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A preliminary study of reproduction, age and growth of *Sardinella aurita* (Valenciennes, 1847) in the southern of Atlantic Moroccan area

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Abstract. The round sardinella, *Sardinella aurita* (Valenciennes, 1847), was sampled from ship research Al Amir Mouley Abdellah in the period between June and July 2015 (southern Atlantic sea, Morocco) in the area between Cape Boujdor and Cape Blanc. The present study is about reproduction, age and growth of the round sardinella. The sex ratio varies with length. Females are more numerous than males especially for the high size (>34.5). The estimated lengths of fish of which 50% were mature, were 25.54 and 23.73 cm for males and females respectively. Growth parameters estimated, using direct method of Von Bertalanffy, gave asymptotic length, $L\infty$, 33.72 and 33.66 cm and curvature parameter, K, of 0.83 and 0.97 per year for females and males respectively. The comparison of growth parameters for round sardinella, from Mediterranean and Atlantic waters, indicated different growth patterns between the two areas. We determined that the growth of *S. Aurita* is fast, reaching the size of 19 cm in the first year.

Key Words: *Sardinella aurita*, reproduction, southern Atlantic sea, Morocco.

Introduction. The round Sardinella, *Sardinella aurita* (Pisces, Clupeidae) is a marine pelagic fish that is widely distributed throughout the tropical and subtropical seas of the world, including the entire Mediterranean and the Black Sea (Froese & Pauly 2003). It is a key species inhabiting the ecosystem of the northwest African upwelling region (Bard & Koranteg 1995).

Species migrations are performed in relationship with the thermal front, *S. Aurita* is present in waters less than 100 m depth and temperature about 18°C. Biomass of sardinella has known fluctuations these last years; progressive increase of biomass is found between July 2008 and December 2009. After that, there was an important decrease in 2010. In 2013, the catch of sardinella, landed in southern of Moroccan area, is 94 443 tons. The sardinella represents 14% of small pelagic catch (INRH 2013).

Biology of *S. Aurita* was studied several times in Atlantic and Mediterranean areas. However, the study of stock dynamics of this species exploited was rarely initiated. The lack of study is rather surprising given the considerable catches of round sardinella and the strong contributions in the total catch in particular in the southern Moroccan Atlantic.

This work aims to study the age, growth and reproduction of *S. Aurita*, these parameters are necessary for to understand the dynamic of this population.

As part of the study and regular monitoring of biomass indices and abundance of pelagic resources at the Moroccan exclusive economic zone (E.E.Z) for the year 2015, an acoustic survey was conducted aboard ship research Al Amir Moulay Abdellah in the period between June 26 and July 16 2015, in the southern area of the Atlantic extending between Cape Boudjor and Cape Blanc.

Material and Method

Samples were collected onboard a ship research Al Amir Moulay Abdellah using a pelagic trawl in the area between Cape Boujdor and Cape Blanc (zone C). In general depths are between 20 to 500 m. Sampling frequency is a function of the availability of sardinella because it is not also available in fishing areas. During this campaign, 80 operations of fishing control were carried out which 20 stations containing *S. Aurita* (Figure 1). For every haul, technical data is collected like geographic position, fishing time, trawl depth and trawling speed. Catch are also sorted, identified, inventoried and weighed. The Data collected concerned the measure of the total length (Lt), weight of each individual, and determination of sex and maturity stages. Otoliths are taken and fixed on black plates by resin EUKITT type.

