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RESEARCH ARTICLE

The Length-Weight Relationship and Condition Factor of white grouper (*Epinephelus aeneus,* Geoffroy Saint Hilaire, 1817) at the south-west coast of Senegal, West Africa

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Abstract

This study describes some biological parameters including length-weight relationships and condition factors of *Epinephelus aeneus* (Geoffroy Saint Hilaire, 1817) in the western coasts of Senegal (Joal, Mbour and Soumbédioune). The 973 specimens (average length 422.48 ± 133.79 mm and weight 1249.62 ± 1243.91 g) were monthly sampled from fishermen from January 2010 to June 2013. For each of the specimen, length (mm) and weight (g) were measured following standard equipments. Length-weight relationship was described by the equation: $W = a L^b$ while the condition factor was determined using the equation: $K = 100 (W/ L^3)$. The values of the regression coefficient'b' obtained for the length-weight relationship for the species of Joal, Mbour and Soumbédioune were respectively 2.99, 3.00 and 2.96 having r^2 values respectively 0.975, 0.980 and 0.985. General well being of the fish of Joal, Mbour and Soumbédioune was found to be good, as indicated by the mean values of condition factor (1.311 ± 0.172 for Joal, 1.361 ± 0.165 for Mbour and 1.212 ± 0.147 for Soumbédioune), which was greater than 1. There was not a significant difference in condition factor between stations (Fisher LSD test, $p > 0.05$).

INTRODUCTION

Fish plays an important role in the development of a nation. Apart from being a cheap source of highly nutritive protein, it also contains other essential nutrients required by the body (Sikoki and Otobotekere, 1999). *Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817) can be found throughout the southern Mediterranean (up to 44°N in the Adriatic Sea) and along the west coast of Africa to southern Angola, including islands of the Gulf of Guinea (Thierry et al., 2008). Adults are found on rocky or mud and sand bottoms in depths of 20 to 200 m; juveniles have been found in coastal lagoons and estuaries (Heemstra and Randall, 1993). *E. aeneus* is of considerable economic importance in fisheries and caught with hooks and lines and by trawls. The white grouper is listed as Near Threatened both in the Mediterranean Regional Red List and Global Red List of IUCN (Abdul Malak et al., 2011). This species is also reported to be an excellent candidate for mariculture because of the rapid growth rate and the potential for induced spawning in captivity and good results of aquaculture have been achieved in Israel (Hassin et al., 1997; Koven et al., 2007; Gorshkov, 2010). The maximum total length is reported as 120 cm and weight as 25 kg (Heemstra and Randall, 1993). It is a protogynous hermaphrodite species that is reported to be mature first at 5 to

7 years, as a female (total length 50-60 cm, weight about 4kg) and sex change occurs at 10 to 13 years (total length 80-110 cm, weight 6-15 kg) in Tunisia (Bouain et al., 1983; Bruslé, 1985). Gökçe et al. (2003) studied the gonad histology and spawning pattern of this species in Iskenderun Bay (Turkey) and reported that the spawning period started in the beginning of June and continued till the end of August.

The length-weight relationship of fish is an important fishery management tool. Its importance is pronounced in estimating the average weight at a given length group and in assessing the relative well being of a fish population (Bolger and Connoly, 1989). Consequently, length-weight studies on fish are extensive. Pauly (1983) reported the importance of length-weight relationship in the calculation of an equation of growth in length into an equation of growth in weight. Whereas Arsalan et al. (2004) stated that it is usually easier to measure length than weight and weight can be predicated later on using the length-weight relationship which helps among other fish given its definite length. The study of length-weight relationship is of paramount importance in fishery science, as it assists in understanding the general well being and growth patterns in a fish population. According to Bashir et al. (1993) the length-weight relationship of fish varies depending upon the condition of life in aquatic environment. Length-weight relationship is of great importance in fishery assessments (Garcia et al., 1998; Haimovici and Velasco, 2000). Apart from this, the length-weight relationship can also be used for deriving comparisons between different stages in life history and between fish populations from regions or habitat groups (Petrakis and Stergiou, 1995; Gonçalves et al., 1997) and tracking seasonal variations in fish growth (Richter et al., 2000). Length-weight relationships can also be used to know the growth pattern of the fish in the culture system. It is also used to estimate fish biomass from length frequency distributions, infer fish condition (Petrakis and Stergiou, 1995). Like other morphometric measurements, length-weight relationships may change during the events of life cycle like metamorphosis, growth and onset of maturity (Le Cren, 1951). Length-weight relationships can be used as character for differentiation of taxonomic units. An already established length-weight relationship will be useful for assessing the data that contains only length frequency measurements. This relationship can be used in setting up of yield equations, estimate the number of fishes landed and for comparing the population over space and time (Beverton and Holt, 1957). The mathematical parameters of the relationship between the length and weight of fish furnish further information on the weight variation of individuals in relation to their length (condition factor, K). This factor estimates the general well-being of the individual and is frequently used in three cases: (a) Comparison of two or more co-specific populations living in similar or different conditions of food, density or climate; (b) Determination of period and duration of gonadal maturation and (c) Observation of increase or decrease in feeding activity or population changes, possibly due to modifications in food resources.

