Growth parameters of *Chloroscombrus chrysurus* (Linnaeus, 1766) in the Saloum Delta (Senegal)

Running title: Length-frequency analysis for estimating growth parameters

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Abstract

It is important to know the biological parameters of the commercially exploited species for an efficient management of fishery. The aim of this study is to estimate the growth parameters of *Chloroscombrus chrysurus* (Linneaus, 1766) using length-frequency data in ELEFAN system. From September 2014 to December 2015, biological aspects of *C. chrysurus* were examined out of a total of 352 specimens collected from the Saloum Delta (Senegal). The length-weight relationship and the von Bertalanffy equation were used to evaluate the fish growth. The total length (TL, cm) of the captured fishes ranged from 10 to 21 cm and from 11 to 25 cm with an average of 15.5±1.6 cm, 18.3±2.8 cm, in estuary and marine, respectively. The length-weight relationship shown a positive allometric growth (b = 3.11) in marine population and a negative allometric growth (b = 2.87) in estuarine population. The relationship linking the total length to the fork length showed a slope greater than 1 and a strong correlation (r^2 = 0.99). The estimated growth parameters were: L_∞ = 29.6 cm, k = 0.20, t_0 = -0.84, Φ' = 2.25 in marine and L_∞ = 23.2 cm, k = 0.18, t_0 = -0.86, Φ' = 2.23 in estuary. With regards to condition factor (K), there was a decreasing trend over the hot period (wet season) probably corresponding to the seasonal reproductive activity. The *C. chrysurus* grew rapidly during the first two years of its life and then growth slows down.

Keywords: *Chloroscombrus chrysurus,* length-weight relationship, condition factor, growth parameters, Senegal.

Résumé

Pour une gestion efficace de la pêche, il est important de connaître les paramètres biologiques des espèces exploitées commercialement. L'objectif de cette étude est d'estimer les paramètres de croissance de *Chloroscombrus chrysurus* (Linneaus, 1766) à partir des données de fréquence de taille dans le système ELEFAN. De Septembre 2014 à Décembre 2015, les paramètres biologiques de *C. chrysurus* ont été examinés sur un total de 352 spécimens capturés dans le Delta du Saloum (Sénégal). La relation taille-poids et l'équation de von Bertalanffy sont utilisées pour évaluer la croissance des poissons. La longueur totale (TL, cm) des poissons a varié de 10 à 21 cm et de 11 à 25 cm avec une moyenne de 15,5±1,6 cm, 18,3±2,8 cm, en estuaire et en mer, respectivement. La relation taille-poids a montré une croissance allométrique positive (b = 3,11) pour la population marine et une croissance allométrique négative (b = 2,87) pour la population estuarine. La relation entre la longueur totale et la longueur à la fourche a montré une pente supérieure à 1 et une forte corrélation (r^2 = 0,99). Les paramètres de croissance estimés ont été : L_∞ = 29,6 cm ; k = 0,20 ; t_0 = -0,84 ; Φ' = 2,25 en mer et L_∞ = 23,2 cm ; k = 0,18 ; t_0 = -0,86 ; Φ' = 2,23 en estuaire. Le facteur de condition (K) a indiqué une tendance baissière au cours de la période chaude (saison humide) qui correspondrait probablement à l'activité reproductrice. *C. chrysurus* a connu une croissance rapide au cours des deux premières années de sa vie, puis la croissance ralentit.

Mots clés : *Chloroscombrus chrysurus*, relation taille-poids, facteur de condition, paramètres de croissance, Sénégal.

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I. Introduction

On the West African coastline, the estuaries are generally shallow with highly varying gradients. As transitional areas with intense fluctuations of environmental conditions, these ecosystems influence complex multi-species dynamics and impose physiological constraints on the associated biota (Baran, 2000). The marine resources in Senegal are still relatively abundant, and fishery generates a high economic value for local communities. Fishery, from a nutritional point of view, plays a significant role since it remains a main supplier of animal proteins in the diet of most Senegalese people. Since the 1970s, it has gained a key role in rebalancing the economy after the decline of groundnut and phosphate exportations (Ganapathiraju & Pitcher, 2006).

