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Reproductive biology of the African moonfish, *Selene dorsalis* (Gill, 1862) (Carangidae) in continental shelf of Côte d'Ivoire fishery (West Africa)

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Abstract
The present investigation was conducted to study the reproductive biology of the *Selene dorsalis* (Gill, 1862) in continental shelf of Côte d'Ivoire fishery from March 2016 to February 2017. Sampling was done each month by trawler fishing. A total of 386 (7.5 to 30.3 cm and 7.20 to 496.63 g) were used. The sex ratio was 1: 0.97. All Length-Weight Relationship were statistically highly significant. The coefficient b (3.00, 3.06 and 3.03 respectively for male, female and both sexes) of the Length-Weight Relationship of *S. dorsalis* showed isometric growth. The condition factor indicated that Females (1.94 ± 0.14%) had higher condition factor than males (1.88 ± 0.14%). GSI ranged from 0.03 % to 5.76%. HIS varied between 0.37 % and 1.97 %. *S. dorsalis* didn't use energy stored in liver for development of the ovaries. Size at first maturity of females (21.29 cm) was slightly higher than males (19.09 cm).

Keywords: Carangidae; *Selene dorsalis*; biology; Côte d'Ivoire

1. Introduction
In several parts of the world, fish stocks are currently overexploited or have not been adequately managed. As a result, catches are declining [1]. However, for a good and sustainable management of Ivoirian marine ecosystem, it is important to have a genuine knowledge of all the fish of continental shelf of Côte d'Ivoire. Among these knowledges, we can mention some important aspects of fish reproductive biology such as Length-Weight Relationship [2], Gonadosomatic Index, Sex ratio [3] and size at first sexual maturity [4], which gives necessary informations for successful of fisheries management. Ivorian coast contains many economically important fish species like *Selene dorsalis* which is one of semi-pelagic resources [5]. It forms part of the trawl fishery catch in the Ivorian coast and belongs to family Carangidae. *Selene dorsalis* is a very common species of Cap Verde Islands, and from Senegal to South Africa [6]. Despite its importance to fisheries, little is known of the reproductive biology of this species, particularly concerning Length-Weight Relationship, Condition factor, Gonadosomatic index, Hepatosomatic index, Sex ratio and size at first sexual maturity. Thus another's authors are worked on morphological discrimination in juveniles of two Selene Species [7], on Larval Development of the Atlantic Moonfish *Selene Setapinnis* (Osteichthyes, Carangidae) from Southeastern Brazil [8] and on community ecology of the metazoan parasites of Atlantic Moonfish, *Selene setapinnis* [9].
The aim of the present study was to estimate reproduction parameters like Length-Weight Relationship, Condition factor, Gonadosomatic index, Hepatosomatic index, Sex ratio and size at first sexual maturity, of *S. dorsalis* in order to assess the stock and provide data that could be useful for management.

2. Materials and Methods
2.1 Study Area and sampling protocol
Continental shelf of Côte d'Ivoire surface is 11000 km^2 and estimate to about 550 km. It is influenced by two marine's seasons: The cold season start from December to January and then from July to September. However, the warm season extending from February to June and October to November [10].

The period from January to February corresponds to the minor upwelling whilst a major upwelling is usually observed between July and October [11]. *Selene dorsalis* specimens were collected from March 2016 to February 2017 in continental shelf of Côte d'Ivoire fishery at Port (Abidjan, Côte d'Ivoire) through the industrial fishing carried out by trawlers. A total of 386 specimens (17.46 cm ± 3.34 (Fork Length); 113.21 ± 66.27 g Total Weight) of this species were transported to the research laboratory and preserved in a deep freezer until examination and analysis.

