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Research Article

# ASPECT OF POPULATION DYNAMIC AND STOCK STATUS OF THE AFRICAN MOONFISH *Selene dorsalis* (Gill, 1863) FROM THE COASTAL WATERS OF CÔTE D'IVOIRE

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## ABSTRACT

Some aspects of population dynamic and the stock status of *Selene dorsalis* were investigated in the coastal waters of Côte d'Ivoire from March 2016 to February 2018. For this purpose, 869 fish species were collected. The range length of collected species was 7.5cm to 30.3 cm. The asymptotic length ($L\infty$) was 32.02 cm, with a growth rate (K) of 0.56 per year. The growth performance index ($\Phi'$) was 2.76 per year with longevity of 5.35 year. The natural mortality rate (M) was estimated at 1.16 year$^{-1}$ and lower than the fishing mortality rates (F) estimated at 1.19 year$^{-1}$. The current exploitation rate (0.50) was higher than E0.5 (0.38). The main losses in the stock up to 13.5 cm size was due to natural causes and after this size mortality due to fishing increased and eventually outnumbered the natural losses. The annual total stock and biomass were estimated at 10.412, 5.546 tons respectively.

**Keywords:** Population dynamic, Fisheries, Stock status, *Selene dorsalis*, Côte d'Ivoire.

## INTRODUCTION

Fishery resources are an important source of proteins, vitamins and miconutrients that are available in such quantity and diversity either in crops or in other animal products. They represent circa 17% of animal protein consumed by many low-incom populations in rural areas (Fernandes *et al*., 2016). Serial depletions of marine fish stocks because of over-exploitation are endangering the future of marine fisheries and this issue is largely debated within the scientific community (Myers and Worm, 2003). It is thus imperative to pay attention to the sustainable management of the fish stocks. Fishery management aims to preserve economic value of a fishery usually by implementing a set of regulations that will lead to an economically beneficial, but demographically sustainable, harvest of desired species (Peter, 2002). Stock assessment involves the use of varius statistical and mathematical calculations to make quantitative predictions about the reactions of fish populations to alternative management choices (Hilborn and Walters, 1992).The fundamental models used are based on some parameters such as growth, recruitment patterns, mortalities and exploitation rate (King, 1981). The Carangidae fishes also called Jacks travalies, Scad are widely distributed in all tropical and subtropical seas from Portugal to South-Africa including madeira and Cape verde (Froese and Pauly, 2020). The family contains about 30 genera and 140 species worldwide (Laroche *et al*., 1984). Ivoirian coast contains many economically fish species such as the African moonfish *Selene dorsalis* which is one the semi-pelagic resource in trawl fisheries catches. Despite its importance informations about the population dynamics of the species are very scarce. Thus the present work aims to assess *Selene dorsalis* stock status. Information gained from this study will facilitate sustainable management of *Selene dorsalis* within Côte d'Ivoire's coastal fishing operations.

## MATERIALS AND METHODS

### Study area and sampling protocol

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The Ivorian oceanic zone is bordered to the north by the Gulf of Guinea shoreline stretching from the Cape Palmas (7°30W) and the Cape Three Points (2°W) (Figure 1). The shoreline is 550 km long with a narrow continental shelf of 10, 200 km² and is characterized by a series of sandy beaches forming a wide arch opened to the Atlantic Ocean (Le Loeuff and Marchal, 1993). It is influenced by two marine seasons: The cold season start from January to February and then from July to September. However, the warm season is extending from March to June and November to December (Djagoua, 2003). According to Colin (1988), the coastal upwelling occurs seasonally along the shoreline from July to October which is the major event and from January to February (the minor event). Senegal jack specimens come from the industrial bottom trawlers catches, caught along the coast of Côte d'Ivoire. Those specimens were collected from March 2016 to February 2018 in continental shelf of Côte d'Ivoire fishery at the fishing harbour of Abidjan through the industrial fishing carried out by trawlers.