The Carangidae is one of the most diverse and abundant fish family in the world, occurring mainly in tropical waters and almost all species are exploited to some degree (Gushiken, 1988). The Carangidae family of fishes occurs worldwide throughout tropical and temperate waters, primarily occupying the epipelagic (upper 200 m) water column (Mohan *et al*., 2017). This important family of fishes supports 5% of the annual marine finfish landings owing to its value as bait, sport fishery, and food in many recreational and commercial fisheries (Ditty *et al*., 2004; Leak, 1981). Nevertheless, detailed biological information is very limited for tropical fishes, especially for those with low economic value, such as the Atlantic bumper,

Chloroscombrus chrysurus (Linnaeus, 1766).

The extension of the distribution range of *Chloroscombrus chrysurus* may be linked to many factors, but especially to the current warming of the North Atlantic (Stebbing *et al.,* 2002). The *C. chrysurus* shows a wide distribution along Senegalese coasts, mainly in the Saloum Delta. Few studies exist due to its low commercial value (Conand & Franqueville, 1973).

No biological characterization of *C. chrysurus* with respect to its length-weight relationship (LWR), condition factor and growth parameters was recorded in Senegalese coasts using the length-frequency distribution method. As there are insufficient information about the biology, species discrimination and fisheries status especially in Saloum Delta, Senegal, the current work was suggested to fill such gab. It will provide information on the growth, length-weight relationship and condition factor of Atlantic bumper in the Saloum Delta for the future stock assessment studies.

II. Materials and Methods

II. 1. Study area.

The Saloum Delta (13° 35' and 14° 10' N, 16° 50' and 17° 00' W) is situated on the Senegalese coast about 100 km South of Dakar (Fig. 1). It covers an area of about 180,000 hectares that integrates several types of wetlands. The watershed which hosts the Sine-Saloum estuary covers an area of about 80,000 hectares. The river system is made up of three main tributaries: the Saloum (110 kilometers long) in the North and North-East, the Bandiala (18 kilometers) in the south and south-east and the Diomboss (30 kilometers) between them. The delta is formed by the confluence of the three rivers flowing South to West into the Atlantic. Freshwater inflows are recorded in the rainy season from July to September. They do not compensate for the intense evaporation (Ndiaye *et al*., 2015).

II. *2. Sampling method*

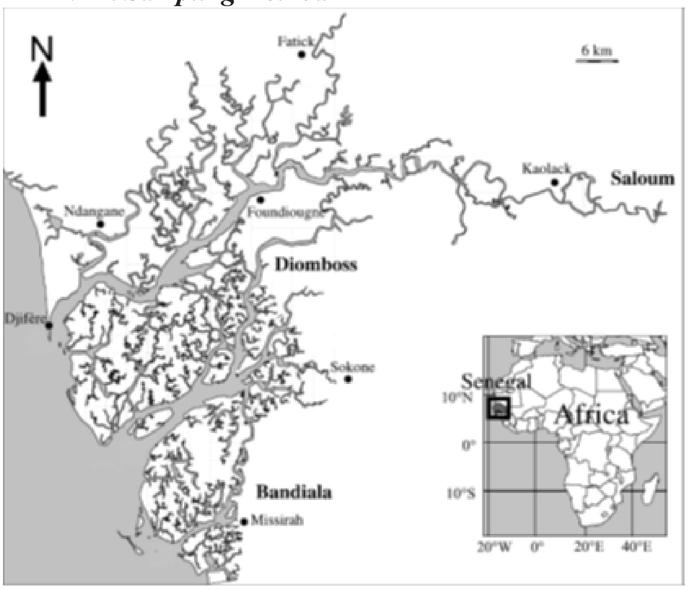

Figure 1. Study area, the Saloum Delta of Senegal

The samples were collected from September 2014 to December 2015 on a quarterly basis during the experimental fisheries for the jack gillnets selectivity study. Gillnets made up of six (6) layers of 28; 30; 32; 36; 40 and 46 mm of mesh size were used to target small and large size species of Atlantic bumper. Fish were identified using a key manual (Seret *et al.,* 2011). After each fishing operation, data on total length (TL) and fork length (*FL*) in mm and body weight (*TW*) in g were recorded for each individual of *Chloroscombrus chrysurus*. Specimens were grouped and not classified as male, female, or undetermined sex.

