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Growth and exploitation parameters of *Ilisha africana*, by-catch of the experimental fishing for the study on selectivity of gill nets for *Ethmalosa fimbriata*, in the Saloum estuary and Joal (Senegal)

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Growth and exploitation parameters *Ilisha africana* were determined from the size frequency for the first time in Senegal. The size distribution showed average sizes equal to 19.26 ± 1.70 and 19.75 ± 2.03 cm, respectively in the estuary and at the sea. The values of allometric rates of the length-weight relationship were, respectively equal to 2.88 and 2.93 in the estuary and at the sea indicating a negative allometric growth for this species. Von Bertalanffy growth parameters are estimated to L∞ = 24.7 cm, K = 0.33 year^{-1}, t_0 = -0.53 in the estuary and L∞ = 25.5 cm, K = 0.34 year^{-1}, t_0 = -0.51 at the sea with growth performance index, respectively equal to Φ' = 2.30 and Φ' = 2.34. The values calculated for the total mortality (Z), natural mortality (M) and the fishing mortality (F) were: Z = 1.08, M = 0.93, and F = 0.14 year^{-1} in the estuary while at the sea these mortality rates were estimated respectively at Z = 1.25, M = 0.91, and F = 0.33 year^{-1}. The current exploitation rates in the estuary (0.10) and at the sea (0.25) indicated that *I. africana* was under-exploited in Senegal.

Key words: Allometric, mortality, Von Bertalanffy, condition factor.

INTRODUCTION

The small pelagic group consists of all the small fish that spend most or almost all of their adult phase on the surface or in open water. These species are totally free towards the bottom and are independent of the nature of the substrate (Laloë and Samba, 1989; Collignon, 1991). Among these small pelagic, the gender *Ilisha* occupies an important place. Species of the gender *Ilisha* (family Pristigasteridae) have a circumtropical distribution in estuaries and coastal waters, with one species in West Africa (*Ilisha africana*), two species in South America (one duçaquicole and one coastal) and 11 species in tropical Asia (Whitehead, 1985; Zhang et al., 2009).

I. africana is a species of this family (family: Pristigasteridae) and is very abundant in West African waters from Senegal to Angola (King, 1991). It is an estuarine species of marine origin (EM). *I. africana*

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spends part of its life cycle in the estuary for feeding or breeding. Reproduction can also occur in the marine area. Its diet consisted of mysids, rubbish, decapod crustaceans and fish eggs (King, 1991; Abowei, 2010). *I. africana* is one of the small pelagic species whose biology is less known until now. The few works in the West African region on its biology were carried out in Nigeria (Marcus, 1982; King, 1991; Stokholm and Isebor, 1993; Fafioye and Oluajo, 2005; Abowei, 2010), Sierra Leone (Showers, 1996; Vakily and Cham, 2003), and Ghana (Yankson and Azumah, 1993); so this species is a representative species in the estuarine and coastal fisheries in West Africa. Because of its relatively low economic value that species did not attract the attention of biologists. Whereas in the future, it could be a target species for the fish flour processing industry.

In Senegal, there are no study on growth and reproductive biology of *I. africana* until then while it is relatively abundant in Senegalese waters. It is landed in relatively large quantities in the south of Senegal. The works of Simier et al. (2004) in the Sine Saloum estuary showed that *I. africana* is the most important small pelagic in terms of abundance after *Sardinella maderensis* and *Ethmalosa fimbiata*.

This work aims to provide knowledge about some aspects of the growth of *I. africana* in Senegal.

MATERIALS AND METHODS

Study area

The study was conducted in estuarine waters of the Saloum Delta (13° 35' and 14° 10' north and 16° 50' and 17° 00') and in coastal marine waters of Joal (14°13'30'' and 14° 08' 30'' North and longitude 16° 52' 30'' and 16° 47' 00''). These sites are both located at the south of Senegal. The Saloum estuary belongs to the category of inverse estuaries (Barusseau et al., 1985; Pages and Citeau, 1990; Diouf, 1996). This estuary is no longer receiving freshwater inflow. The estuary is characterized by a predominance of sea water due to the low slope, a positive gradient of salinity upstream-downstream and considerable losses by evaporation (Albaret and Diouf, 1994). Sine-Saloum presents upstream a hyper-haline situation with extreme salinity values that reach (sometimes exceed) four times those of the sea (Gning et al., 2008). The locality of Joal is characterized by sea water omnipresence with its Atlantic coastline that stretches over more than 10 km (Anonymous, 2010).