The condition factor of fishes is the most important biological parameter which provides information on condition of fish species and the entire community and is of high significance for management and conservation of natural populations (Sarkar et al., 2009; Muchlisin et al., 2010). It is also a quantitative parameter of the state of well-being of the fish that determines present and future population success because of its influence on growth, reproduction and survival (Richter, 2007). Condition factor compares the wellbeing of a fish and is based on the hypothesis that heavier fish of a given length are in better condition (Bagenal and Tesch, 1978). Condition factor has been used as an index of growth and feeding intensity (Fagade, 1979). Condition factor decrease with increase in length (Bakare, 1970; Fagade, 1979); and also influences the reproductive cycle in fish (Welcome, 1979). This factor estimates the general well-being of the individual and is frequently used in three cases: (1) comparison of two or more co-specific populations living in similar or different conditions of food, density or climate, among others; (2) determination of the period and duration of gonadal maturation; (3) observation of the increase or decrease in feeding activity or population changes, possibility due to modifications in food resources (Weatherley and Gill, 1987) thus making the conservation possible. Condition factor (K) is widely used in fisheries and fish biology studies. This factor is calculated from the relationship between the weight of a fish and its length, with the intention of describing the "condition" of that individual fish (Froese, 2006). Different values in K of a fish indicate the state of sexual maturity, the degree of food sources availability, age and sex of some species (Anibeze, 2000). These relationships are also an important component of FishBase (Froese and Pauly, 2012). In addition, the data on length and weight can also provide important clues on climate and environmental changes, and change in human subsistence practices.

The aim of this study is to provide basic informations on the length-weight relationship and variations in the condition factor among months and zones of *E. aeneus* that would be useful for fishery biologists or managers to impose adequate regulations for sustainable fishery management. A study of the length-weight relationship of this species from the Senegalese coasts adds more information on the Epinephelidae family to complement the existing data in the management and culture of the species in West Africa. This article describes the whole study the in detail which seems to be valuable information for the fishery biologists, conservation specialist and aquaculture specialists trying to develop hill aquaculture in western region of Senegal.

Materials and methods

Study area

Senegal is the most western country of Africa. It lies in the crossover between the sahelian zone and the tropics. Its neighbors are Mali in the East, Mauritania in the North and Guinea and Guinea-Bissau in the South. Gambia, which also verges on the Atlantic Ocean, is completely surrounded by Senegal. The Exclusive Economic Zone (EEZ) of Senegal is located at East Atlantic and extends from 18°00'N, 20°00'W to 12°15'S, 16°30'E. The Cape Verde peninsula is located between 14°30'N and 15°00'N and divides the EEZ into two areas with distinct topographic characteristics. In the northern part, the continental shelf is fairly narrow, with the edge oriented north-north-east. South of the peninsula, the continental shelf widens and the edge is oriented north-south. The Peninsula of Cape Verde separates the Grande Côte in the north region and the Petite Côte in the south. It represents the most occidental area of the Africa continent. Soumbédioune is located within this region. The Petite Côte in the south is an important geographical and economic region, being the largest for traditional fishing activities in Mbour and Joal. The region extends from the peninsula of Cape Verde to Sine Saloum (Fig 1).