II. *3. Length-weight relationship*

The length-weight relationship of combined sex fishes was estimated by using the expression:

$$TW = a \times TL^b$$

where TW = total weight (g), TL = total length (mm), a and b are the intercept and the slope of the regression line, respectively (Ricker, 1973).

The b-value gives information on the kind of fish growth. Moreover, the statistical significance level of r^2 was estimated, and the b-value was tested by t-test to verify if it was significantly different from the isometric (b = 3). The growth is isometric if $b = 3$ and allometric if $b \neq 3$ (negative allometric if $b < 3$ and positive allometric if $b > 3$).

III. *4. Total length-fork length relationship*

The total length-fork length relationship were estimated by conversion among length measurements (TL and FL). This relationship was established using linear regression analysis

$$TL = b\ FL + a$$

where TL = total length (mm), FL = Fork length (mm), a and b are the intercept and the slope of the regression line, respectively (Ricker, 1973).

II. 5. Growth parameters

Length-frequency distribution was analyzed to assess indirect fish growth. The estimation of the growth parameters was based on size classes, by using the ELEFAN in R software Electronic LEngth Frequency ANalysis method (Pauly & Greenberg, 2013). This routine estimates the von Bertalanffy growth parameters by defining L_∞ and k values through the growth curves plan, which represents cohorts on sequential samples. The von Bertalanffy growth equation (VBGE) was used to estimate the growth parameters:

$$Lt = L_\infty (1 - exp(-k(t - t_0)))$$

where Lt is the length at the age t, L_∞ the asymptotic length (the length at which growth rate is theoretically zero), k is the body growth rate coefficient (rate of asymptotic growth) and t_0 is the time when length would have been zero on the modeled growth trajectory.

II. 6. Growth performance index

The comparison of the results obtained on the growth with other studies was made by using the growth performance index (Φ') and the auximetric grid (Pauly & Froese, 2006). This index has been defined by correlating k, which shows how the speed of growth decreases as age increases (Daget & Le Guen, 1975) and the L_∞ length (Pauly, 1980). It is supposed to be almost constant for close species in both taxonomic and ecological point of view.

$$\Phi' = log_{10}(k) + 2log_{10}(L_\infty)$$

II. 7. Condition factor

The condition factor (K) was estimated according to Froese (2006) using the equation:

$$K = 100 \times WTL^{-3}$$

where W is the total body weight in g and TL is the total length in mm.

II. *8. Auximetric grid*

Comparisons of growth among populations have been expressed using auximetric grid. The auximetric grid was available on Fishbase which indicated the relationship between the logarithms of L_∞ and k of different studies.

II. 9. Statistical analysis

The data were presented as the mean ± standard deviation (SD). For the statistical analysis of the data, a one-way ANOVA (Analysis of Variance) was done by using the Statistica® version 6. Significance was assigned at the 0.05 level of significance.

III. Results

III. 1. Length-frequency distribution

During the sampling, a total of 352 fish were measured in the two areas, 187 in marine and 165 in estuary. Length-frequency distribution was given in Figure 2. The fish collected in marine ranged from 11 to 25 cm and from 10 to 21 cm TL in estuary. The average size of *Chloroscombrus chrysurus* was 15.5±1.6 cm, 18.3±2.8 cm, in estuary and marine, respectively. A significant spatial difference ($p < 0.05$) was shown for fish average length, with the marine zone showing higher values than the estuary zone.

III. 2. Length-weight relationship

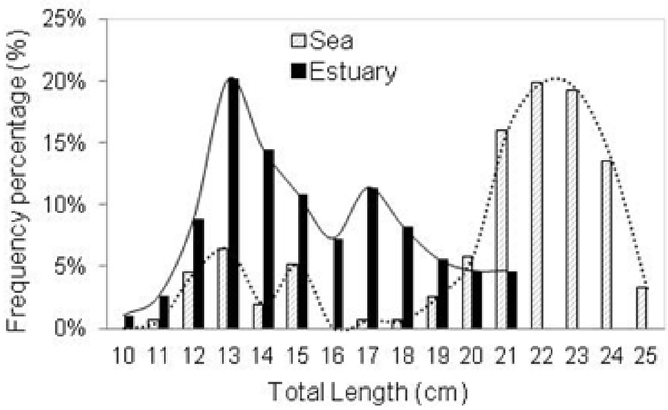

Figure 2. Length frequency distribution of *Chloroscombrus chrysurus* in the Saloum Delta