Sampling strategy

The samples were collected on a quarterly basis from September 2014 to June 2016 during the experimental fisheries for studying the selectivity of gill-nets for *E. fimbiata*. A gill-net with 28, 30, 32, 36, 40 and 46 mm side mesh was used. After each fishing haul, data on total length (L) in mm and body weight (W) in g were recorded for each individuals of *I. africana.*

Size structure

It is the length frequencies distribution. The measurements of the total length performed on specimens allowed to draw the size structure of *I. africana*. Length frequency data were grouped into 1 cm class intervals. The Student's t-test at $\alpha = 0.05$ significance level was used to verify difference between mean lengths of *I. africana* in the estuary and at the sea.

Length-weight relationship

For many of the fish species, the weight (W) is related to the size (L) by a non-linear relationship:

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

where W is the total weight in g; L is the total length in cm; a is the coefficient related to the density and proportion of fish; b is the allometric rate. Knowledge of this relationship finds applications in fisheries biology and in the assessment of fish stocks (Kochzius, 1997). Length-weight relationships allow conversion of growth-in-length into growth-in-weight in stock assessment models of biomass from length frequency distributions, and estimation of fish condition (Petrakis and Stergiou, 1995; Morato et al., 2001; Furuya et al., 2014). Length-weight relationship is of great importance in fishery assessments (Garcia et al., 1989; Haimovici and Velasco, 2000). In order to verify if the b value was significantly different from the isometric (b = 3), the Student's t-test with a confidence level of ±95% ($\alpha = 0.05$) was employed.

Linear growth

The Von Bertalanffy model is the most commonly used for modeling fish growth with the following equation:

$$L_t = L\infty \times [1- \times e^{-k(t-t_0)}] \quad (2)$$

where L_t is the predicted length at age t, L∞ is the asymptotic length that an average fish would achieve if it continued to live and grow, K is the Von Bertalanffy curvature parameter and t_0 is the length at age zero. The ELEFAN in R software was used to estimate L∞ and K of the Von Bertalanffy equation. It is a recently updated Electronic LEngth Frequency ANalysis method (Pauly and Greenberg, 2013). t_0 was estimated by using Pauly's empirical equation (Pauly, 1979):

$$\text{Log}(-t_0) = -0.3922 - 0.275 \times \log(L\infty) - 1.038 \times K \quad (3)$$

The present results on the linear growth were compared with other studies by using the growth performance index (Φ') (Pauly and Munro, 1984):

$$(\Phi') = \text{Log}(k) + 2\,\text{Log}(L\infty) \quad (4)$$

The Student's t-test was used to confirm if the growth performance indexes (Φ') obtained for estuarine and marine individuals were significantly different or not.

Condition factor

The coefficient of condition has usually been represented by the letter K when the fish is measured and weighed in the metric system. The value of K is calculated from the weight and length, and can be used to estimate changes in nutritional condition. The formula most often used is:

$$K = (W/L^3) \times 100 \quad (5)$$

where W is the body weight in g, L is the total length in cm. In this study, the condition factor was calculated based on the warm season and the cold season. The average values of K were tested to verify if they were significantly different between the two seasons using the Student's t-test at α = 0.05 significance level.

Exploitation parameters

A stock of a species undergoes an evolution characterized by gains (inputs) and losses (outputs). Gains are represented by the annual recruitment and fish growth while losses are due to total mortality (Z). Total mortality (Z) is the sum of fishing mortality (F) generated by the various fishing operations and a natural mortality (M) which expresses mortality from any cause other than fishing (Bouaziz, 2007).