### Data collection

Samples of the targeted fish species were collected from trawlers commercial landings at the fish sampling sites from March 2016 to February 2018 at a rate of at least 30 specimens per month in fishing port of Abidjan through industrial fishing at the Ivorian continental shelf. The total and fork lengths of individuals of species were measured to the nearest 0.1 cm using a 100 cm rule measuring board. Total body weight of each specimen to the nearest 0.1 g was determined using a weighing balance (Sartorius electronic model) after excess water on each has been drained with filter paper. The length measurements were grouped into 1 cm class intervals to make monthly length distribution. Identification of fish samples was carried out to the species level using Paugy *et al.* (2003) identification keys. Overall, a total of 869 individuals of *Selene dorsalis* were sampled.

### Growth parameters

Tropical fishes are assumed to follow the Von Bertalanffy Growth Function (VBGF), such as growth rate (K), asymptotic length (L∞), and the growth performance index (Φ′). These growth parameters were obtained using the VBGF equation. According to VBGF, as expressed below, individual fishes grow on average towards the asymptotic length at an instantaneous growth rate (K) with length at the time (t) following the expression:

$Lt = L\infty\ (1 - e^{-K(t-to)})$ (Pauly, 1984)

The theoretical age at length zero (to) was calculated according to the equation below:

$\text{Log } 10\ (-t_0) = -0.3922 - 0.2752 \log 10\ L\infty - 1.038 \log 10\ K$ (Pauly 1984)

The longevity (Tmax) was estimated as

$Tmax = 3/K + t_0$ (Pauly, 1983).

The growth performance index was calculated from the below-expressed equation:

$(\Phi') = 2\log L\infty + \log K$ (Munro and Pauly, 1983)

The length at optimum yield (Lopt) was estimated as follows:

$Lopt = (3/ (3 + M/K)) * L\infty$ (Beverton, 1992)

### Mortality Parameters

Total mortality (Z) was computed using Linearized length converted catch curve fitted (Gayanilo *et al*., 2005). The natural mortality rate (M) was calculated using the 'Then Method'. Fishing mortality (F) was calculated by subtracting the natural mortality from the total mortality,

F = Z-M (Gulland, 1971).

The Exploitation rate (E) was calculated as:

E = Fishing mortality / Total mortality rate (F/Z) (Gulland, 1971).

The exploitation ratio (U) was estimated as:

$U = E\ (1-e^{-z})$ where E is the exploitation rate

The optimum fishing mortality (Fopt), which forms the precautionary target, was calculated as

Fopt = 0.4*M (Pauly, 1983)

The limiting fishing mortality (Flimit) was calculated as

Flimit = (2/3) * M (Patterson, 1992)

### Probability of Capture

The probability of capture was estimated using the procedure outlined in the FISAT II tool (Gayanilo *et al.*, 2005). By plotting the cumulative probability of capture against mid-length, a resultant curve was obtained, from which the length at first capture (Lc50) was taken as corresponding to the cumulative probability at 50%. Additionally, the lengths at which 25% and 75% of the stock is captured were taken as corresponding to the cumulative probability at 25% and 75% respectively. The age at first capture (tc50) was estimated as

$tc50 = -(1/ K)\ \text{Ln}\ (1-Lc50/L\infty) + t_0$ (Beverton and Holt, 1957)

### Recruitment pattern

The recruitment patterns of the stocks were determined by backward projection on the length axis of the set of available length-frequency data as described in FiSAT. This routine reconstructs the recruitment pulse from a time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse. The length at first recruitment (Lr50) was estimated as the midlength of the smallest length interval (Gheshlaghi *et al.*, 2012). The age at first recruitment (tr50) was estimated as: $tr50 = -\ (1/K)\ \text{Ln}\ (1-Lr50/L\infty) + t_0$ (Beverton & Holt, 1957).