The length-weight relationship of combined sex was analyzed by the exponential form of equation $W = 0.0057 \times TL^{3.11}$ in marine and $W = 0.0084 \times TL^{2.87}$ in estuary indicating positive allometric and negative allometric growth respectively (Fig. 3). The value of coefficient of determination (r^2) estimated for the species was 0.98 in marine and 0.97 in estuary ($p < 0.05$) which shows that the relationship between length and weight of the fish was highly significant.

III.3. Total length-fork length relationship

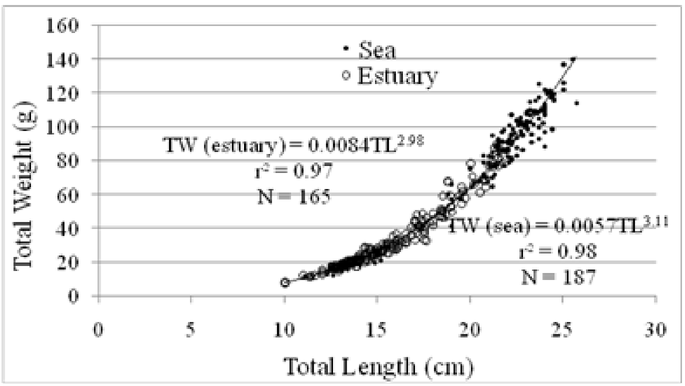

Figure 3. Length-weight relationship of *Chloroscombrus chrysurus* in the Saloum Delta

The total length-fork length relationship results compared among the two areas was *b* (1.18 in marine) inferior to *b* (1.20 in estuary) with a very high correlation in the two areas ($r^2 = 0.99$) (Fig. 4).

III.4. Growth parameters

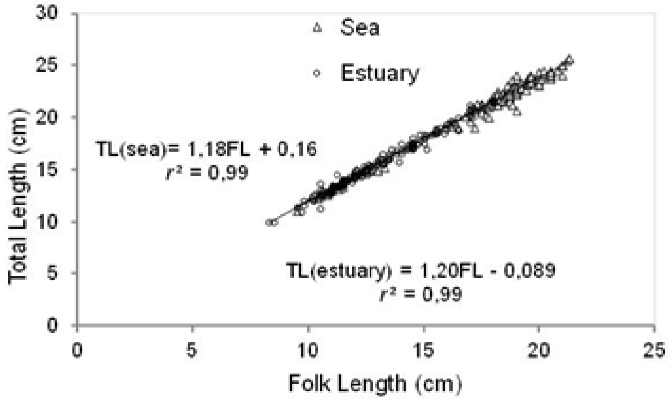

Figure 4. Total length-fork length relationship of *Chloroscombrus chrysurus*

Table 1 summarized the growth parameters of *Chloroscombrus chrysurus* in Saloum Delta. The maximum asymptotic value (L_∞) was estimated at 29.6 cm in marine and 23.2 cm in estuary. This estimate was used with the fixed values of *C* and *WP* (*C = 0* and *WP = 0*) giving the best fit value of $k = 0.20$ and 0.18 in both marine and estuary. The growth performance index (Φ') was 2.25 in marine and 2.23 in estuary. The estimated t_0 value obtained in marine and in estuary was respectively -0.84 year and -0.86 year.

C. chrysurus grew fast in the first year. The growth rate decreased gradually with age and reached 25 and 19 cm in 5 years, respectively in marine and in estuary (Fig. 5).