Total mortality was estimated from length-converted catch curves by the method of the curve catches modified from age-structured catch curves with the ELEFAN in R software (Pauly and Greenberg, 2013). The different methods of estimating total mortality, which use linearized catch curve according to the size classes, were derived from the catch curve method based on ages (Ricker, 1980).

For estimation of natural mortality, several methods can be used. In the present work, the method of Pauly (1980, 1984a), which is recommended for pelagic fish was used. Pauly (1980) links natural mortality and growth parameters (L∞ and K), and the annual average temperature of the environment (T°) by the formula:

$$\text{Ln}(M) = -0.0066 - 0.279\,\text{Ln}(\mathbf{L_\infty}) + 0.6543\,\text{Ln}(K) + 0.4634\,\text{Ln}(T) \quad (6)$$

where M is natural mortality; L∞ is the asymptotic length that an average fish would achieve if it continued to live and grow, K is the Von Bertalanffy curvature parameter; T is annual average temperature of the environment (T = 29.5°C at the estuary; T = 27.4°C at sea).

Fishing mortality here expresses the quantity of *I. africana* picked up by fishing activities in a year. After calculating M and Z, fishing mortality was deducted by the formula:

$$F = Z - M \quad (7)$$

Exploitation rate (E), which represents the proportion of deaths due to fishing was given by the following equation (Pauly, 1985):

$$E = F/(F + M) = F/Z \quad (8)$$

where E is the exploitation rate, F is the fishing mortality, M is the natural mortality and Z is the total mortality.

This rate indicates whether a stock is overfished or not depending on whether its value is greater or less than 0.5 (optimal value of E (E_{OPT}) is close to 0.5).

Statistical analysis

Statistical processing and graphics were performed with Microsoft Office Excel 2010, ELEFAN in R and R softwares. The Student's t-test was used to verify the significance of the results at α = 0.05 significance level.

RESULTS

Size structure

A total of 519 specimens were used in this study of which 190 sampled in the estuary and 329 at the sea. The length frequencies distribution of *I. Africana* is as shown in Figure 1. Size classes varied between 12 and 24 cm for individuals caught at the sea and 15 and 23 cm for those caught in the estuary, with mean lengths, respectively equal to 19.75 ± 2.03 and 19.26 ± 1.70 cm. The comparison of average length of *I. africana* captured in the estuary and at the sea indicated that there was no significant difference between them (p>0.05). However, the length frequencies distribution showed that smaller and larger individuals were met in the sea.

Length-weight relationship

The length-weight relationships for *I. africana* in the estuary and at the sea were (Figure 2). The results obtained highlighted allometric coefficients (b) significantly less than 3 (p<0.05) reflecting a negative allometric (Table 1). The allometric coefficient (b) of *I. africana* was slightly greater for specimens caught at the sea. However, there was no significant difference (p> 0.05) in allometric coefficient coefficients (b) for both areas.

Linear growth

The size frequency analysis was used to estimate L∞ and K parameters by ELEFAN in R software. The parameters (L∞, K) for individuals sampled at the sea and estuary are reported in Table 2. From the couple value (K and L∞), t_0 and (Φ') were deducted and the growth equations of Von Bertalanffy were established (Table 2). It appears from the analysis of the results that the linear growth of *I. africana* was slightly faster for individuals from the sea.

Comparison of growth performance indexes between estuarine (Φ' = 2.30) and marine (Φ' = 2.34) specimens indicated that there was no significant difference (p> 0.05) in linear growth.

From Von Bertalanffy growth equations, linear growth curves for *I. africana* were established (Figure 3). These curves have both the same look of growth. However, analysis of these curves indicated growth of *I. africana* was slightly faster at the sea. This slight difference was manifested in the first year of their life and remained in favor of marine individuals.

Condition factor

Box plots were used to represent the seasonal variation of the condition factor for *I. africana* at the sea (Kseason hot = 0.69 ± 0.06, Kseason cold = 0.07 ± 0.70) and in the estuary (Kseason hot = 0.71 ± 0.06; cold Kseason = 0.72 ± 0.05) (Figure 4). There were no significant differences (p>0.05) in condition factor between the two seasons in both areas (estuary and sea). However, the condition factor of *I. africana* was slightly better during the cold season in both areas.