Sample size and data collection

A total of 973 *E. aeneus* were obtained from three fish landing stations (Joal, Mbour and Soumbédioune), sampled monthly from January to December 2010 (Soumbédioune) and July to June 2013 (Mbour and Joal) in order to calculate the length-weight relationship and the condition factor. These stations are ones of the main landing sites in the sub-region and are the main landing ports for *E. aeneus* on the Senegalese coasts. After the collection of the fish, samples were temporarily placed in cooling box filled with ice and transported to the research laboratory. For each individual the total length (TL, mm) and total weight (TW, g) were measured. The total length (TL) of each fish was taken from tip of snout (mouth closed) to the extended tip of the caudal fin. Then, for each individual, the TL was measured in millimeters using a measuring board. Lastly, the total weight (TW) in grams was measured to the nearest 0.1 gram using electronic weighing balance (ACCULAS Sartorious Group).

The statistical significance level of r^2 was estimated, and the b-value for each species was tested by Fisher's LSD (Least Significant Difference) test to verify if it was significantly different from the isometric ($b = 3$). 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% ($p < 0.05$).

The relationship between length (TL) and total weight (TW) of fish was analyzed by measuring length and weight of fish specimens collected from study area. The statistical relationship between these parameters of fishes was established by using the parabolic equation: $TW = a\,TL^b$ where TW = weight of fish in (g), TL = total length of fish in (mm), a = proportionality constant (intercept) and b = regression coefficient (slope).

The association degree between TL and TW was calculated by the determination coefficient (r^2). Value of the exponent b provides information on fish growth. When $b = 3$, the increase in weight is isometric, otherwise it is allometric (positive allometric if $b > 3$, negative allometric if $b < 3$).

Condition factor is used for comparing the condition, fatness, or well-being of fish, based on the assumption that heavier fish of a given length are in better condition. Therefore, fishes with condition factor values greater than one (≥ 1) were considered as high while those less than one (< 1) were low. The coefficient of condition K was calculated using the relationship:

$K = (TW / TL^3) * 100$ where K = condition factor, TW = total weight of fish (g), TL = total length of fish (mm) and 100 is a factor to bring the value of K near unity.

The significance of the length-weight relationship and condition factor (k) of the specimens were tested among stations by means of one-way Analysis of Variance (ANOVA) and the values for each station were tested by Fisher's LSD (Least Significant Difference) test to verify its significance level in different months of a year. All the statistical analysis was done in STATISTICA software package (Version 7).

Results

Length-weight relationship

Of 973 collected individuals during this study, 323 were measured in Joal, 354 in Mbour and 296 in Soumbédioune. The total length of the white grouper ranged from 179 to 948 mm and the total weight between 62.8 and 10934 g. The smallest specimen was found to Joal and the heaviest to Mbour. The differences in total length and weight of the specimens were statistically significant among stations ($p < 0.05$). According to the results of the Fisher's LSD (Least Significant Difference) test for pairwise comparison, there were difference only between Soumbédioune and Mbour ($p < 0.05$) in total length and in weight, Soumbédioune was different to Mbour and Joal ($p < 0.05$).

The relationship between fish total length and total weight of Joal, Mbour and Soumbédioune was derived respectively as $TW = 0.006 * TL^{2.99}$; $TW = 0.006 * TL^{3.00}$ and $TW = 0.013 * TL^{2.96}$. The slop b-value for the population of Mbour (3.00) was found to be higher than the Joal (2.99) and Soumbédioune (2.96). However, b values did not differ significantly (Fisher LSD test, $p > 0.05$) when compared with the isometric value ($b = 3$) between the three population studied. The mean value of 2.98 obtained for b indicated that the length-weight relationship follow the cube law showing isometric growth of the species in it natural habitat. In this study the length-weight relationship in *E. aeneus* populations were found to be highly correlated (Fisher LSD test, $p < 0.05$) and all r^2-values were greater than 0.80. The general length-weight relationship was described by the equation: $TW= 0.008*TL^{2.98}$ (r^2: 0.980). Ecosystematical values of slope (b) ranged from a minimum of 2.96 in Soumbédioune to a maximum of 3.00 in Mbour. According to Froese (2006), the expected range of b value was reported between 2.5 - 3.5.