### Virtual population analysis (VPA)

The estimated length structured VPA was carried out using the FiSAT routine (Gayanilo *et al*., 2005). The values of the L∞, K, M, F, a (constant) and b (exponent) for the species were used as inputs. The constants a and b (exponent) for the species were estimated from the length-weight relationship using the expression W= aLb, where W is the body weight and Length is the corresponding standard length (Pauly, 1984). Length structured virtual population analysis (VPA) of FiSAT was used to obtain fishing mortalities per length class. The Total stock (P) and biomass (B) were estimated as: P = Y/U and B = Y/F respectively; where Y is the annual average yield in tonnes, U: exploitation ratio, F: fishing mortality.

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

Relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)' values as a function of E were determined from the estimated growth parameters and probability of capture by length (Pauly and Soriano, 1986). Evaluations of resource status were made using estimates of exploitation rates associated with a marginal increase of relative yield per recruit which is 0.1 of its value at E = (0.1), a reduction in the stock to 50% of its unexploited size (E0.5), maximum sustainable yield (Emax ).The relative yield per recruit (Y/R)' and relative biomass per recruit (B/R)' were estimated by using the Selection Ogive method of Beverton and Holt (1966), as modified by (Pauly and Soriano, 1986).

## RESULTS AND DISCUSSIONS

The mean length of *Selene dorsalis* from the current study was 17.83 ± 16.12 cm FL with a range of 7.5-30.3 cm (figure 2). The modal length class of *S. dorsalis* was 16-17 cm FL. The length frequency distribution revealed three size class notably small size class from 7 cm to 17 cm FL representing 56.04% of the population ; medium size class 39.8% and including species with fork length (18 cm to 23 cm) and large size class only 4.14% including species with fork length (24-31 cm).