2.2 Morphometric measurements
The Specimens were brought out of the deep freezer and allowed to thaw. The fish were weighed to the nearest 0.01g; fork length was measured to the nearest 0.1 cm. The gonads and livers were weighed to the nearest 0.001 g**.**

2.3 Sex ratio
The sex of each individual was determined by examining the gonads. The relative proportion of males and females was used to calculate the sex ratio. Chi-square tests were used to investigate the differences in sex ratios from an expected 1:1 ratio.

2.4 Length-Weight Relationship (LWR)
The Length-Weight Relationship of fish was estimated by using the equation [12]:

$$W = a \times FL^b \quad (1)$$

Where, W = body weight in grams (g), FL = fork length in centimetres (cm), "a" is a coefficient related to body form and "b" is the allometric growth coefficient. This equation was log transformed to estimate the parameters "a" and "b"; and the association degree between Length–Weight variables was calculated by the correlation coefficient (R^2). The statistical significance level of R^2 was estimated [13]. The values of constant "a" and "b" were estimated using the least-square method applied to the log transformed data [14] as:

$$\log W = \log a + b \times \log FL \quad (2)$$

The growth is isometric if b = 3 and the growth is allometric if $b \neq 3$ (negative allometric if $b < 3$ and positive allometric if $b > 3$). All the statistical analyses were considered at significance level of 5% ($p < 0.05$). For this species, the length-weight relationship for all individuals grouped, males and females are determined.

2.5. Condition factor
The condition factor which shows the degree of well-being of the fish in their habitat was determined by using the equation [15],

$$K = 100 \times W/FL^b \quad (3)$$

Where, K = Condition factor, W = Weight of the fish in gram (g), FL = Fork length of the fish in centimetres (cm), "b" = the value obtained from the length-weight equation.If the growth is isometric, "b" = 3 is used to calculate K value. If the growth is allometric, "b" value was obtained from the estimated Length-Weight Relationship equation ($W = a^{\times}FL^b$) as suggested by Lima-Junior *et al*. [16].

2.6 Different stages of gonadal development
According to Nikolsky [17], the different stages were: Stage I, immature; Stage II, quiescent; Stage III, maturing; Stage IV, mature; Stage V, running; Stage VI, spent. Gonadal stages were examined macroscopically and classified.

2.7 Gonadosomatic index
The gonad somatic (GSI) which represent the gonad weight expressed as a percentage of the wet body weight was calculated according to Wootton [18]; Nunes *et al*. [19].

$$GSI\ (\%) = \frac{Gonad\ weight\ (gram)}{gutted\ weight\ (gram)} \times 100 \quad (4)$$

After calculating, *Selene dorsalis* period of maturity was divided into following stages [20]: Prespawing phase, Spawning phase, Postspawning phase and Preparatory phase.

2.8 Hepatosomatic index (HSI)
HSI was calculated according to Pardoe *et al.* [21] and Nunes *et al.* [19] by liver weight and body weight ratio using following formula:

$$HIS\ (\%) = \frac{Liver\ weight\ (gram)}{gutted\ weight\ (gram)} \times 100 \quad (5)$$

2.9. Size at first sexual maturity
Equation model to estimate size at first maturity [22] is:

$$P = \frac{1}{1+e^{-(a+bFL)}} \quad (6)$$

Where, P = frequency of adult individual; FL= Fork length (cm); a and b are parametres. The size at first sexual maturity (FL_{50}) as the length in which 50% of the individuals joined the reproductive population was calculated as:

$$FL_{50} = -\frac{a}{b} \quad (7)$$

Where, a and b are the same parameters of equation 6.

2.10 Statistical analyses
The sex ratio was tested for the expected 1: 1 ratio by using chi-square test at 95% significance level. The b-value for each species was tested by Student t-test to verify if it was significantly different from the predictions for isometric growth (b = 3). The ANOVA test was used for length and weight mean comparisons between male and females.

3. Results and Discussion
3.1 Results
3.1.1 Sex ratio
A total of 196 males and 190 females were observed out of 386 samples examined. The sex ratio was 1: 0.97 (male to female). The difference in sex ratio was not significant ($p > 0.05$).