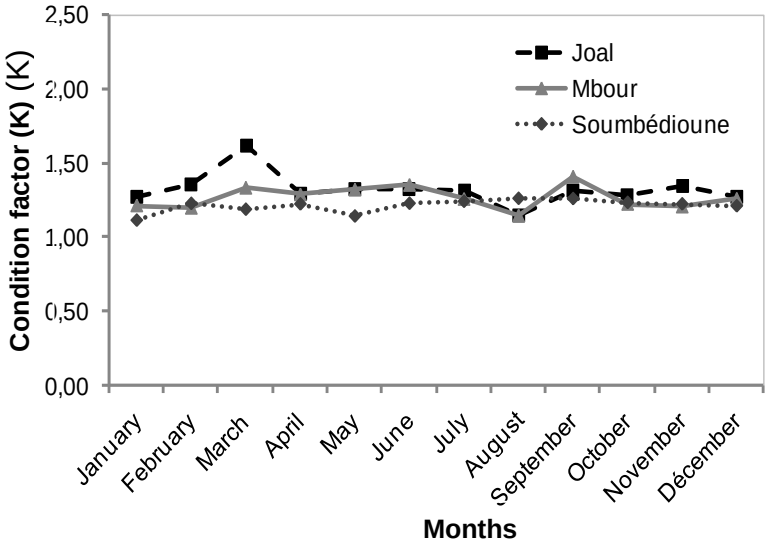
Condition factor

The graphical presentations of the monthly condition factor for *E. aeneus* studied is shown in Figure 2. The condition factor of *E. aeneus* showed no variation in different months, it was noticed that the K was higher when fish entered into the maturation phase during the month of March, for rest of the months K showed slightly lower values. The mean values of condition factor (K) recorded in the present study are 1.311 ± 0.172; 1.361 ± 0.165 and 1.212 ± 0.147 in Joal, Mbour and Soumbédioune, respectively. Condition factor of greater than one showed the well being of fishes fed with different experimental diets. It is difficult to infer the start of the spawning season from Figure 2 because monthly differences in K values were very small. The K-values did not differ significantly (Fisher LSD test, $p > 0.05$) in stations.

Parameter	n	TL range (mm)	TW ranged (g)	a	b	r^2
Joal	323	179 - 816	62.8 - 7760	0.006	2.99	0.97
Mbour	354	184 - 948	76.7 - 10934	0.006	3.00	0.98
Soumbédioune	296	217 - 774	106.9 - 5300	0.013	2.96	0.98

Fig. 1 Map of the study area

Fig. 2 Monthly variations in condition factor (K) of *Epinephelus aeneus* in three stations of Senegalese coast (Joal, Mbour and Soumbédioune)



Discussion

Length-weight relationship

The values related to the well-being index present the highest values associated to the individuals that present highest weights for a given length. The highest b values indicate the inflection of the curve for the asymptotic values, indicating allometric growth, that is, the length becomes an irrelevant variable in relation to the weight. The values obtained for the weight-length relationship showed that *E. aeneus* is isometric in his growth in Mbour (b = 3.00) while we obtained negative allometric in Joal (b = 2.99) and Soumbédioune (b = 2.96). Several authors have reported both isometric and allometric growth for *E. aeneus* from various water bodies. Ceyhan (2009) reported an isometric growth patterns (b = 3.043) from small-scale fisheries in Gökova Bay (southeastern Aegean Sea). Seasonal values of slope (b) were reported by Özbek (2013) in the Gulf of Antalya, Turkey and they were allometric. These values ranged from a minimum of 2.523 in autumn to a maximum of 2.922 in summer. In Özbek (2013) study, differences in allometric coefficients were recorded between seasons, depth levels and stations. Our study based only on the variation of the slopes of length-weight relationships between ecosystems (stations). Cury and Worms (1982) found a positive allometric in Senegal (b = 3.230). The same type of growth, positive allometric was found by Magnússon and Magnússon (1987) in Cape Verde coasts, Atlantic Ocean (b = 3.580). Fiogbe (2003) obtained a negative allometric growth patterns for *E. aeneus* from Benin, West Africa. Can et al. (2002) also reported a negative allometric (b = 2.90) growth pattern from İskenderun Bay-Turkey (NE Med.). Sangun et al. (2007) also observed negative allometric (b = 2.987) in Turkey.