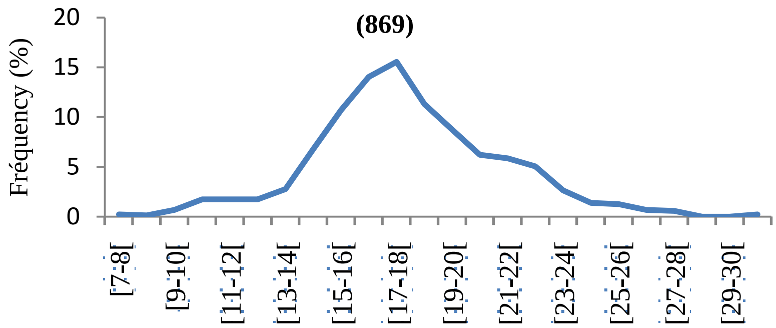


**Figure 2.** Length frequency distribution for *Selene dorsalis*in the coastal waters of Côte d'Ivoire

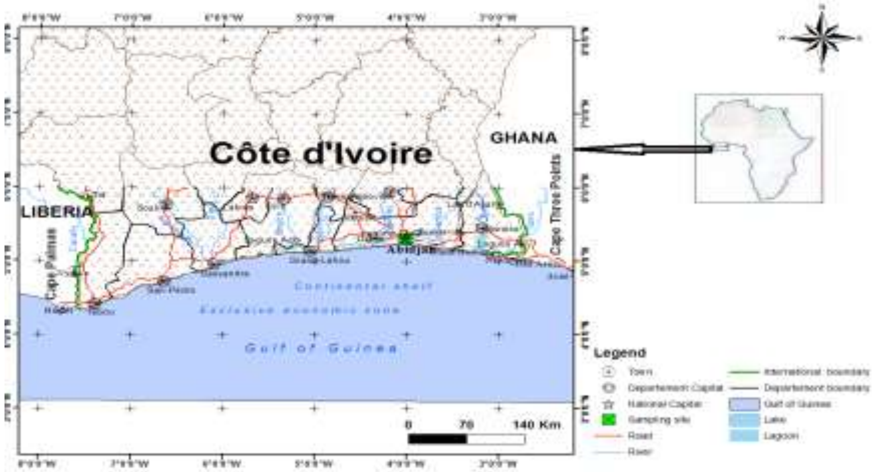


**Figure 1.** Map showing the samplingzone (Continental shelf of Côte d'Ivoire) (Arra *et al*., 2020).

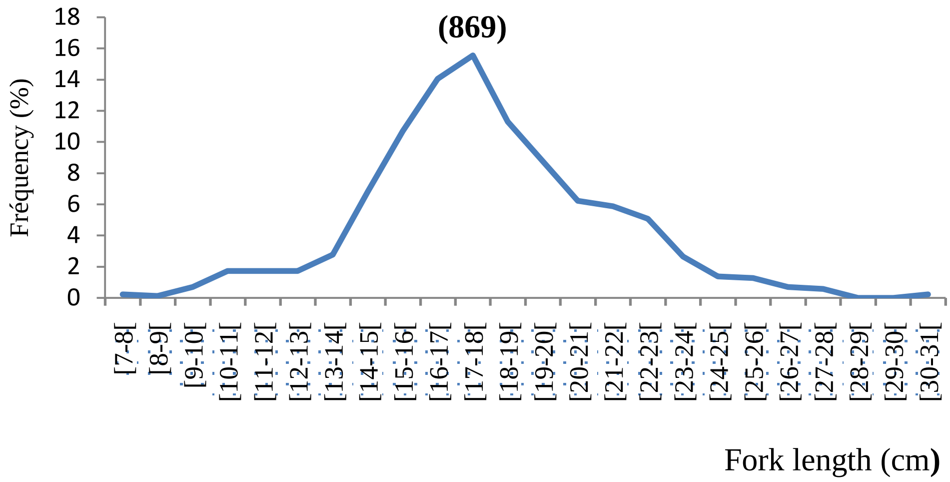


**Figure 2.** Length frequency distribution for *Selene dorsalis*in the coastal waters of Côte d'Ivoire.

**Table 1 .**Estimated population parameters of *Selene dorsalis* caught in the coastal waters of Côte d'Ivoire.

| Population parameters | *S. dorsalis* |
|---|---|
| Length at optimum yield Lopt (cm) | 18.4 |
| Longivity (tmax) year | 5.35 |
| Theoretical age ($t_0$) year | -0.29 |
| Asymptotic length (cm) | 32.02 |
| Asymptotic weight (g) | 629.42 |
| Growth rate (K) year $^{-1}$ | 0.56 |
| Growth perfermance index (φ') | 2.76 |
| ELEFAN I goodness of fit index (Rn) | 0.24 |
| Mean length at first capture L50 (cm) | 15.12 |
| Age at first capture year | 1.01 |
| Age at first recruitment tr50 (year) | 0.18 |
| Length at first recruitment (cm) | 7.5 |
| Natural mortality M (year$^{-1}$) | 1.16 |
| Fishing mortality F (year$^{-1}$) | 1.19 |
| Total mortality Z (year$^{-1}$) | 2.35 |
| Exploitation rate (E) | 0.51 |
| Allowable limit of exploitation (Emax) | 0.69 |
| Limiting fishing mortality (Flimit) | 0.77 |
| optimum fishing mortality (Fopt) | 0.58 |
| Z/K ratio | 4.196 |

The growth parameters of *S. dorsalis*are shown in table 1. The asymptotic length (L∞) was 32.02 cm, with a growth rate (K) of 0.56 per year. The Theoretical age at length zero (to) was estimated as -0.29 year.

The VBGF for *S. dorsalis* was :

$$L_t = 32.02\ (1- e^{-0.56\ (t + 0.29)})$$

The length at optimum yield (Lopt) was estimated at 18.94 cm. The growth performance index (Φ′) was 2.76 per year. The longevity (Tmax) et the theoretical age ($t_0$) were calculated as 5.35 and -0.29 year respectively with an Rn value of 0.24. The length at optimum yield was estimated at 18.4 cm.