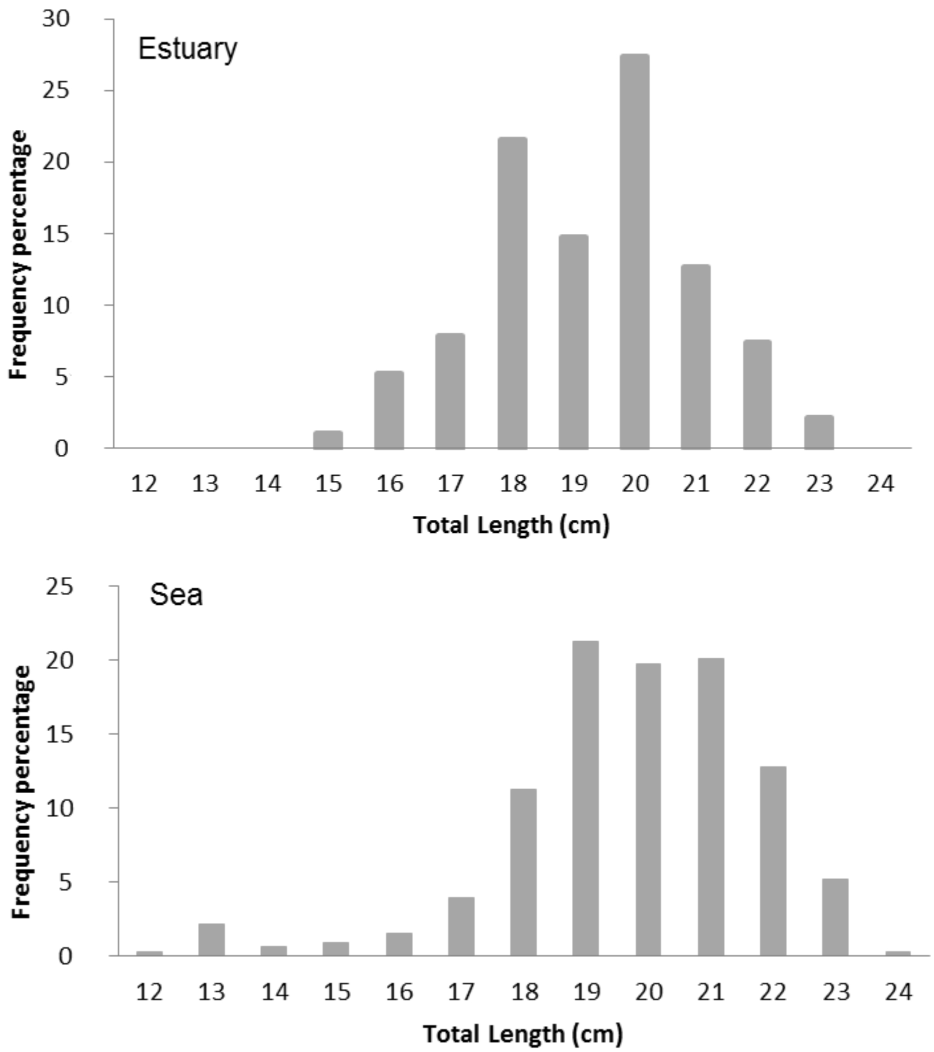

Figure 1. Length frequency distribution of *I. africana* in estuary and at sea.

Exploitation parameters

In the estuary, total mortality (Z), natural mortality (M) and fishing mortality were equal to 1.08, 0.93, and 0.14 year^{-1} at an annual average temperature of 29.5°C while at the sea, these mortality rates respectively were estimated at 1.25, 0.91 and 0.33 year^{-1} at annual average temperature of 27.4°C. The exploitation rates (E) were equal to 0.10 and 0.25 for estuarine and marine individuals, respectively.