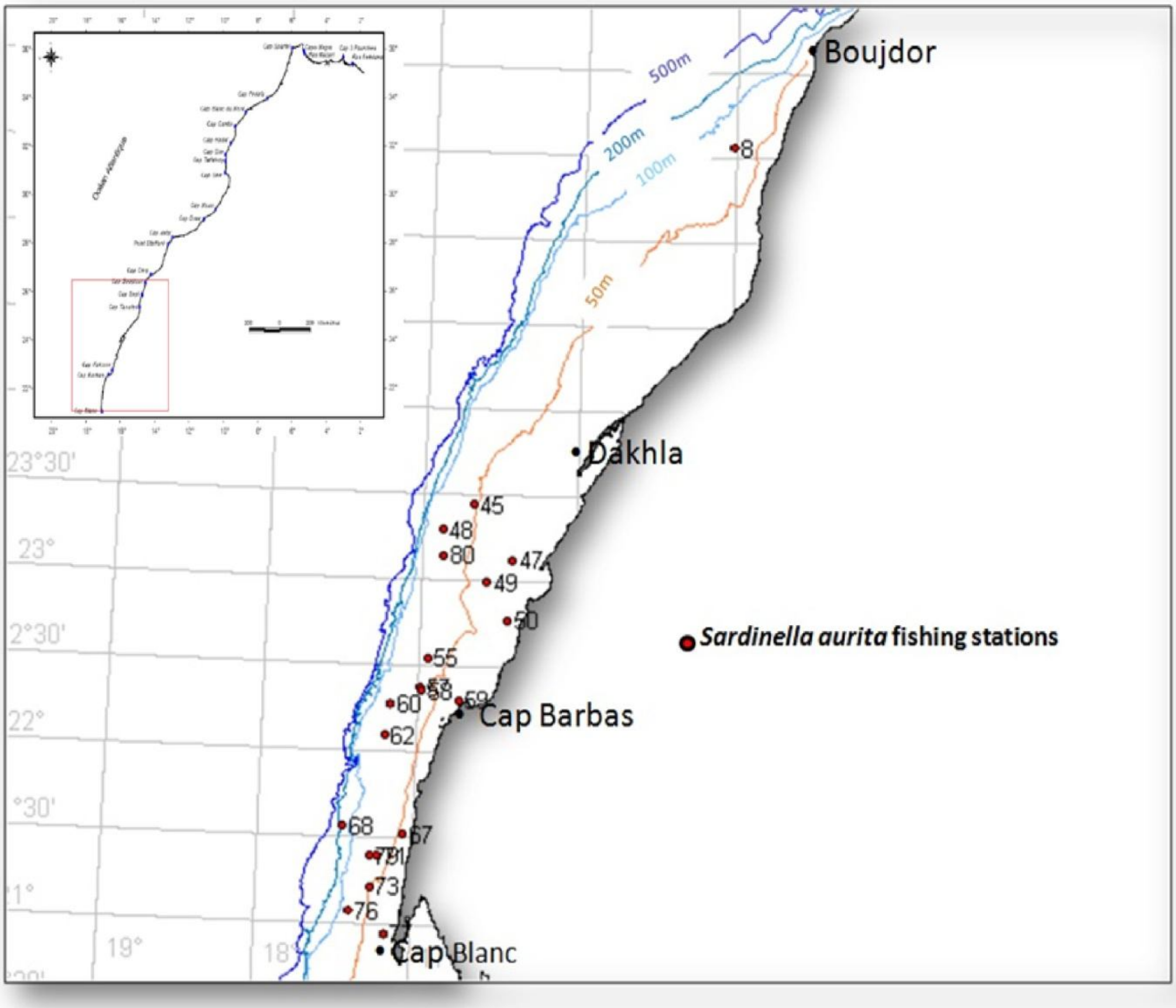


Figure 1. Sampling stations of *Sardinella aurita* in the southern of Atlantic Moroccan area.

Reproduction study. The study of reproduction concerned the sex ratio and sexual maturity of *S. Aurita* during this campaign.

Sex ratio. The sex ratio is defined as the individual proportion of each sex, determined by macroscopic observation of gonads in a given population.

The χ2 test is used in order to compare sex proportions. It consists of comparing the observed values and theoretical values equality of the workforce.

$$\chi^2_{obs} = \Sigma\, (n_{obs} - n_{the})^2 / n_{the}$$

Where n_{obs} is the observed effective of sex in samples, n_{the} is the theoretical effective calculated of sex in samples.

Principal hypothesis supposes that we have equal sex ratio. The alternative hypothesis proposes that we have a significant difference between the sex ratio.
If $\chi_{obs} < \chi$ µ; 0.05, principal hypothesis is accepted.
If $\chi_{obs} > \chi$ µ; 0.05, principal hypothesis is rejected.

Sexual maturity. The total lengths at which 50% of specimens attains maturity (stage 3 is retained as the point at which the fish is considered mature) was deduced using theoretical maturity curve which corresponds to the regression between P parameter depending on the fish size.

$$P = 1 / (1+e^{-(a + b * L)}) \text{ (Pope et al 1983)}$$

Where P is a mature proportion by class size, L is a total length, a is an intercept and b is a slope.
The linearization of this formula by introducing the natural logarithm gives:

$$-\ln((1 - P) / P) = a + b * L$$

The regression between Ln (P/1-P) and total length (L) makes finding the parameters a and b.
So:

$$L50 = -a / b$$

Age and growth. We chose the sagittae which has a large size for better readability brands.