3.1.2 Structure of Sampling
Among the 386 *S. dorsalis* individuals, 196 males and 190 females were determined, with a fork length ranging from 7.5

to 30.3 cm and from 8.8 to 27.2 cm respectively for the males and females; however, the body weight of *S. dorsalis* ranging from 7.2 to 496.63 g. The difference in fish length between males (17.42 cm ± 3.35 cm FL) and females (17.45 cm ± 3.21 cm FL) is not significant (P > 0.05).

3.1.3 Length-Weight Relationship

All Length-Weight Relationship were statistically highly significant (P<0.01). The determination coefficients (R^2) of all population, male and female of *S. dorsalis* were 0.985, 0.986 and 0.985 respectively. The statistical analysis shows that the type of growth is isometric (t < 1.96; p < 0.05) for the males, females and all fish of *S. dorsalis* (Fig.1).

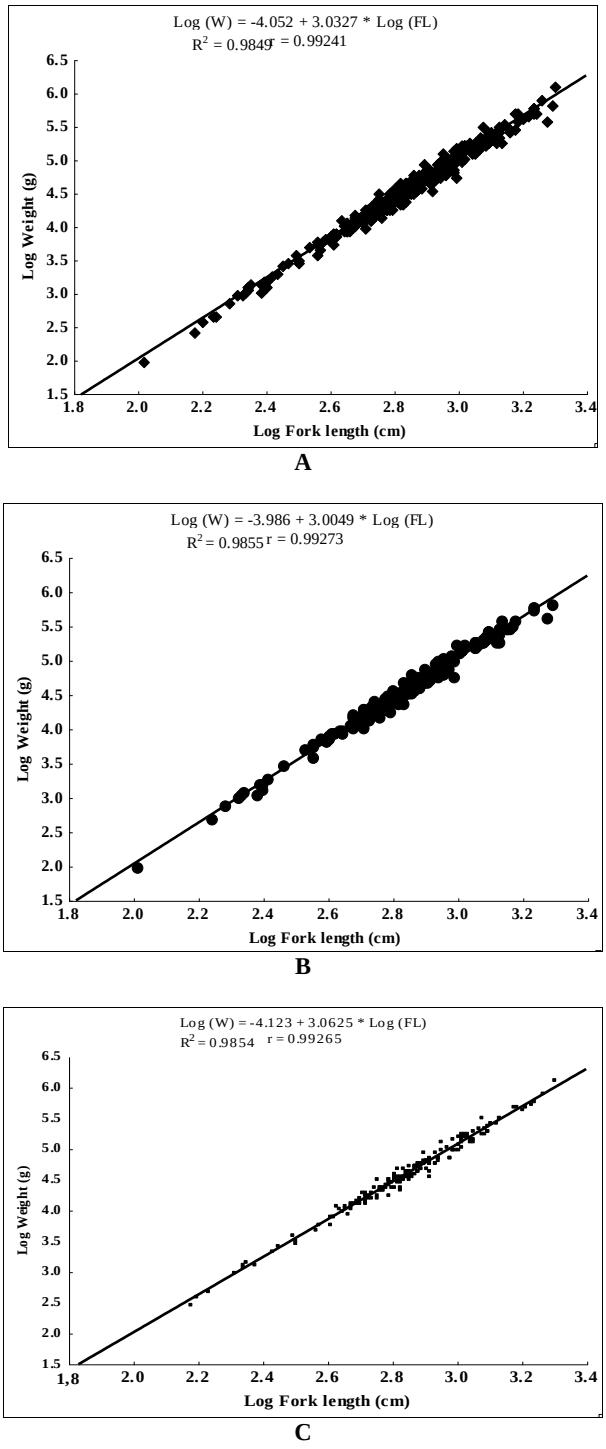

Fig 1: Length - Weight Relationship for combined sexes (A), males (B) and females (C) of *Selene dorsalis* of Ivorian continental shelf

3.1.4 Condition Factor (k)

The Condition factor, K (%) for the combined sexes ranged from 1.45 to 2.39 with a mean value of 1.91 ± 0.14. K for males (1.88 ± 0.14; range = 1.45 – 2.25) was significantly (p < 0.01) different that of females (1.94 ± 0.14; range = 1.51 – 2.39) (Fig. 2).

