), and growth performance index (Φ′) was 24.9 cm, 0.84 $year^{-1,}$ and 2.72, respectively, with a Response surface (Rn) value of 0.79. The total mortality (Z), natural mortality (M), and fishing mortality (F) rates *C. chrysurus* from the continental shelf of Ghana were 3.27 $year^{-1}$, 1.31 $year^{-1}$, and 1.96 $year^{-1}$, respectively. The exploitation rate (E) estimated was above the optimum level of 0.5 which indicates that the species is overexploited. Based on the Emsy (0.69) value, analyses show that the exploitation rate has exceeded the sustainable limit and hence the need for proper fisheries management measures.

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Introduction

Chloroscombrus chrysurus Linnaeus 1766*,* known as the Atlantic bumper or Sapater, is an ecologically and economically important fish species of the family Carangidae (Smith-Vaniz, 1990; Edwards et al., 2001). This pelagic species is found in the tropical and subtropical Western Atlantic range, occuring from the coast of West Africa from Mauritania to Angola. Also, it is found in brackish and marine environments; usually at depths of 0-55 meters and inhabits soft bottoms, however, juveniles are often found in more oceanic waters (Gabis et al., 2012).

Atlantic bumper is characterized by its readily distinguishable body shape, in which the lower profile is more arched than the upper part, and by having the small oblique mouth (Edwards et al., 2001). It has a black spot on the upper part of the tail, is silvery, and many rainbow reflections when fresh (Edwards et al., 2001; Schwartz, 2013). This species primarily feeds on fish, cephalopods, and zooplankton and is one of 12 species of the Carangidae family landed in Ghana (Edwards et al., 2001; Gabis et al., 2012). In Ghana, *C. chrysurus* is caught from January to April (Edwards et al., 2001).

Several researchers have documented the biology and stock status of *C. chrysurus* from several coastal countries, including growth and exploitation rate in Benin (Sossoukpe et al., 2017), life-history in tropical waters of the Atlantic Ocean (De Queiroz et al., 2018), growth and mortality rates in the Caribbean Sea (Garcia and Duarte, 2006). However, there is limited information on the population dynamics of the commercially important *C. chrysurus* occurring in the waters of Ghana. According to Arra et al. (2020), population dynamics of fishes are undertaken with the major objective of sustainable management and conservation of fish species. Therefore, this study aimed to examine the growth, mortality, and exploitation rate *of C. chrysurus* from *the continental shelf of Ghana,* West Africa, between July 2018 and

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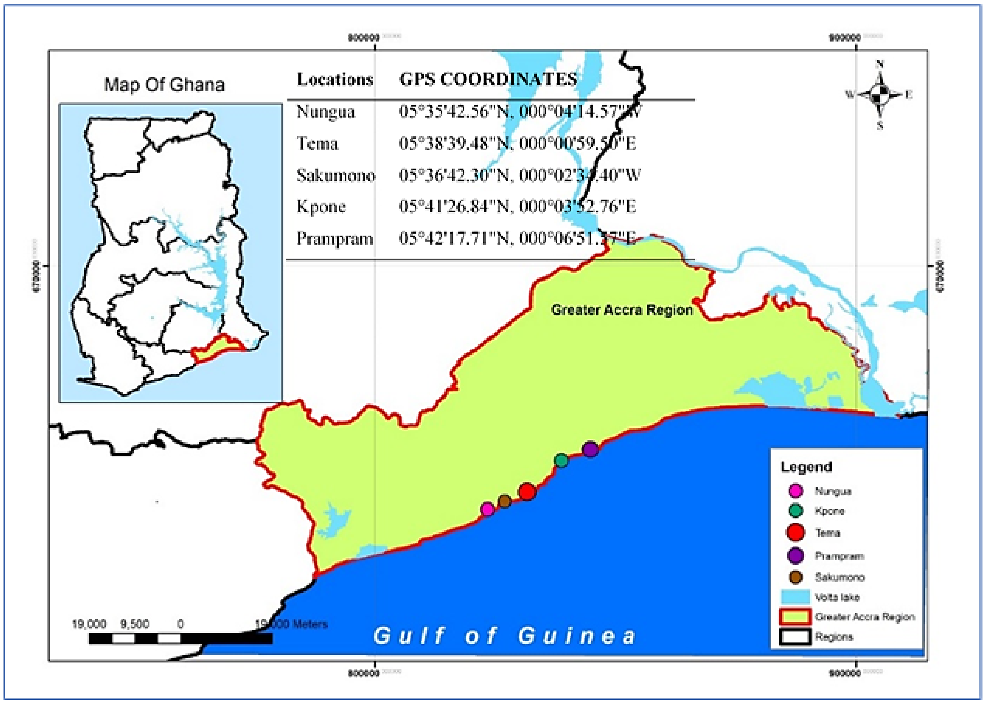

Figure 1. Map showing the fish landing sampling locations.