Linear growth. The growth study amounts to determining body size based on age, which is why all stock assessment methods are mainly based on composition data by age (Campana 2001).

In the temperate waters, these data can obtain by enumeration of the resulting rings of sharp fluctuations in environmental conditions between the summer and winter and vice versa (direct method).

In this work, we are interested in the mathematic model of individual growth elaborated by Von Bertalanffy (1938), which is the most used, since it has been demonstrated that it is firstly consistent with the observed growth of most species of fish and secondly, since it serves as a template for more complex models describing the dynamics of fish populations (Sparre & Vienema 1996). This model is represented by the following equation:

$$L_{(t)} = L_{\infty} (1-\exp^{-K (t-to)})$$

Where $L_{(t)}$ is the total length at age t, L_{∞} is the asymptotic length, K is a growth coefficient, and t_0 is the theoretical age at which predicted mean length is zero.

Length-weight relationship. It is also used in fish biology to estimate the modifications that can cause the growth on species morphology. It allows us to follow depending on the size the sex changes and maturity of gonads. It is translated by the equation:

$$W(t) = aL^b$$

Where W (t) is a weight at age t, a is the intercept and b is allometric coefficient. a and b are determined by the adjustment of the function to the cloud points observed after logarithmic transformation of the function.
When the coefficient of allometry b is close to 3, two cases are distinguished:
If $b>3$, the weight is growing faster than the length and allometry is majorant.
If $b<3$, the weight is growing slower than the length and allometry is minorant.

The test used for checking the isometry (b=3) or allometry (b#3) of length-weight relationships is the t test of student after linearization of the relationship by logarithmic transformation (Pajuelo & Lorenzo 2000; Snecdore & Cochran 1967; Arneri et al 2001).

This test consists of comparing the slope of the regression line (b) with a theoretical slope equal to 3. The main hypothesis proposes that there is no significant difference between the slope (b) and the value 3. The alternative hypothesis assumes that there is a significant difference between the slope (b) and the value 3.

So:

If $t_{obs} < t_{0.05}$, n, the main hypothesis is accepted.

If $t_{obs} > t_{0.05}$, n, the main hypothesis is rejected.

Weight gain. The combination of the linear growth model of Von Bertalanffy and length-weight relationship can deduct the weight growth model of Von Bertalanffy.

$$W_{(t)} = W_{\infty}\ 1\text{-}\exp^{-K\ (t-to)\ b}$$

Where W_{∞} is an asymptotic weight and $W_{(t)}$ is a fish weight at time t.

Results

Reproduction study

Sex-ratio. 207 individuals of *S. aurita* were sampled in the southern Moroccan Atlantic area during our study period. They were divided into 58 males and 103 females. The difference between the two sexes is significant (Table 1).

The proportions of males, females and indeterminate sampled during this campaign are shown in Figure 2.

Table 1

Comparison of the proportions of males and females and decision rule

Number of males	*Number of females*	*χ2 obs*	*χ2 (1 ; 0.05)*	*Rule decision*
58 (36.02 %)	103 (63.98%)	12.57	3.84	Significant difference between proportions of sexes