DISCUSSION

Size structure

The sizes of fish caught vary between 12 and 24 cm for individuals sampled at the sea and 15 and 23 cm for those collected in the estuary. The smaller and larger size classes were encountered at the sea. This result could be related to environmental factors such as salinity. Indeed the Saloum estuary is an inverse estuary with salinity rates which reach four times those of the sea (Gning et al., 2008). Juveniles of *I. africana* would struggle to bear excessive salinity. This is in accordance with the results of Blaber et al. (1998) in the Sarawak estuaries in Malaysia. The juveniles of *Ilisha filiger*, *Ilisha pristigastroides*, *Ilisha elongata* and *Ilisha megaloptera* were recorded in low salinities (1 to 5) in the upper reaches of estuaries. The larger sizes encountered at the sea suggest that the reproduction could occur in marine waters. According to Vakily and Cham (2003), larger individuals were usually found in deeper water. The size ranges found in this study were similar to those of King (1996) (11.3 to 21.1 cm) in Qua Iboe estuary in Nigeria. However, other authors have sampled much smaller sizes for *I. africana*. It was the case of Vakily and Cham (2003) in Sierra Leone who worked on sizes which

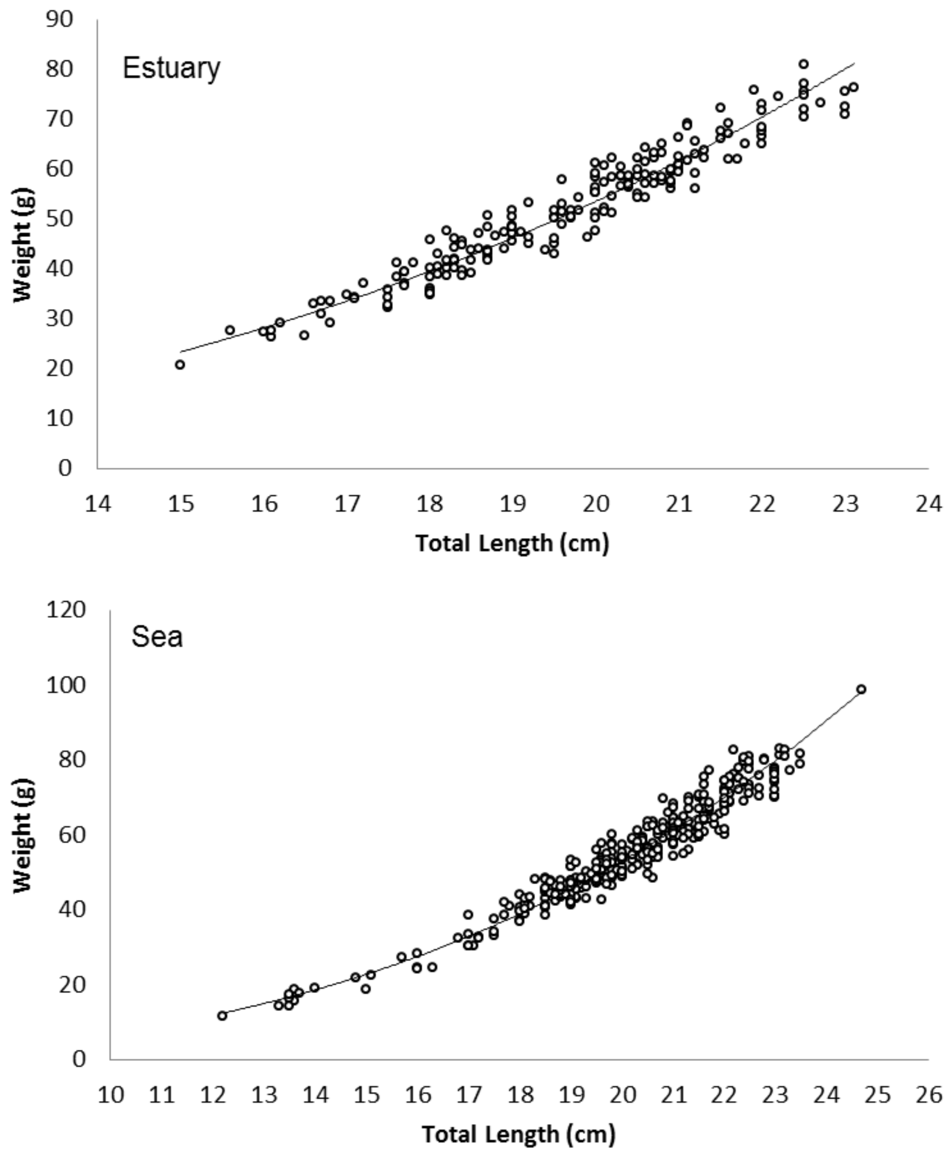

Figure 2. Length-weight relationships for *I. africana* in estuary and at sea.

