Growth, Mortality and Exploitation Rates of African Moonfish (*Selene dorsalis*, Gill 1863) Encountered in the Coast of Ghana (West Africa)

Samuel K. K. Amponsah, Berchie Asiedu, Selasi Yao Avornyo, Seyramsarah Blossom Setufe, Nana Ama Boadu Afranewaa and Pierre Failler

ABSTRACT

Growth, mortality and exploitation rate of *Selene dorsalis* (Gill, 1863) from the continental shelf of Ghana (West Africa) were examined between July 2018 and June 2019. The study provided results on fishery dynamics parameters needed to estimate the stock status and characteristics of *S. dorsalis* in the coast of Ghana. Monthly length-frequency data were collected from 629 samples and analysed using fisheries models fitted in TropFishR package in R software. The von Bertalanffy growth parameters were utilised to analyse the population dynamics of the species using ELEFAN Simulating Annealing. Based on the estimates, the asymptotic total length (L_∞) was 22.2 cm, the coefficient of growth (K) was 0.76 year^{-1}, and the calculated growth performance index (phi) was 2.58 with Rn value of 0.55. The total mortality rate (Z) was 3.32 year^{-1} with a natural mortality rate (M) of 1.21 year^{-1} and fishing mortality rate (F) of 2.11 year^{-1}. The exploitation rate (E) estimated for the species was above the optimum level of 0.5, which indicates that *S. dorsalis* is overexploited in the coast of Ghana. It can be concluded that the exploitation rate of *S. dorsalis* has exceeded the optimum limit, hence the need for enforcement and improvement of fisheries management measures such as mesh size regulations, capping of canoes, closed fishing seasons and compliance with fisheries policies.

Keywords: Ghana, Growth rate, Mortality rates, Population parameters, TropFishR.

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I. Introduction

Fish and fisheries make important contributions to food and nutrition security in many countries. However, in many parts of the world, fish stocks are on the decline. This is greatly going to affect the contribution of the seafood industry to achieve the United Nations Sustainable Development Goals. It is thus imperative to give attention to the sustainable management of fish stocks. The population characteristics of fishes are very important inputs in the assessment and management of fish stocks [1]. With world fish stocks currently being inadequately managed resulting in overexploitation and decline [2], there is the need for information on key parameters to help in ensuring adequate management of fisheries. Population dynamics of fishes are determined with the major objective of sustainable management and conservation of fish species [3]. Biological parameters such as population dynamics also allow tests of life-history hypothesis and empirical estimations of important parameters of biological and fishery relevance such as length at first maturity and length at maximum yield per [4], [5].

Despite the importance of the estimation of these parameters to fisheries management, there is little information on these key parameters of the over 300 marine species in Ghana including *Selene dorsalis*. Belonging to the family Carangidae and the order Perciformes, *S. dorsalis* also known as the African moonfish is an important commercial fish species native to the Atlantic Ocean [6]. Its distribution is from Portugal to South Africa, including Madeira and Cape Verde [7]. According to [8], out of the twenty-two (22) species of the Carangidae family encountered on the mainland coast of tropical West Africa, *S. dorsalis* is one of the twelve (12) species of the family, landed in Ghana. It is characterized by a short silverly body, a head with a hump above its eyes, and a steep frontal profile that is slightly concave in front of the eyes and possesses a lower prominent jaw [9]. In Ghana, *S. dorsalis* is used as food and is often smoked, contributing substantially to the annual per capita fish consumption of 25 kg. It is caught in seines when young, particularly from July to November. It is also caught by *ali* and *watsa* nets at night, however, when older it may be caught by hooks in deep water [8].

Previous studies on this species include the study on the reproductive biology of the African moonfish, *S. dorsalis* in the continental shelf of Côte d'Ivoire fishery (West Africa) by [2], the study on community ecology of the metazoan parasites of Atlantic Moonfish, *Selene setapinnis* (Osteichthyes: Carangidae) from the coastal zone of the state of Rio de Janeiro, Brazil by [10] and the study on some aspects of the biology of *S. dorsalis* from Forcados river estuary, Niger delta, Nigeria by [6].