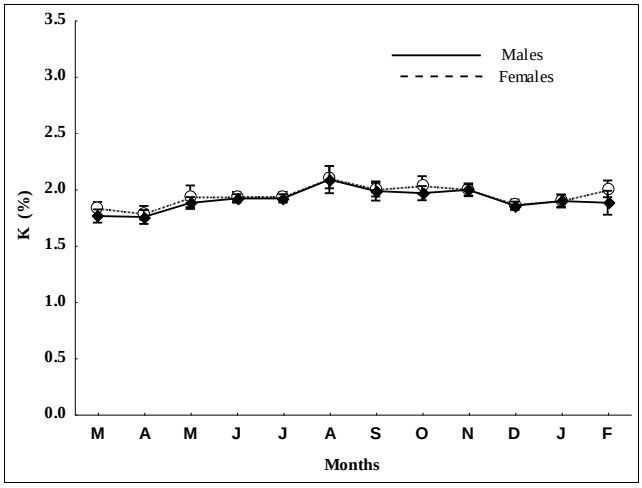

Fig 2: Monthly changes in condition factor of *Selene dorsalis* of Ivorian continental shelf

3.1.5 Gonadal and repartition development stage

In this study, six stages of gonadal development were observed in male and female *Selene dorsalis*. These Stage I (Immature); Stage II (Early maturing); Stage III (Developing); Stage IV (Developed / Pre spawning); Stage V (Spawning); Stage VI (Spent) (Fig.3). The size (length and weight) and colour of the gonads varied during sexual development.

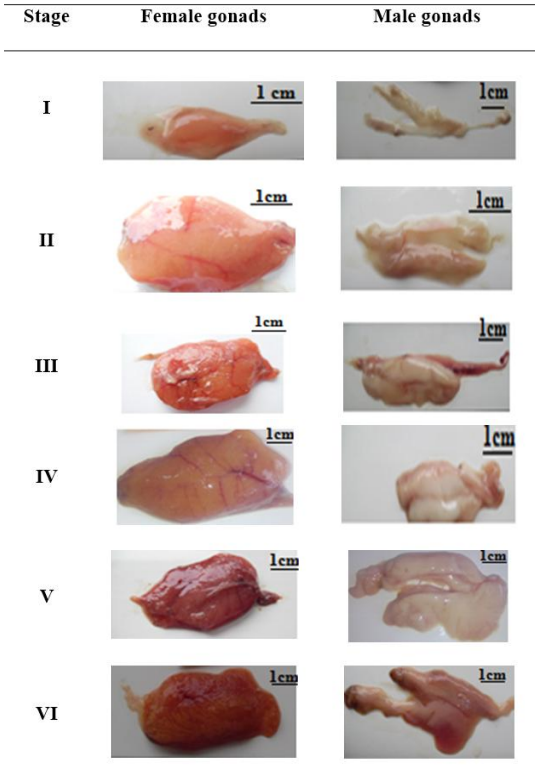

Fig 3: Six macroscopic maturity stages of female and male 's gonads. Stage I (Immature); Stage II (Early maturing); Stage III (Developing); Stage IV (Developed / Pre spawning); Stage V (Spawning); Stage VI (Spent)

Monthly variation in maturity stages of gonads for males and females of *S. dorsalis* shows in Fig.4. The macroscopic examination of the gonads showed that the species are immature between September and December (stages I and II). The gonads were mature (stage III to Stage VI) from March to December with a high proportion from March to September.