Table 1. Parameters of length-weight relationship for *I. Africana*.

Sites	Parameter				Equations
	a	b	R^2	Number	
Estuary	0.009	2.88	0.936	190	$W = 0.009 \times L^{2.88}$
Sea	0.008	2.93	0.955	329	$W = 0.008 \times L^{2.93}$

Table 2. Linear growth parameters of Von Bertalanffy for *I. Africana*.

Areas	Parameter					Equation
	$L\infty$ (cm)	K ($year^{-1}$)	t_0	Φ'	Number	
Estuary	24.7	0.33	-0.53	2.30	190	$L(t) = 24.7 \times [1- e^{(-0.33\times(t_0+0.53))}]$
Sea	25.5	0.34	-0.51	2.34	329	$L(t) = 25.5 \times [1- e^{(-0.34\times(t_0+0.51))}]$

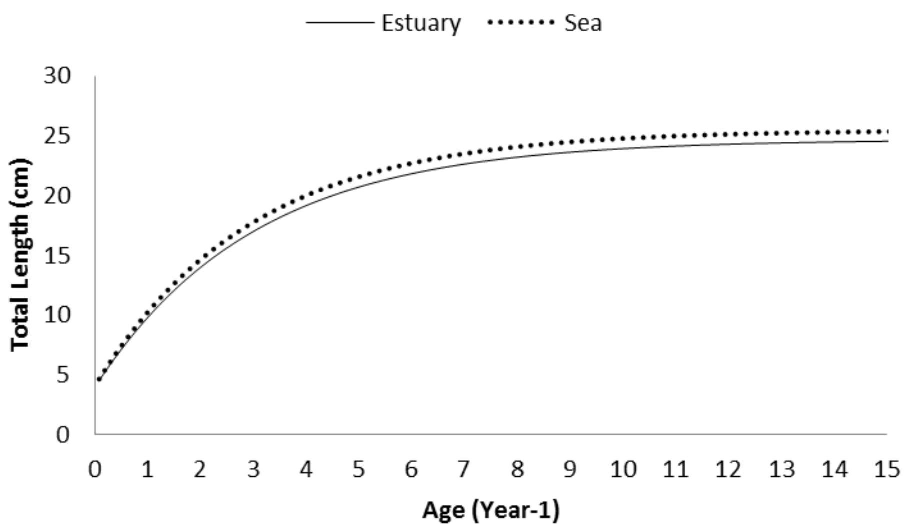

Figure 3. Linear growth curve of Von Bertalanffy for *I. africana* in estuary and at sea.