In Ghana, however, studies on *S. dorsalis* includes the study on species diversity and relative abundance of fisheries resources found in beach seine along the central coast of Ghana by [11] and the study on the investigation on fish catch data and its implication for management of small-scale fisheries of Ghana by [12]. Given the paucity of published information on the population dynamics of *S. dorsalis* and the importance of the fishery in the coastal waters and population of Ghana, the purpose of this study was to estimate the exploitation status of *S. dorsalis*, for which information is required to enhance the sustainable management of *S. dorsalis* in Ghana. On a broader scale, this work will also contribute to the FAO initiative of building a comprehensive global database on fish stocks and their main characteristics [13].

II. Materials and Methods

A. Study Area

Five fishing communities in the Greater Accra Region of Ghana were selected for the current study. The selection of the five fish landing sampling sites was based on the level of fishing activity and geographical location. These five fish landing sampling locations were Sakumono, Tema, Nungua, Kpone and Prampram (Fig. 1). The primary livelihood of the majority of the inhabitants in the selected five fish sampling sites is fishing and other activities related to pre-harvesting of fish from the wild. The geographical coordinates of the five fish sampling locations are outlined in Table 1.

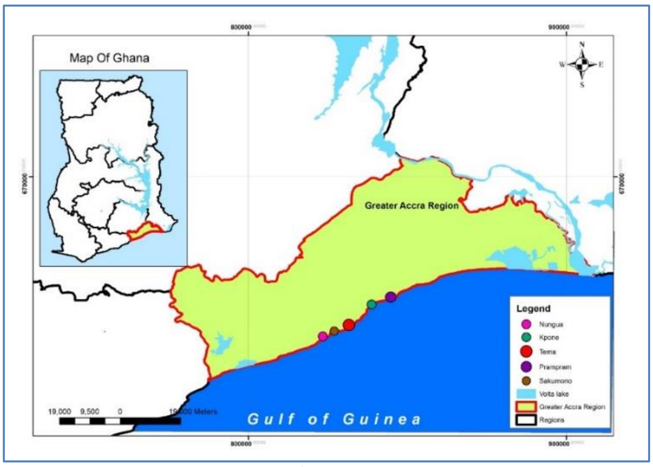

Fig. 1. Map showing the fish landing sampling locations.

TABLE 1: Sampling Sites and Their Coordinates

Sampling Locations	GPS Coordinates
Nungua Beach	05°35'42.56"N, 000°04'14.57"W
Tema Canoe Beach	05°38'39.48"N, 000°00'59.50"E
Tema Inshore Fishing Harbour	05°38'23.57"N, 000°01'00.38"E
Kpone	05°41'26.84"N, 000°03'52.76"E
Prampram	05°42'17.71"N, 000°06'51.57"E

B. Data Collection

Monthly samples were obtained from randomly selected fishermen who apply multifilament fishing gears in their fishing operations. Samples were obtained over a twelve (12) month period (i.e., July 2018 to June 2019), preserved on ice, and transported to the laboratory of the Department of Marine and Fisheries Sciences, University of Ghana for analyses. At the laboratory, identification of the species was done to the lowest level of taxonomy using identification keys by [14]. Measurement of length was performed using a 100 cm graduated wooden measuring board. In all, 629 specimens of *Selene dorsalis* were obtained during the study period.

C. Growth Parameters

Parameters for the Von Bertalanffy Growth Function (VBGF) including growth rate (K), asymptotic length ($L\infty$) and the growth performance index (Φ') were estimated using the ELEFAN Simulating Annealing (ELEFAN_SA). Estimation of longevity (T_{max}) for the species followed the formula:

$$T_{max} = 3/K + to \ [15]$$

The growth performance index was calculated using the formula:

$$(\Phi') = 2\log L_{\infty} + \log K \ [16]$$

The theoretical age at length zero (t_o) followed the equation:

$$\text{Log}_{10} (-t_0) = -0.3922 - 0.2752 \log_{10} L_{\infty} - 1.038 \log_{10} K \ [17]$$

D. Mortality Parameters

Total mortality (Z) was computed using the Linearized length converted catch curve [18]. The natural mortality rate (M) was calculated using the equation:

$$M = 4.118K^{0.73}L\infty^{-0.333} \ [19]$$

Fishing mortality (F) was calculated as:

$$Z - M \ [20]$$

The exploitation rate (E) was computed as:

$$F/Z \ [21]$$

E. Length at First Capture (Lc_{50})

The ascending left part of the length converted catch curve was used in estimating the probability of length at first capture (Lc_{50}) in addition to the length at both 75 and 95

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percent capture which correlates with the cumulative probability at 75% and 95%, respectively [22].