Table 1. von Bertalaffy growth parameters estimates generated by length-frequency analysis programs for a population of *Chloroscombrus chrysurus* in the Saloum Delta of Senegal

	Parameters				Equation
Area	L_∞ (cm)	k	t_0	Φ'	
Marine	29.6	0.20	-0.84	2.25	$Lt\ (sea) = 29.6\ [1- e^{-0.20(t+0.84)}]$
Estuary	23.2	0.18	-0.86	2.23	$Lt\ (estuary) = 23.2\ [1- e^{-0.18(t+0.86)}]$

III.5. Auximetric grid

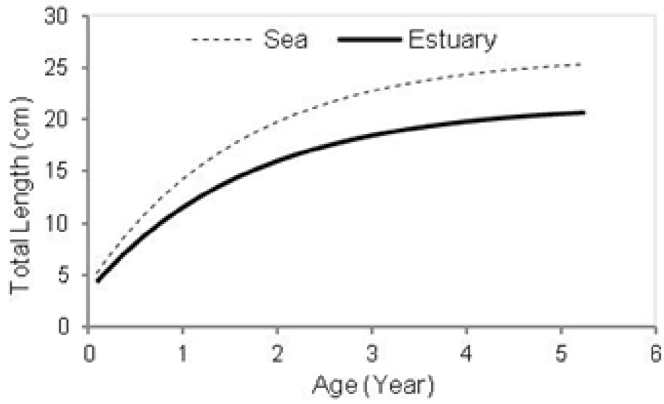

Figure 5. von Bertalanffy linear growth curve of *Chloroscombrus chrysurus* in the Saloum Delta of Senegal

Figure 6 suggested that Atlantic bumper had a growth performance similar to that of the slower-growing species among the carangids. There was also some indication that some groups may have a lower growth performance.

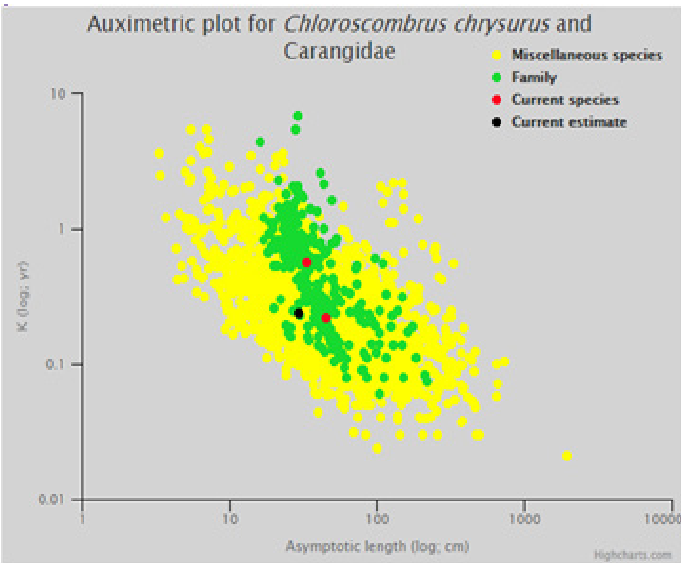

Figure 6. Auximetric plot for *Chloroscombrus chrysurus* in Senegalese waters. Dots represent the growth performance index (*φ*') fitted against Log_{10} (*K*) on the y-axis and Log_{10} (L_∞) on the x-axis

III.6. Condition factor (K)

The condition factor in marine area exhibited a clear seasonal variability with a maximum in the dry season, in March (1.45±0.31) and a minimum in the rainy season in September (1.35±0.23) (Fig. 7). The average condition factor was equal to 1.39±0.33. In estuary, the condition factor ranged from 1.29±0.46 (September) to 1.36±0.65 (June) with an average of 1.31±0.22. The average *K*-value showed a significant difference between marine (*K*=1.39) and estuary (*K*=1.31) ($p < 0.05$) suggesting a better fitness for this species in the marine area. These values suggest a state of wellbeing for the species tested in the two areas.

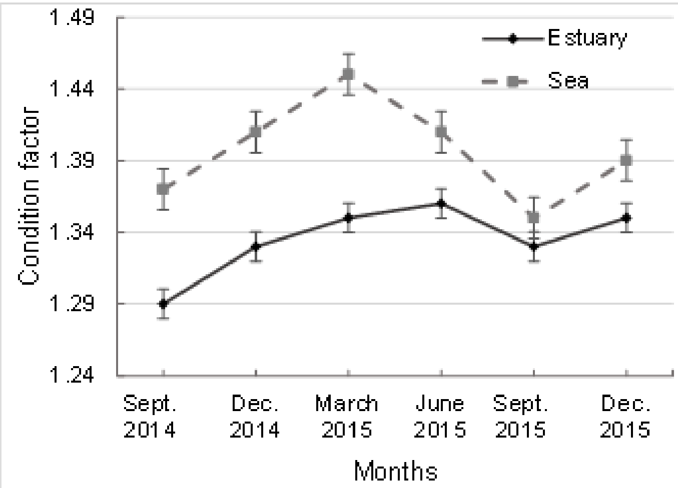

Figure 7. Condition factor variation of *Chloroscombrus chrysurus* in the Saloum Delta of Senegal