The coefficient of determination (r^2) for length-weight relationships was high for all fish species which indicated that the length increased with increase in weight of the fish. This was in agreement with previous studies on different fish species from various water bodies (Konan et al., 2007; Tah et al., 2012; Koffi et al., 2014).

Condition factor

Ekpo (2013) has reported a high condition factor (1.24) for *E. aeneus* in the Qua Iboe River estuary, Akwa Ibom State, southeastern Nigeria. In Alexandria region and Salloum Bay region (Egypt), Ezzat (1982) found respectively 1.123 and 1.114 for K-values. By comparing the condition factor in the three stations studied, we could see that the condition factor was clearly higher in fishes of Mbour region (K = 1.361) than that in Joal (K = 1.311) and

Soumbédioune (K = 1.212) regions. This could be explained by the higher productivity of Mbour station than the Joal and Soumbédioune. This explained the well being of these fishes in Mbour station compared with those in Joal and Mbour. The values obtained from the study showed that *E. aeneus* was in good condition. Le Cren (1951) reported that environmental factors, food supply and parasitism have great influence on the health of the fish. The condition factor reflects the well-being of the fish (Kumolu and Ndimele, 2010; Abowei, 2010). It gives information on the physiological state of the fish in relation to its welfare. Ighwela et al. (2011) reported that the condition factor gives information when comparing two populations living in certain feeding, density, climate and other conditions when determining the period of gonad maturation, and when following up the degree of feeding activity of species to verify if it is making good use of its source. It is influenced by both environmental conditions and can be affected by factors like sex, season, age and maturity stages of fish. Condition factor can also be used as an index to access the status of the aquatic ecosystem (Edah et al., 2010). It is usually decreases as the fish increases in size. It was observed in the present study, that condition factors for all stations were of values of 1.21 above which indicated that fish were doing well in the Senegalese coasts. This could have been caused by adverse environmental factors (Anene, 2005). Sarkar et al. (2013) noted also that condition factor is not constant for a species or population. From a nutritional point of view, there is the accumulation of fat and gonadal development (Le Cren, 1951). The condition factor of a fish reflects physical and biological circumstances and fluctuations by interaction among feeding conditions, parasitic infections and physiological factors (Le Cren, 1951). This also indicates the changes in food reserves and therefore an indicator of the general fish condition. Moreover, body condition provides an alternative to the expensive *in vitro* proximate analyses of tissues (Sutton et al., 2000). Therefore, information on condition factor can be vital to culture system management because they provide the producer with information of the specific condition under which organisms are developing (Araneda et al., 2008). From a reproductive point of view, the highest condition factor values are reached in some species (Angelescu et al., 1958). Condition factor also gives information when comparing two populations living in certain feeding, density, climate and other conditions; when determining the period of gonadal maturation and when following up the degree of feeding activity of a species to verify whether it is making good use of its feeding source (Bagenal and Tesch, 1978). Furthermore, Vazzoler (1996) confirmed that lowest K values during the more developed gonadal stages might mean resource transfer to the gonads during the reproductive period. Braga (1986), through other authors, showed that values of the condition factor vary according to seasons and are influenced by environmental conditions. The same may be occurring in the environment under study since the floodplain is influenced by many biotic and abiotic factors, which favor the equilibrium of all the species in the ecosystem.

In present study, length-weight relationship and condition factor recorded on acclimatization of wild stock of *E. aeneus* under experimental condition indicated a favorable response of the fish to the ecological transition from the wild habitat to the experimental environment. The appreciable growth rate exhibited by the fish during rearing period indicated that the prevailing environmental conditions were within the tolerance range for the species. Condition factors would allow biologist to understand its population status and future success. The findings of the present study support that the species can be cultured in large scale as food fish to meet the nutritional demand. The present studies provide the first hand information about the growth pattern and relative conditions of *E. aeneus* from its in-situ habitat. This study will help biologists to know the status of this fish and develop culture technology in natural waters and will be useful for the fishery biologists and conservation biologist, for successful development, management, production and ultimate conservation of the most preferred food fishes of the states.

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Table 1 Parameters of length-weight relationships of *Epinephelus aeneus* in three stations of Senegalese coast (Joal, Mbour and Soumbédioune). n: number of specimens, TL: total length, TW: total weight, a = proportionality constant (intercept), b = regression coefficient (slope) and r^2: correlation coefficient.

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