The annual total mortality (Z) derived from length frequency catch curves was 2.35 year$^{-1}$ (Figure 3). The natural mortality rate (M) derived from Pauly's equation was estimated at 1.16 year$^{-1}$. The fishing mortality rates (F) was 1.19 year$^{-1}$. The current exploitation rate (E) was obtained at 0.51. Limiting fishing mortality (Flimit) and the optimum fishing mortality (Fopt) were calculated as 0.77 per year and 0.58 per year, respectively.

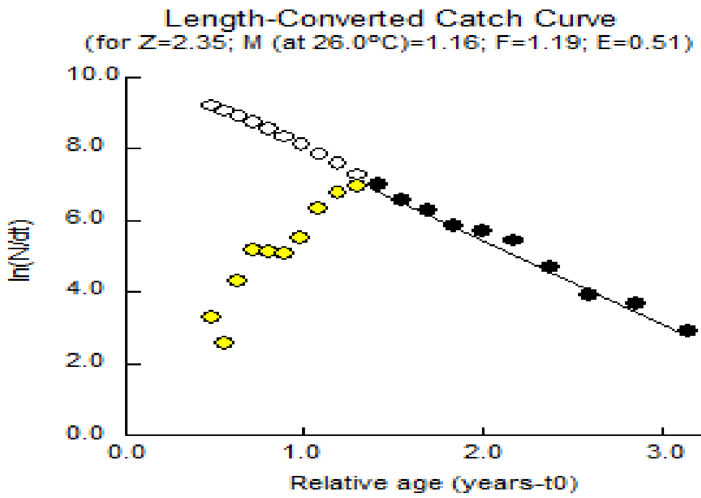


**Figure 3.** Length-converted catch curve for *Selene dorsalis* in the coastal waters of Côte d'Ivoire.

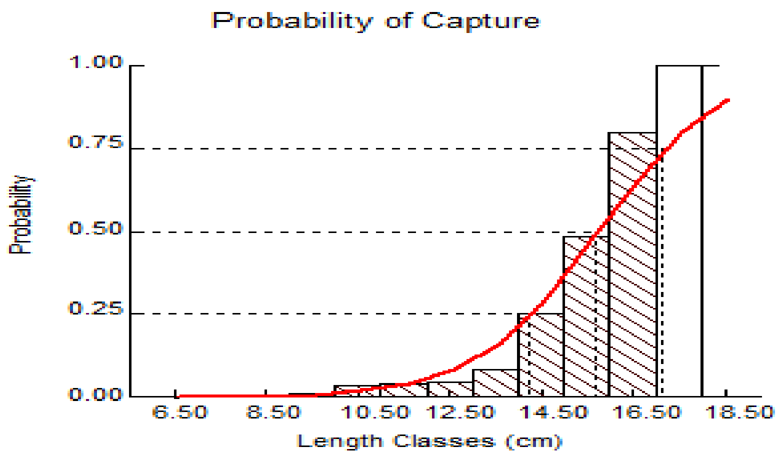


**Figure 4**. Probability of capture analysis for *S. dorsalis* in the coastal waters of Côte d'Ivoire.

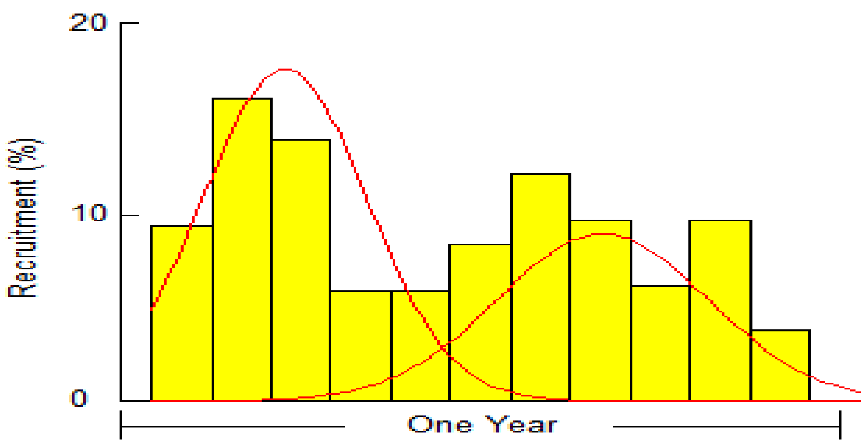


**Figure 5.** Recruitment patterns for *S. dorsalis* in the coastal waters of Côte d'Ivoire.

The estimated length at first capture L50 or Lc (length at which 50% of the fish entering the gear are retained) was 15.12 cm (Figure 4).The recruitment patterns (Figure 5) showed two peaks, one major occurring in March with 18% recruits and the other minor occurring in August with less than 10 % recruits. The length at first recruitment (Lr50) was estimated as 7.5cm while the age at first recruitment (tr50) was calculated as 0.18 year (Table 1). VPA (Figure 6.) indicated that main loss in the stock up to 13.5 cm size was due to natural causes. Fishes became more vulnerable to the gear after this size and mortality due to fishing increased and eventually outnumbered the natural losses. Maximum fishing mortality of 1.5 was recorded at size of 22.5 cm. Increasing fishing mortality (F) resulted in decreasing populations of *S. dorsalis* (Figure 6). The terminal fishing mortality (Ft) for *S. dorsalis* was 2.15 year$^{-1}$. The annual total stock and biomass were estimated at 10.412, 5.546 tons respectively. The plots of relative yield-per-recruit against exploitation rate showed that the present exploitation rate (0.51) was less than the maximum exploitation rate Emax (0.69). However, the present exploitation rate was higher than the rate of exploitation at which 50 % of the biomass-per-recruit was fished (E current > E0.5) (Figure 7).