IV. Discussion

The results of this study indicated that Atlantic bumper sizes ranged from 10 to 25 cm. with a positive allometric in marine and negative in estuary. Growth parameters results suggested a slightly slower growth for estuarine individuals with a seasonal variability of condition factor.

The sizes of fish caught vary between 11 and 25 cm for individuals sampled in marine areas. For those collected in the estuary, their sizes vary between 10 and 21 cm. This result could be related to environmental factors such as salinity. Indeed, the Saloum Delta is an inverse estuary with salinity rates which reach four times those of the sea (Gning, *et al.*, 2008). The larger sizes encountered in the marine areas suggest that the reproduction could occur in marine waters. According to Vakily & Cham (2003), larger individuals were usually found in deeper water. Our results corroborated those reported by da Costa *et al.* (2005) in a tropical bay at Southeastern Brazil. They reported that *Chloroscombrus chrysurus* juveniles move toward the middle and outermost part of the bay following a seaward migration to join the adults. Then they move to deeper areas in the middle and outer zones, as they grow and search for new resources. This matches with Johnson (1978) reporting that this species explores deeper areas (up to 1800 m) as they grow, in the middle Atlantic Bight. The length-frequency distribution of *Chloroscombrus chrysurus* highlighted two groups ranging respectively from 10 to 16 cm and17 to 25 cm. These two groups corresponded to the juveniles and adults. According to Panfili *et al.* (2006) in estuaries in the eastern central Atlantic, 13.7-15.4 cm is the length of first maturity of females and 14.7 cm maturity for males. Indeed, the samples did not come from commercial fishing. The sampling was carried out from experimental fishery with nets of different mesh sizes. The data from experimental fisheries covered wider range of lengths comparison with those data from the commercial fisheries where there was usually the presence of only individuals of larger sizes due to the selectivity of the used fishing gears.

The length-weight relationship plays a major role in fisheries research since it is often associated with providing population parameters necessary for proper fisheries management and sustainable yield of the stocks (Ecoutin & Albaret, 2003). According to Jennings *et al.* (2001), population *b*-values are dependent on physiological condition of fishes, for example, gonad stage development and food availability. Besides the biological and environmental conditions, the geographical, temporal, and sampling procedure also affects the observed growth pattern of the fish (Bagenal & Braum, 1978). In addition, Muchlisin *et al.* (2010) stated that *b*-value is also affected by fish behavior; for example, active swimming fish may show lower *b*-values compared to passive swimming fish. This is probably related to the energy allocation for movement and growth. The relative growth coefficient obtained for *C. chrysurus* was significantly lower than 3 in estuary ($b = 2.87$) suggesting that this species growth had a negative allometric nature supported by high values of correlation indicating an elevated predictability between length and weight. The exhibited negative allometric growth pattern implied that the rate of increase in total length was higher than the rate of increase in weight. A positive allometric nature was found in marine with a b-value greater than 3 ($b = 3.11$). The *b*-values obtained from *C. chrysurus* in the Saloum Delta were in accordance with the range of values usually encountered for this parameter in marine species, which lies between 2.5 and 3.5 (Froese, 2006). The values obtained in this study were consistent with those of Ecoutin and Albaret (2003) in the Delta of Saloum in Senegal and those of Joyeux *et al.* (2008) in Brazil. However, the rate values of allometry observed in other countries such as Colombia (García *et al.*, 1998), Mexico (Passos *et al.*, 2012; Ditty *et al.*, 2004), Benin (Fiogbe *et al.*, 2003), Nigeria (King, 1997), Cuba (García-Arteaga *et al.*, 1997) and Brazil (Fonseca, & Souza, 2002; Vianna *et al.*, 2004; Masumoto & Cergole, 2005) were different from those we have found in Saloum Delta. Nevertheless, the *b*-value is an indicator of the fish condition or the condition of the fish stock (Petrakis & Stergiou, 1995; Pauly & Froese, 2006) and may vary over time and space.