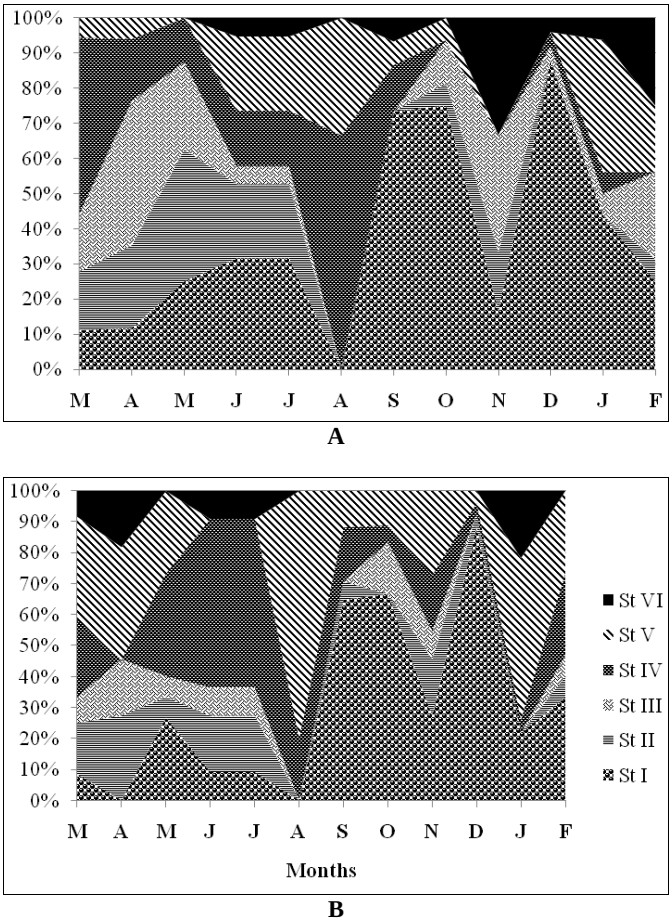

Fig 4: Monthly variation in maturity stages of gonads for males (A) and females (B) *S. dorsalis*; St= Stage

3.1.6 Gonadosomatic index (GSI)

The gonadosomatic index of *S. dorsalis* was estimated monthly for both sexes and values are expressed as percentages. There are two peaks periods of maturity. GSI ranged from 0.03 % to 5.76%. The mean gonadosomatic index was 1.04 ± 0.84%. High gonadosomatic index were observed in August for all fish and January for males and February for females. GSI increased for both males and females respectively from 0.23 ± 0.17 in May to 0.85 ± 0.03% in August and from 0.82 ± 0.65 in April to 2.51 ± 0.85 % in August. There was gradual decline in GSI for males and females respectively to 0.64 ± 0.17% and 1.74 ± 0.67% in September. There is again abrupt decline in GSI to 0.53 ± 0.17 % for male and to 0.62 ± 0.87 % for female in October.

There is a second increase in GSI from 0.53 ± 0.17 % in October to 1.05 ± 0.41% in January for male and from 0.62 ± 0.87 % in October to 2.44 ± 1.25% in February for female. There is decline in GSI from 1.05 ± 0.41% in January to 0.58 ± 0.28% in March for male and from 2.44 ± 1.25% in February to 1.37 ± 0.78% in March for female. And again there is further decrease from 0.58 ± 0.28% in March to 0.23 ± 0.17% in May for male and from 1.37 ± 0.78% in March to 0.82 ± 0.65% in April for female (Fig.4 A).

3.1.7 Hepatosomatic index (HSI)

The Hepatosomatic index (%) of S. dorsalis was estimated monthly for both sexes. The HSI was significantly lower for males than females ($P < 0.01$). High hepatosomatic index were observed in July (0.97 ± 0.21%) and August (1.58 ± 0.21%) respectively for males and females (Fig. 4 B).