F. Length at First Maturity (Lm_{50})

The length at first maturity (Lm_{50}) as:

$$Lm_{50} = 0.8979 \times \text{Log}_{10}(L\infty) - 0.0782 \text{ [4]}$$

G. Data Analyses

The TropFishR package in R programming [23] was used in assessing the population parameters of specimens of *S. dorsalis* that were encountered during the study period.

III. Results

A. Growth Parameters

Fig. 2 shows the reconstructed length-frequency distribution superimposed with the growth curves. The asymptotic length ($L\infty$), growth rate (K) and growth performance index were 22.2 cm TL, 0.76 $year^{-1}$and 2.58, respectively with Rn value of 0.55 (Table 2).

The Von Bertalanffy Growth Function (VBGF) for *S. dorsalis* was:

$$L_t = 22.2 \times (1- e^{-0.76\ (t + 0.23)})$$

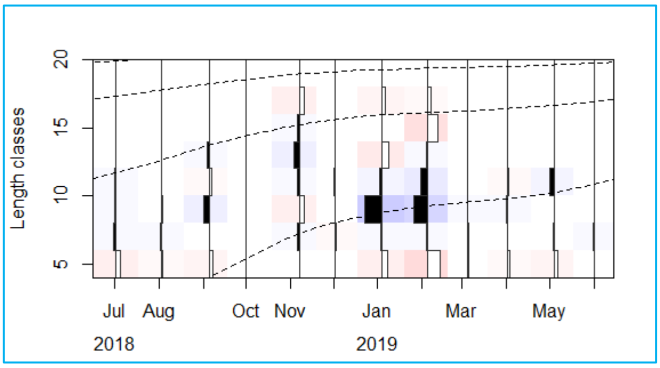

Fig. 2. Reconstructed monthly length-frequency distribution of *S. dorsalis.*

The estimated theoretical age at birth (t_o) and longevity for the assessed fish species are presented in Table 2.

B. Length at First Maturity (Lm_{50})

The length at first maturity (Lm_{50}) was estimated as 13.5 cm (Table 2).

TABLE 2: ESTIMATED POPULATION PARAMETERS OF *S. DORSALIS* FROM THE GHANAIAN CONTINENTAL SHELF

Indicators	Unit	Value
Growth rate (K)	$year^{-1}$	0.76
Asymptotic length (L_∞)	cm TL	22.2
Age at birth (t_o)	Years	-0.23
Longevity (t_{max})	Years	3.72
Growth performance index(phi)		2.58
Response surface (Rn)		0.55
Length at first maturity (Lm_{50})	cm TL	13.5
Natural mortality rate (M)	$year^{-1}$	1.21
Total mortality rate (Z)	$year^{-1}$	3.32
Fishing mortality rate (F)	$year^{-1}$	2.11
Exploitation rate (E)	-	0.63
Length at first capture (Lc_{50})	cm TL	7.61
Critical length at capture (Lc)	-	0.34
M/K	-	1.60
Number of data points (N)		629

C. Mortality Parameters

From the length converted catch curve (Figure 3), the total mortality rate (Z) estimated for *S. dorsalis* was 3.32 $year^{-1}$. The natural mortality rate (M) was 1.21 $year^{-1}$. The fishing mortality rate (F) was 2.11 $year^{-1}$ whiles the exploitation rate (E) recorded was 0.63.

D. Probability of Capture

The length-at-first capture (Lc_{50}) was 7.6 cm. Fig. 3 shows the corresponding age for length at first capture.

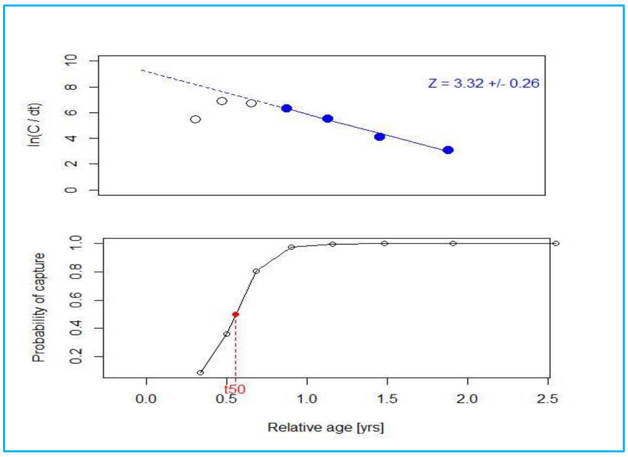

Fig. 3. Length converted catch for Total mortality and probability of capture for *S. dorsalis.*