June 2019.

Materials and Methods

Study area: Based on two stage-sampling, criteria included the level of fishing activity and geographical isolation, five fishing communities in the Greater Accra region of Ghana were selected for the current study. These five fish landing sampling locations were Sakumono, Tema, Nungua, Kpone, and Prampram (Fig. 1). The primary form of livelihood for many of the inhabitants in the selected sampling sites is fishing and other activities related to the post-harvesting of fish from the wild.

Data collection: Samples of fish species from the coastal waters of Ghana were obtained from randomly selected fishermen who apply different fishing types and gears. Samples were collected over 12 months (i.e. July 2018 to June 2019), preserved on ice, and taken to the laboratory. At the laboratory, identification of the species was done based on Schneider's (1990) identification key. In all, 697 specimens of *C. chrysurus* were obtained during the study period. The total length (TL) of the specimens was measured to the nearest 1 cm.

Growth parameters: Parameters for which the fish growth is assumed to follow von Bertalanffy Growth Function (VBGF) were estimated using the ELEFAN Simulating Annealing. The theoretical age at length zero (t_0) and longevity (T_{max}) were calculated according to the equations: $\text{Log}_{10}(-t_0) = -0.3922 - 0.2752 \log_{10} L_\infty - 1.038 \log_{10} K$ (Aleev, 1952) and $T_{max} = 3/K + t_0$ (Pauly, 1984), respectively. The growth performance index (Φ′) was estimated using the formula: $\Phi' = 2 \log L_\infty + \log K$ (Munro and Pauly, 1984).

Mortality: The total annual mortality rate, Z, was estimated by constructing linearized length-converted catch curves (Spare and Venema, 1992). The natural (M) and fishing mortality (F), and exploitation rate (E) were calculated as $M = 4.118K^{0.73} L_\infty^{-0.333}$ (Then et al., 2015), F = Z – M (Qamar et al., 2016), and F/Z (Georgiev and Kolarov, 1962), respectively.

Lengths at first capture (Lc_{50}) and first maturity (Lm_{50}): The left ascending part of the length converted catch curve was used to estimate the probabilities of length at 50, 75, and 95 capture which correlates with the cumulative probability at 50, 75 and 95 percent, respectively (Pauly, 1984). The length at first maturity (Lm_{50}) was estimated by $\text{Log}_{10}(Lm_{50}) = 0.8979 \times \text{Log}_{10}(L_\infty) - 0.0782$ (Froese and

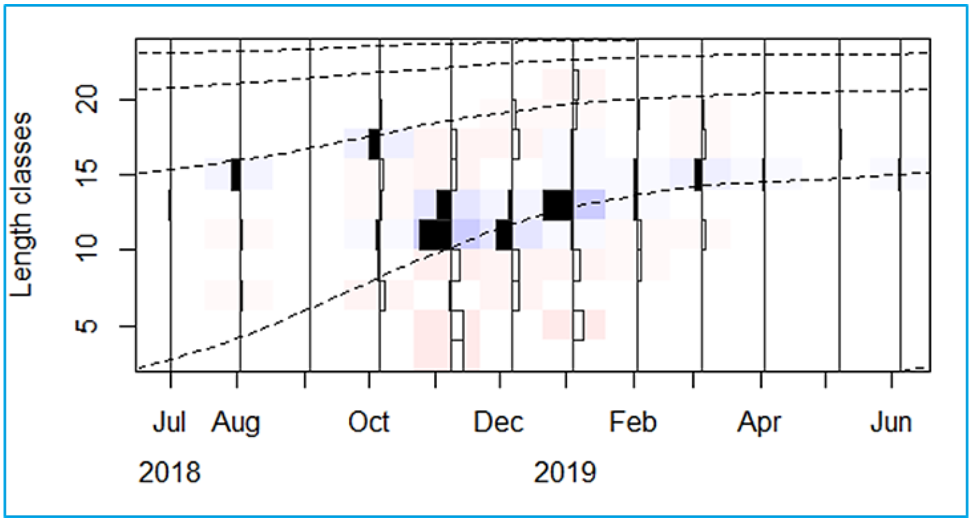

Figure 2. Reconstructed length-frequency distribution of *Chloroscombrus chrysurus* from Continental shelf of Ghana.