3.1.8 Size at first sexual maturity

Size at first sexual maturity (FL_{50}) for males and females were respectively 19.09 and 21.29 cm. The size at first sexual maturity of females was slightly higher than males. However, the male to female size was not significantly different ($\chi^2 = 0.12$; $P > 0.05$) (Fig.4 C).

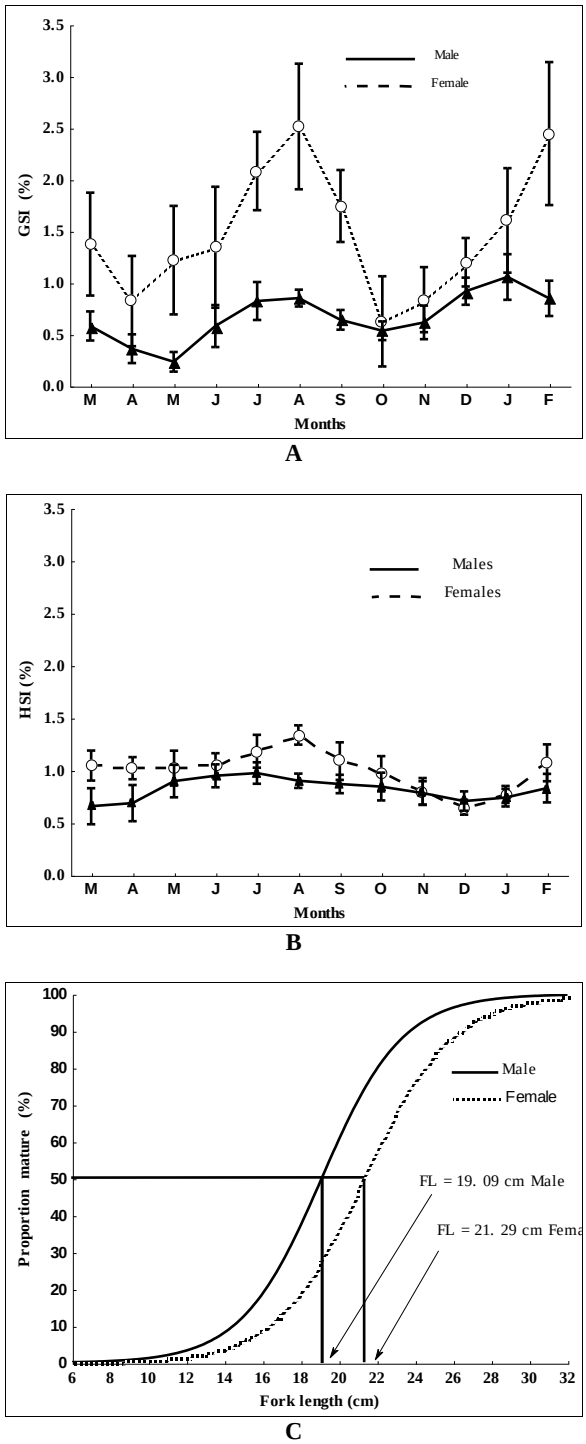

Fig 4: Monthly changes in Gonadosomatic Index (A), Hepatosomatic Index (B) and Size at first sexual maturity (C) of *Selene dorsalis* of Ivorian continental shelf.

3.2 Discussion

In the present study, there were more males than females and males had the maximal fork length (30.3 cm). The male to female ratio (1: 0.97) was not significantly different from the expected ratio of 1: 1. The Sex ratio obtained is highly desirable for broodstock development and hatchery operations for S. dorsalis. It may depend by numerous factors and on different populations inhabiting in different regions. Sylla *et al.* [23] observed in the population of *Trachinotus teraia* species of the same family which is similar to the findings of this study. According to Sylla *et al.* [24], the sex ratio in fish populations is governed by a number of factors such as differences in mortality or longevity between the sexes, and size dimorphism between sexes leading to differences in catchability between sexes. The coefficient "b" of the Length-Weight Relationship for male, female and combined sexes fish are very close to 3, reflecting isometry. Isometry growth is an indication that the species had symmetrical growth [25, 26] and by implication the species were neither too heavy nor light for their size. The coefficient "b" in fish affected by several factors such as season, habitat, gonad maturity, sex, diet, stomach fullness, health, preservation techniques and annual differences in environmental condition [27]. High correlation coefficient implies that the fish's lengths and weights were growing proportionately. A similar result was observed by Lawson *et al.* [28]; they were obtained for another Carangidae such as *Caranx hippos* in Nigeria.