The estimated values of the asymptotic length from the Saloum Delta (L_∞ = 29.6 cm in marine and 23.2 cm in estuary) were less than what were found by da Costa *et al.* (2005) in the Bay of Sepetiba in the South of Brazil (L_∞ = 31.6 cm), by Cergole *et al.* (2006) in southern Brazil ($L\infty$ = 45.1 cm) and by García and Duarte (2006) in Caribbean Sea (L_∞ = 30.5 cm). Furthermore, they were close than those obtained by Sossoukpe *et al.* (2017) in Benin ($L\infty$ = 28.35 cm) and by De Queiroz *et al.* (2018) (L_∞ = 25.4 cm). The growth parameters found in marine area (L_∞ = 29.6 cm and k = 0.20) were significantly ($p < 0.05$) greater than those found in the estuary (L_∞ = 23.2 cm and k = 0.18). This difference may be due to the difference in environmental conditions in the two areas. The slightly slower growth for estuarine individuals might be tight to the hypersaline nature of the estuary. Indeed, the major energy allocation to osmoregulation causes a decrease in growth in the estuary of the Saloum (Panfili *et al.,* 2006).

The auximétric grids showed the relationship between the logarithms of L_∞ and k of the various studies done on *Chloroscombrus chrysurus* species. This grid allowed seeing the performance of *C. chrysurus* growth studied in different localities. In the present work, the auximetric grid was used for comparing the growth of this species in Saloum Delta of Senegal with the studies of the same species in other countries. It showed that growth is slower in Senegal than in other countries.

The condition factor (K) showed in general the health, productivity and physiological condition of the fish population (Blackweel *et al.,* 2000; Ricker, 1973). It reflects the condition of morphological characteristics of the fish, lipid content and growth rates Bister *et al.,* 2000; Froese, 2006; Stevenson & Woods, 2006). It is affected by the biotic and abiotic factors (Blackweel *et al.,* 2000), for example water quality and the density of prey (feed) and predator. Seasonal variations of the condition factor are relatively low with a slight decrease in the hot season (September). This could be explained by several factors, including the abundance of food during the cold season when waters are more productive with the phenomenon of upwelling. Condition factor calculated in this study (K = 1.39 and 1.31 respectively in marine and estuary) were more important than those reported by Sossoukpe *et al.* (2017) in Benin (K = 0.49), reflecting a higher growth of the species from the Saloum Delta waters of Senegal and indirectly a higher achievement of the asymptotic length. During the wet season, *Chloroscombrus chrysurus* would suffer a great loss of energy related product, sexual development and sexual maturation of the gonads which leads to a decline in condition factor. Also, we discuss results in term of spawning period.

The growth performance index (Φ' = 2.25 in marine and 2.23 in estuary) found in this study were close than those reported by Sossoukpe *et al.* (2017) in Benin (Φ' = 2.25). This study values were lower than those found by King (1997) in Nigeria (Φ' = 2.80) and Masumoto & Cergole (2005) in Brazil (Φ' = 2.65). Thus, our results indicate a slower growth of *C. chrysurus*. These differences may also be due to the specificity and ecological characteristics of the study about the environments. The Saloum Delta is known for its hypersaline character (higher than 60) which affects the growth of the fish. Understanding the fish community structure in the Saloum estuary could be an important tool in the management of the fisheries of the estuary.

V. Conclusion

This research provides a description of *Chloroscombrus chrysurus* growth in the Saloum Delta of Senegal, including the length-weight relationship and the condition factor. The study confirmed that the length of a fish has a close relationship with its weight. It was evident from the study that the b-exponent and condition factor of *C. chrysurus* were higher in the marine area than in estuary. Regarding the estimation of VBGF parameters, a low estimate of L_∞ and a high k indicated that this species is a fast growing, short-lived fish. Marine growth parameters were higher than estuary parameters. The information reported in this study will greatly improve understanding of *C. chrysurus* life history and directly inform the future management of the Saloum Delta stock.

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