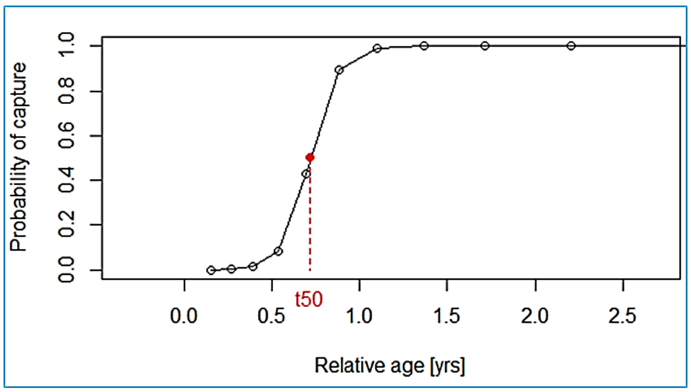

Figure 3. Probability of age at first capture for *Chloroscombrus chrysurus* from Continental shelf of Ghana.

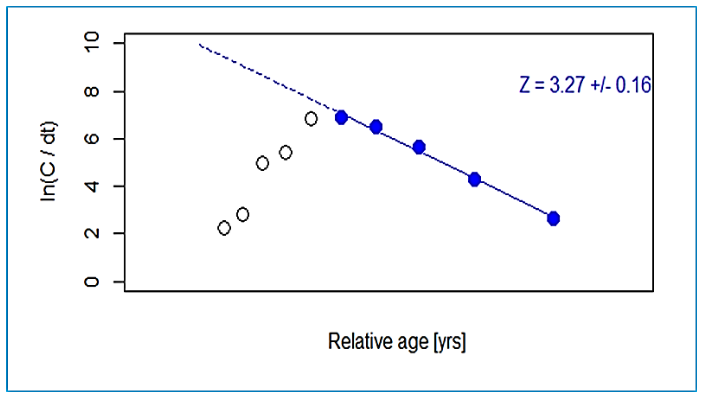

Figure 4. Length converted catch for *Chloroscombrus chrysurus* from Continental shelf of Ghana.

Binohlan, 2000).

Biological reference points: E_{msy} which depicts exploitation rate producing maximum yield and $E_{0.5}$ implying exploitation rate under which the population is reduced to half its virgin biomass were computed together with the corresponding fishing mortality rate (i.e. F_{msy} and $F_{0.5}$).

Data Analyses: The length-frequency data were pooled into groups with 1 cm length intervals. Then the data were analyzed using the TropFish R package in the R software (Mildenberger et al., 2017).

Results

Figure 2 shows the restructured length-frequency with superimposed growth curves. The growth parameters of L_∞, K, and t_0 were estimated as 24.9 cm TL, 0.84 year$^{-1,}$ and -0.20 year with T_{max} of 3.37 years. The Φ′ and Rn were 2.72 and 0.79, respectively. The length at first capture at Lc_{50}, Lc_{75}, and Lc_{95}, was estimated at 11.3, 12.2, and 13.6 cm, respectively (Fig. 3). The length at first maturity (Lm_{50}) was 15.0 cm.

Based on the length converted catch curve method, the Z was estimated at 3.27±0.16 year^{-1} (Fig. 4). The M, F, and E were 1.31 year^{-1}, 1.96 year^{-1}, and 0.60, respectively. The indices of the optimum sustainable yield ($E_{0.5}$) and maximum sustainable yield (E_{max}) were 00.44 and 0.69, respectively (Fig. 5). The corresponding fishing mortality rates were 1.02 yr^{-1} for optimum sustainable yield ($F_{0.5}$) and 2.92 yr^{-1} for the maximum sustainable yield (F_{msy}).

Discussion

The information on growth parameters and the stock status gained from the present study will serve as a