The results of the condition factor indicated that *S. dorsalis* was in good condition. However, females had higher condition factor than males. This difference may be due to certain factors such as: sex, state of the stomach, morphology, age, reproductive state associated with gonadic maturity stages variations [18].

The mature specimens (stages III to VI) are widely represented in the samples all the years. Thus, *S. dorsalis* could be included in the multi-spawner species fish as reported by ICE[29].

S. dorsalis had two periods of maturity. There was increase in GSI for both male and female respectively in August indicating the peak period of maturity. There was gradual decline in GSI for both male and female in September indicating the spawning period. There is again abrupt decline in GSI for male and for female in October indicating post spawning period.

There is a second increase in GSI for male in January and for female in February indicating the pre spawning period. There is decline in GSI for both sexes in March indicating the spawning period. And again there is further decrease for male in May and for female in April indicating post spawning period.

S. dorsalis are two spawning periods. The first period start from March to October with a peak in August for both sexes and the second beginning from November to April with a peak in February for male and from March to April for Female. This founding is similar to that reported for another Carangidea, *Trachinotus teraia*, coastal marine species, typically estuary species [23]. In our study, peak periods of maturity took place during the seasonal upwelling of Gulf of Guinea. The major upwelling is usually observed between July and October whilst the period from January to February corresponds to the minor upwelling [11].

Liver is showed as the metabolic organ [30]. Highest value of liver index (HSI) was in the thirst period on July for male and August for female and in the second period on February for both sexes. The both periods are respectively observed during major upwelling and the minor upwelling; these periods were the periods of higher feeding intensities. HSI and GSI are generally increase and decrease together. This finding revealed that *S. dorsalis* didn't use energy stored in liver for development of the ovaries. This is a reproductive strategy that has evolved in response to temperature, upwelling events, primary productivity, or a combination of these factors [31]. There are two peaks in spawning activity because two different portions of population of *S. dorsalis* are spawning at different times or because an improvement in feeding conditions allows for additional reproductive activity [20].

This is the first attempt to estimate the size at first sexual maturity of these African moonfish species from Ivoirian marine waters and elsewhere, using available literature. The knowledge of size at first sexual maturity is important in the management of fisheries resources [32]. According to Sylla *et al.*, [24], the first sexual maturity is used as capture minimal size. The size at first maturity of females was slightly higher than males. Similar result was reported for other Carangidae species, *Parastromateus niger* [33] and *Trachinotus teraia* [24].

5. Conclusion

The present results indicate that the male to female ratio was not significantly different from the expected 1:1 distribution. *S dorsalis* exhibited presents an isometry growth. The fish's lengths and weights were growing proportionately. Females had higher condition factor than males. GSI study showed that there are two peak periods of spawning in *S. dorsalis*. High gonadosomatic indices recorded of August for both sexes, January for male and February for female suggest the possible spawning period of *S. dorsalis* which coincided the seasonal upwelling. HSI and GSI in generally increase and decrease together. That findings showed that *S. dorsalis* didn't use energy stored in liver for development of the ovaries.The male (19.09 cm) to female (21.29 cm) size at first sexual maturity was not significantly different. But the size at first sexual maturity of females was slightly higher than males. This finding study will contribute to the knowledge needed for fisheries management and the knowledge of reproduction biology of *S. dorsalis*.

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