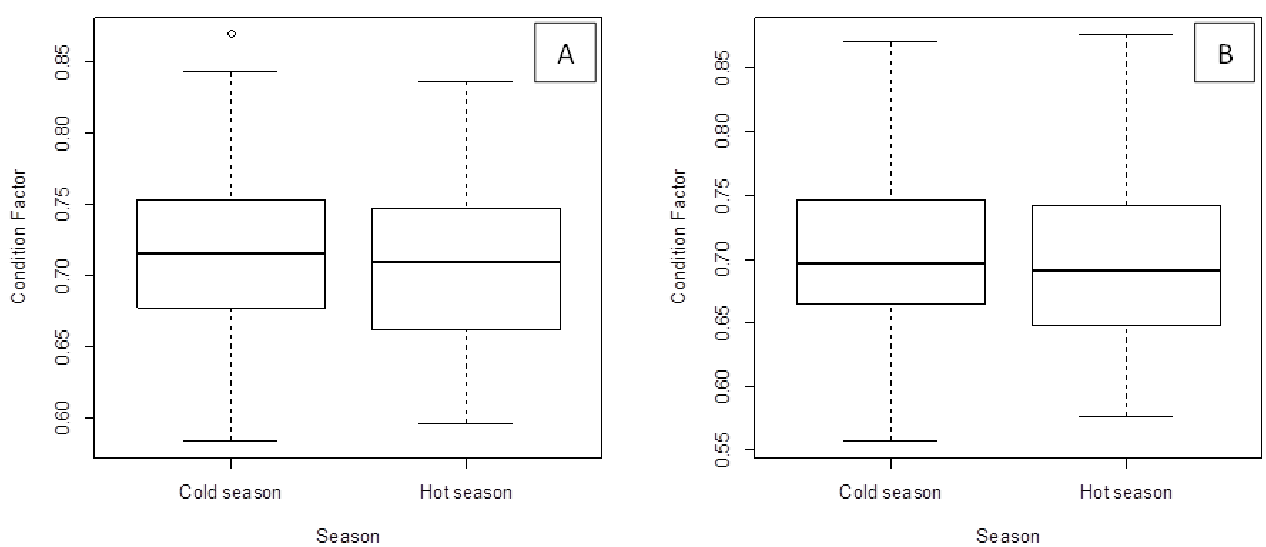

Figure 4. Condition factor of *I. africana* from sea (A) and estuary (B).

ranged between 6.5 and 19.1 cm. The difference in the size ranges could be due to the types of fishing gear used to catch this species or the origin of the samples (commercial fishing or experimental fishing).

Length-weight relationship

The allometric rate (b) values were respectively equal to 2.88 and 2.93 in the estuary and at the sea. This indicated a negative allometric growth for *I. africana* with an allometric rate slightly higher at the sea. The allometric rates (b) calculated for *I. africana* in this study were similar to those reported by Marcus (1982), King (1996), Fafioye Oluajo (2005) and Abowei (2010) in Nigeria. However, they were smaller than those reported by Vakily and Cham (2003) (Table 3). Changes in (b) values is subject to the shape and the adiposite of the species and this is also dependent on others factors such as sex, spawning frequency, season (Olapade and Tarawallie, 2014, Bolarinwa, 2016). The slight difference in the allometric rate between the estuarian and marine individuals could be due to a higher trophic capacity at the sea or to an increased competition in the estuary. According to Bacha et al. (2010), variation of certain parameters such as the availability of food can affect fish growth.

Table 3. Parameters of length-weight relationship for *I. africana* from various regions.

Country	Parameter				Locality	Author
	a	b	R^2	Number		
Nigeria	-	2.79	-	-	-	Marcus (1982)
Nigeria	0.008	2.99	0.972	142	Qua Iboe estuary	King (1996)
Sierra Leone	0.004	2.94	0.945	4456	Goderich village	Vakily and Cham (2003)
Nigeria	0.013	2.79	0.978	2508	Epe Lagoon, 2001-03	Fafioye and Oluajo (2005)
Nigeria	0.060	2.72	0.936	113	Nkoro River	Abowei (2010)
Senegal	0.009	2.88	0.955	190	Estuary	Present study
	0.008	2.93	0.950	329	Sea	

Table 4. Parameters of Linear growth of *I. africana* from various regions.

Country	Type of length	Parameter			Locality	Authors
		L∞ (cm)	K an^{-1}	Φ'		
Nigeria	LT	22	2.33	3.05	East of Niger Delta	Stokholm and Isebor (1993)
Nigeria	LT	29.6	0.80	2.85	Sea	King (1997)
Sierra Leone	LT	28.2	1.00	2.90	Goderich village	Vakily and Cham (2003)
Sierra Leone	LF	25.9	1.37	2.96	Sierra Leone Shelf	Showers (1996)
Senegal	LT	24.7	0.33	2.30	Estuary	Present study
	LT	25.5	0.34	2.34	Sea	

Linear growth

The condition factor (CF) is an individual variable that considers the relationship between the length and weight of the fish. This is a general indicator of "overweight" state for assessing the overall health of the individual. Easily measurable, it is commonly used because it integrates several processes at different levels of individual organization (Sanchez et al., 2007).