IV. Discussion

The growth rate estimated for this study (0.76 $year^{-1}$) was higher than recorded for other related species like *Selene setapinnis* (0.49 $year^{-1}$) [24] but lower than the growth estimate for *Selene peruviana* (0.95 $year^{-1}$) [25]. The growth rate (*k*) from the current study signifies that *S. dorsalis* in Ghana's coastal waters exhibited a fast growth rate, evinced by the low longevity of 3.72 years (Table 2). The estimated fast growth rate of *S. dorsalis* in this study compared to the other related species may be as a result of disparity in ecological characteristics such as habitat, fish adaptive life pattern and location, environmental conditions as a result of regional differences, food abundance or size composition of the stock that directly affect growth rate [15], [21], [20].

The asymptotic length of *S. dorsalis* (22.2 cm TL) varied compared to other related species like *Selene setapinnis* (36.84 cm TL) [24] and *Selene peruviana* (21 cm TL) [25]. According to [26], growth parameters are very sensitive to samples as such, larger individuals tend to increase the asymptotic length as growth rate decreases, hence, individual size ranges play a key role in estimating the asymptotic length. The variations in estimates of asymptotic lengths may therefore be as a result of the maximum observed length, sampling methods, computation methods used and the obtained length-frequency [18], [27]. The alteration in growth parameters may be associated with climate type, latitudinal differences, and ecological characteristics such as habitat, fish adaptive life pattern and location that directly affect the growth rate [28], [20].

The critical length at capture (Lc) from the study indicated that fishermen in Ghana are harvesting more juveniles of the fish because the calculated Lc was lower than 0.5 [29]. The indulgence in such practices over long periods could result in growth overfishing and consequentially, may render recruitment dysfunctional in the future, thereby, leading to a possible collapse and ultimately food insecurity. Furthermore, the length at which this species becomes vulnerable to the fishing gears used by Ghanaian fishermen was lower than the length at first maturity. This implies that the species does not get the opportunity to spawn, at least once, before it is captured. This could negatively impact the recruitment potential of the stocks in the future [30]. There is, therefore, the need to enforce length at ninety-five percent (95 %) capture which is feasible when the mesh size is increased.

According to [31], the consistency of the estimated natural mortality rates (M) was ascertained using the M/K ratio, which has been reported to be within the range of 1.12 and 2.5 for most fishes. The M/K ratio in this study (i.e., 1.60) fell within the acceptable demarcated range. Adaptations to local conditions and exploitation levels may have caused the variations observed in the fishing mortality rate as compared to other studies carried out on other related species [32]. From the present study, the natural mortality rate (1.21 $year^{-1}$) was lower than the fishing mortality rate (2.11 $year^{-1}$) unlike the related species *Selene setapinnis* which had its natural mortality rate (0.94 $year^{-1}$) higher than the fishing rate (0.28 $year^{-1}$) [24]. This suggests that unlike *Selene setapinnis*, the *S. dorsalis* species in the coastal waters of Ghana are more prone to fishing gears than naturally induced mortality situations caused by age, predation, lack of food, spawning stress, diseases, and pollution [27]. The relatively higher fishing mortality rate than the natural mortality rate indicates an imbalanced stock position [33]. This observation reveals derailment from the optimum exploitation rate of 0.5 [34].

The exploitation rate of *S. dorsalis* (0.63) was higher than that of the related species *Selene setapinnis* (0.23) [24]. This observation suggests that *S. dorsalis* stocks are slightly overexploited because the exploitation rate of the species surpasses the optimum level of 0.5 [34]. The assessed species is known to inhabit the 30-metre zone; as such increasing its vulnerability to the fishing gears of the over 100 000 artisanal fishermen in Ghana. This observation may have accounted for the high exploitation rate estimated for the species. This calls for urgent management of the stock through measures including but not limited to reductions in fishing efforts, closed fishing seasons, capping of canoes and creation of marine protected areas (MPAs), to help sustain the stock.

V. Conclusion

From the study, *S. dorsalis* encountered in Ghana's coastal waters is a fast growing species and an immature species under high fishing pressure. The species appears to be overexploited in Ghana's marine waters, hence the need to safeguard the stock through proper management measures. Such management measures may include but not be limited to mesh size regulations, closed fishing seasons, capping of canoes and compliance to fisheries policies.

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