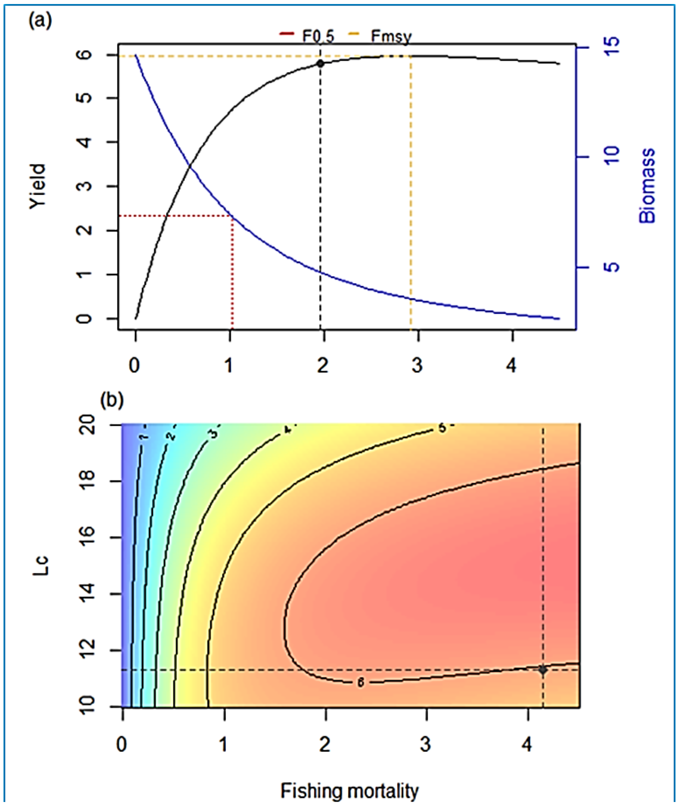

Figure 5. Thompson and Bell model: (A) Curves of yield and biomass per recruit. The black dot represents yield and biomass under current fishing pressure. The yellow and red dashed lines represent fishing mortality for maximum sustainable yield (Fmsy) and fishing mortality to fish the stock at 50% of the virgin biomass (F0.5). (B) Exploration of the impact of different exploitation rates and Lc values on the relative yield per recruit.

springboard for the sustainable management of the assessed species in Ghana. The asymptotic length (L_∞) of *C. chrysurus* (24.9 cm TL) in this study varied from other studies, which De Queiroz et al. (2018), Sossoukpe et al. (2017) and Garcia and Duate (2006) reported higher $L\infty$ values (25.6, 28.3 and 30.5 cm TL, respectively). The growth coefficient, K in the present study (K = 0.84 year^{-1}) was higher than estimates by Sossoupke et al. (2017), da Costa et al. (2005), and De Queiroz et al. (2018) who reported K at 0.49, 0.39 and 0.33 year^{-1}, respectively. The changes in growth parameters as compared to other studies may be associated with climate type, and latitudinal differences (Tarkan and Vilizzi, 2015). Also, the size ranges of individuals play a key role since growth parameters are very sensitive to sample size, which larger samples can increase the L_∞ and decrease the K (Espino Barr et al., 2008). The growth performance index (Ø') of *C. chrysurus* (2.72) is more than that found by Sossoupke et al. (2017) and da Costa et al. (2005) (2.59 and 2.58, respectively).

The critical length at capture which is the ratio of Lc_{50}/ L_∞ (11.3/24.9 = 0.45), indicated that it was lower than 0.5 in the continental shelf of Ghana. This signals the harvesting of more juvenile fish species (Pauly and Soriano, 1986). The indulgence in such practice for a long period of time could result in growth overfishing and consequentially, may render recruitment dysfunctional in the future leading to a possible collapse. Furthermore, the length at which these species become vulnerable to the fishing gears (Lc_{50} = 11.3 cm) used by Ghanaian fishermen was lower than the Lm_{50} (15.0 cm). This implies that species do not get the opportunity to spawn at least once before they are captured which could have some ramifications on the recruitment potential of these stocks in the future (Gheshlaghi et al., 2012). It is therefore necessary to enforce length at 95% capture which is feasible when the mesh size is increased.

The natural mortality rate (M) of *C. chrysurus* (1.31 year^{-1}) was higher than that reported by Sossoupke et al. (2017) and De Queiroz et al. (2018) (1.17 and 0.92 year^{-1}, respectively). According to Macer (1977), the consistency of the estimated M was the ratio of M/K ratio, which has been ranged between 1.12-2.5 for most fishes. This ratio in the present study (1.63) fell within the acceptable demarcated range.

According to the results, the total (Z) and fishing (F) mortality were 3.27 and 1.96 year^{-1}, which the F was higher than M (M = 1.31 year^{-1}). Similar results were reported by Garcia and Duarte (2006), with Z, M, and F at 3.03 year^{-1}, 1.29 year$^{-1,}$ and 1.71 year^{-1}, respectively. In contrast, Sossoupke et al. (2017) reported a lower Z and F for the same species from Benin (1.39 and 0.26 year^{-1}) and the F was lower than M (M = 1.16 year^{-1}). The relatively higher F than M indicates an imbalanced stock position (Azim, 2017).

The exploitation rate (E) of *C. chrysurus* was 0.60, showing that it is slightly overexploited because the exploitation rate surpasses the optimum level of 0.5 (Gulland, 1971). Also, this E was slightly lower than the exploitation rate at the MSY (E_{max} = 0.69) on the *continental shelf of Ghana*. This observation may have accounted for the high exploitation rates estimated for this species, which calls for the management of these stocks through measures such as a reduction in fishing efforts, closed fishing season, creating marine protected areas (MPAs) to help sustain these stocks.

In conclusion, *C. chrysurus* encountered in Ghana's coastal waters is fast-growing fish species. The immature individuals are under high fishing pressure. This species appears to be overexploited in Ghana's marine waters. Hence it needs to safeguard its stocks through proper management measures. Such management measures may include mesh size regulations, closed fishing seasons, and compliance to fisheries policies.

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