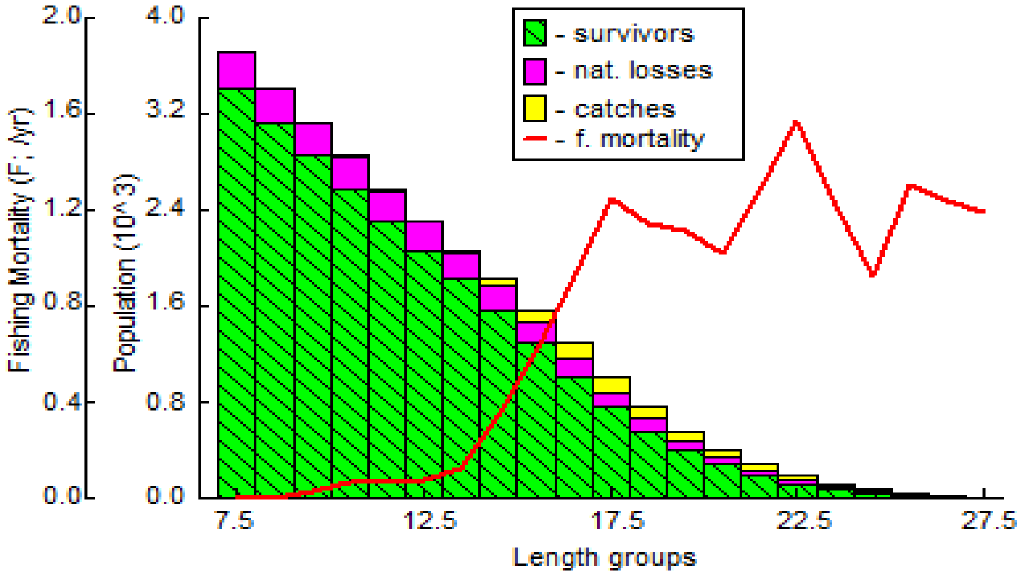


**Figure 6.** Length structured virtual population analysis for S. dorsalis in the coastal waters of côte d'Ivoire.

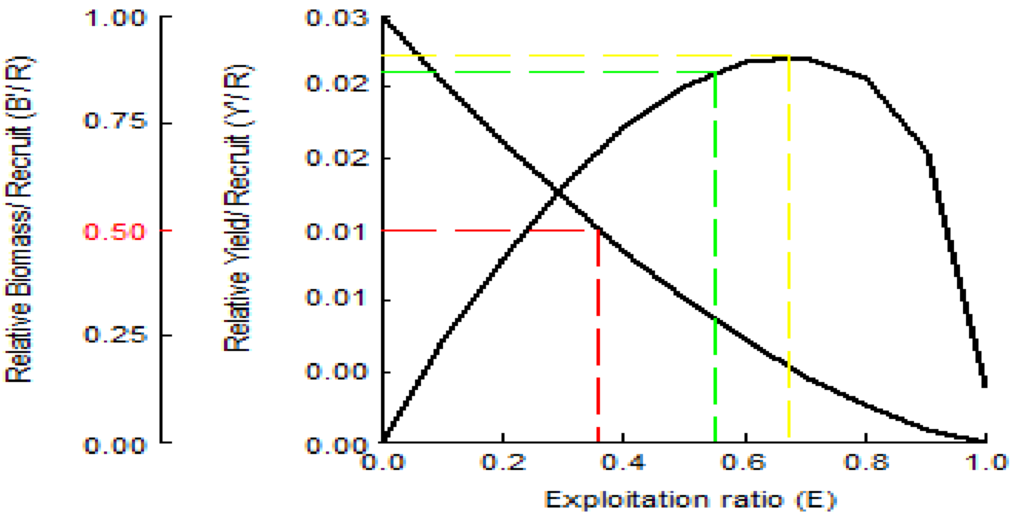


**Figure 7**. Relative yield-per-recruit (Y′/R) and biomass-per-recruit (B′/R) plot for *Selene dorsalis* at different rates of exploitation in the coastal waters of Côte d'Ivoire (Emax = 0, 69, E0.1 = 0, 58, E0.5 = 0, 38).

The mean length of *S. dorsalis* from the current study was 17.83 ± 6.12 cm FL with a range of 7.5-30.3 cm FL. The length range from the present study was different to the results of 3.5-35 cm recorded by Costa *et al*. (2018) in *Selene septapinnis* from a coastal zone (southeastern-Brazil). Although both species belong to the same genune (Selene) some differences due to distribution, environment and fishing gears used can explain the results obtained. The growth rate from the current study (0.56 $year^{-1}$) was lower than the value (0.76 $year^{-1}$) of others researchers (Samuel *et al*., 2021). The growth rate (K) obtained from the current study suggested that *S. dorsalis* in Côte d'Ivoire is a slowgrowing fish species evinced by a high asymptotic length and longitivity. However this value was higher than (0.49 $year^{-1}$) recorded by Coasta *et al*. (2018) in *S. septapinnis*. Regarding the asymptotic length (L∞), the value of the present study was in variance to results reported by some researchers (Coasta *et al*., 2018; Samuel *et al*., 2021). The possible reasons for variation in growth rate (K) and asymptotic length (L∞) could be due to geographical locations, the data analysis method used, the fishing gears used and the fish size classes. The growth performance index from the current study (Φ' = 2.76 $year^{-1}$) was higher than the results (Φ'=2.58 $year^{-1}$) reported by Samuel *et al*. (2021). Variations in growth performance index may be due to the availability of food and change in the marine environment. The estimated length at first capture from the present study was 15.12 cm. The length at first capture of *S. dorsalis*(Lc50= 7.61 cm) in Ghana by Samuel *et al*. (2021) was lower than the current study. The differences in the mesh size of fishing gears used in fishing may have accounted for the observed variation in length at first capture in relation to previous studies. Possibly fishing gears with large mesh size are likely to capture fishes of larger sizes and vice versa. According to Arra *et al.