When confronted different parameter sets is not recommended to compare them one by one (Sparre and Venema, 1996). This is why, some authors recommend the comparison of growth performance indices (Φ') by combining several parameters of the Von Bertalanffy equation (Pauly and Munro, 1984; Chauvet, 1988; Chakroun-Marzouk and Ktari, 2003). The growth performance index (Φ') which has very similar values within neighboring taxa, proves the best overall growth performance index in that it has a minimum variance (Chakroun-Marzouk and Ktari, 2003). Growth performance indices found in this study in the estuary (Φ' = 2.30) and at sea (Φ' = 2.34) were lower than those found by Showers (1996), King (1997), Stockholm and Isebor (1992), and Vakily and Cham (2003), in Nigeria and Sierra Leone (Table 4). This indicates that the linear growth *I. africana* is quicker in these areas. These differences may also be due to the specific nature and ecological particularities of study areas. Indeed, Gulland and Rosenberg (1992) suggested that linear growth may vary from one water body to another, because environmental factors such as the productivity of the areas, the availability of food may vary.

The slightly slower growth for estuarine individuals might be in the estuary hypersaline. Indeed the major energy allocation to osmoregulation causes a decrease in growth in the estuary of the Saloum (Panfili et al., 2006). Certain factors such as increased salinity may also induce a reduction in the growth of some estuarine species (Panfili et al., 2004; Stierhoff et al., 2009).

Condition facteur

Seasonal variations of the condition factor are relatively low with a slight decrease in the hot season. This could be explained by several factors, including the abundance of food during the cold season when the waters are more productive with the phenomenon of upwelling. Another factor leading to the decline in the condition factor in the hot season is reproduction. During warmer months, *I. africana* should undergo a loss of energy related to the development of sexual products and sexual maturation of the gonads; which leads to a decrease in condition factor. According Gayanilo and Pauly (1997), condition factor can be affected by factors such as gender and sexual maturity. The results of King (1991) on reproductive *I. africana* indicate that it is a multiple spawning species with up to the cold season. The results of this study are confirmed by those of Abowei (2010) which is a monthly condition factor of *I. africana* higher in the cold season (February) and a minimum in the hot season (September).

Exploitation parameters

It appears from this study that natural mortality (M) is higher than the fishing mortality (F) regardless of the medium considered. This could be explained by the fact that *I. africana* is not targeted by the Senegalese artisanal fishing. It is taken as by catch by artisanal fishers. However, the value of the natural mortality rate is higher in the estuary. This high natural mortality in the estuary should be due to a higher variability of environmental factors in this environment. Indeed, Estuaries are generally characterized by a high variability of environmental factors (Perkins, 1974; Day and Yanez-Arancibia, 1985; Day et al., 1989; Wootton, 1992).

Stokholm and Isebor (1993) obtained similar results in total mortality ($Z = 1.35$ year^{-1}). However, the works of Valiky and Ham (2003) in Sierra Leone on *I. africana* showed a total mortality ($Z = 5.5$ year^{-1}) higher than those found in the present study. This high mortality in Sierra Leone for *I. africana* could be explained by the fact that *I. africana* is an important component of the landings of the coastal fishery and estuary in Sierra Leone (Okera, 1978). The values of the rate of exploitation (E) are below the optimum operating level ($E_{opt} = 0.5$). This result shows that *I. africana* is underexploited in Senegalese waters. This can be explained by the fact that *I. africana* is not a target species. It is caught only as by catch by the Senegalese artisanal fishing.

Conclusion

I. africana which is a secondary catch species for the Senegalese artisanal fishing is not well-documented, while it is abundant in estuarine and coastal marine waters of Senegal. It appears from this study that *I. africana* in Senegalese waters is relatively a low growing species compared to other countries. This species appears to be underutilized in Senegalese waters. Growth and exploitation parameters estimated in this study allowed to have knowledge of this species in Senegal. The estimated mortality rates can be used for structural adjustment of evaluation models. Knowledge of the growth and exploitation parameters is necessary for fisheries management.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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