* (2018), the length at first sexual maturity (Lm) of *S. dorsalis* was estimated at 21.29 cm for females and 19.09 cm for males. Comparing with the length at first capture of the species this implied that the length at which *S. dorsalis* becomes vulnerable to the fishing gears used was lower than the length at first sexual maturity. This implies that the species does not get the opportunity to spawn, at least once, before it is captured. Regarding the ratio (Lm/L∞ ; 21.29 /32.02= 0.66), *S. dorsalis* becomes mature when attains 66% of its asymptotic length. Such Lm/L∞ ratio less than 1 implies that the fish species invests more energy in growth than reproduction. Indeed, investing more energy into growth by the fish species could be a surviving strategy against natural mortality situations. The recruitment pattern from the study showed a continuous pattern for *S.dorsalis*. The two peaks of recruitment occurred mostly after both the major (March) and minor (August) periods. From the coastal waters of Côte d'Ivoire. Furthermore, the two peaks exhibited by the assessed fish species conform to Pauly's (1987) findings that tropical fish species portray two recruitment peaks. All year-round recruitment pattern could be as a result of the high number of deaths, particularly from the fishing mortality rate. The length at first recruitment for *S. dorsalis* from the current study was 7.5 cm. This was lower than the length at first capture (15.12 cm) and the length at first maturity (21.29 cm) for this species. This result could be explained by the fact that individuals of *S. dorsalis* get recruited into the stock before becoming vulnerable to fishing gears. The computed length at first recruitment (Lr50=7.5cm) was lower than the length at first capture, depicting that recruitment in Selene dorsalis fishery is currently active since juveniles get recruited into the stock before been harvested. Evidently, the outcome of the virtual population analysis (VPA) showed that majority of individuals at the length of first recruitment (Lr50 = 7.5 cm) became survivors (Figure 6), strengthening the assertion that recruitment within the fishery of *S. dorsalis* in the coastal waters of Côte d'Ivoire is functional.

The estimates of mortality rates from the current study (M=1.16 per year; F= 1.19 per year; Z= 2.35 per year) were lower than the mortality rates estimated by Samuel *et al*. (2021) in Ghana where the main mortality contributing to the decline of the species was the fishing mortality (2.21 $year^{-1}$) against a natural mortality of (M=1.21 per year). However the fishing mortality value for the current study (1.19 per year) was slightly higher than the natural mortality value (1.16 per year) indicating a certain fishing pressure on the fish stock. In addition, the exploitation rate of *S. dorsalis* (E = 0.51) is higher than the optimum reference rate defined by Gulland (1971), indicating an overexploitation of the stock of this species. E current> E0.5 implied that a considerable increase in the current exploitation rate of the stock could lead to depletion of the fish stock. This result is confirmed by the Z/K ratio (4.196). Indeed, according to Barry and Tegner (1989) cited by Lederoun *et al*. (2015), if Z/K >2, mortality predominates, and it is therefore overexploited, which is in agreement with our results (Z/K = 4.196> 2). From the study, the fishing mortality rate (1.19 $year^{-1}$) was higher than the optimum fishing mortality rate Fopt (0.58 per year) and the limiting fishing mortality (0.77 per year). This finding imply that the assessed fish species is experiencing high fishing pressure which tends to distort its stock status if prosper measures are not implemented.

## CONCLUSION

The study aimed at assessing the stock status of *S. dorsalis* from the coastal waters of Côte d'Ivoire based on certain population parameters. The assessed fish species was found to be a slow growing species (K=0.56 per year), with a high asymptotic length (32.02 cm) and longitivity. The results revealed year-round recruitment pattern and high fishing mortality rate. The length at first capture Lc50 is lower than the length at first sexual maturity which may lead to recruitment failures in the future if management measures are not taken. The exploitation rate of 0.51 and the high fishing mortality indicated *S dorsalis* is highly overexploited. As part of the recommendation, there should be stringent management measures such as mesh size and fishing effort regulation by the establishment of fishing closure periods.

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