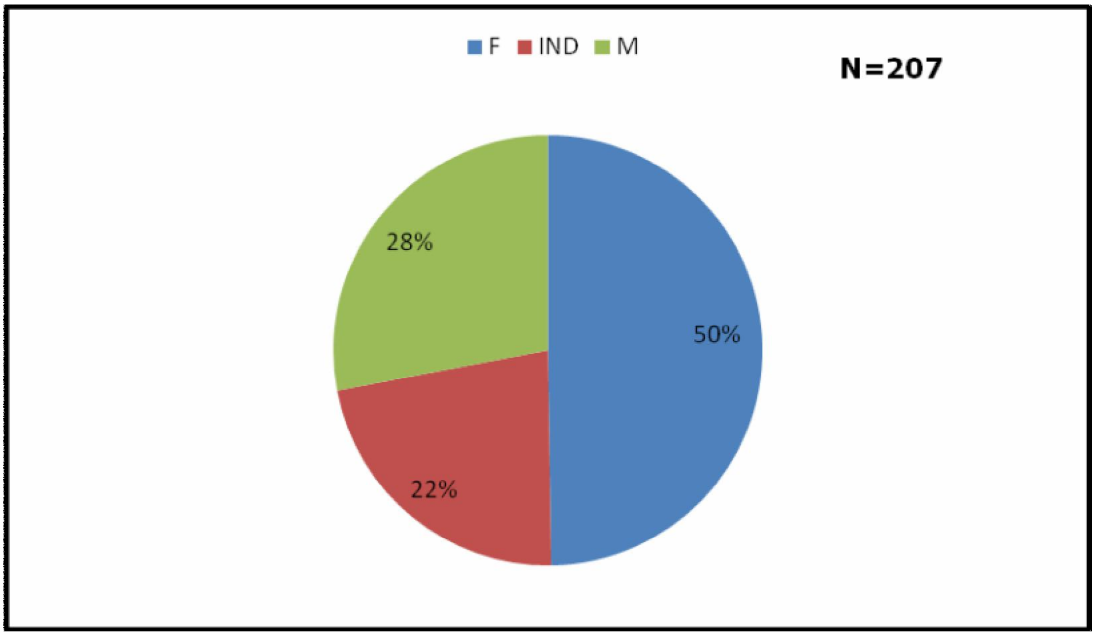


Figure 2. Proportion of males, females and indeterminate in samples of campaign June-July, 2015.

Sex-ratio depending on the size. The samples were gathered in groups of size of half a centimeter, male workforce percentages, female and indeterminate for each size was calculated.

The evolution of the sex-ratio depending on the size shows that the size between 14.5 cm and 24.5 cm is characterized by female dominance and indeterminate. As for the size between 24.5 cm and 34.5 cm, we note that there is a slight predominance of males. For the larger sizes >34.5 cm, we observe the dominance of females (Figure 3).

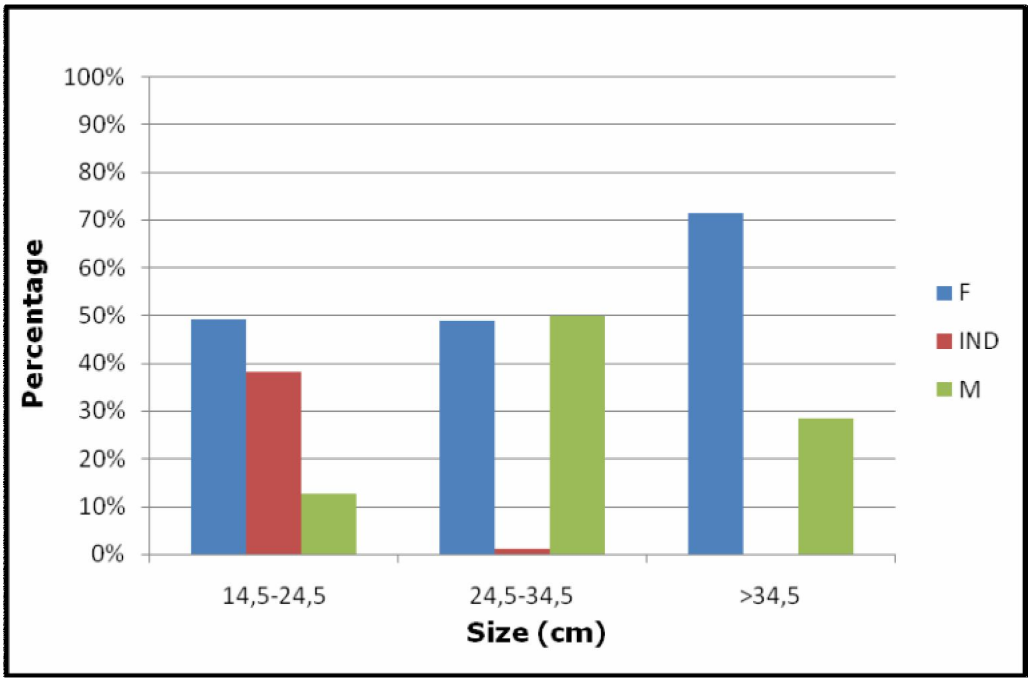


Figure 3. Sex-ratio depending on the size for samples of the campaign June-July, 2015.

Sexual maturity. The total lengths at which 50% of specimens attain maturity was established for the two sexes, 25.54 cm for male and 23.73 cm for female (Figure 4).

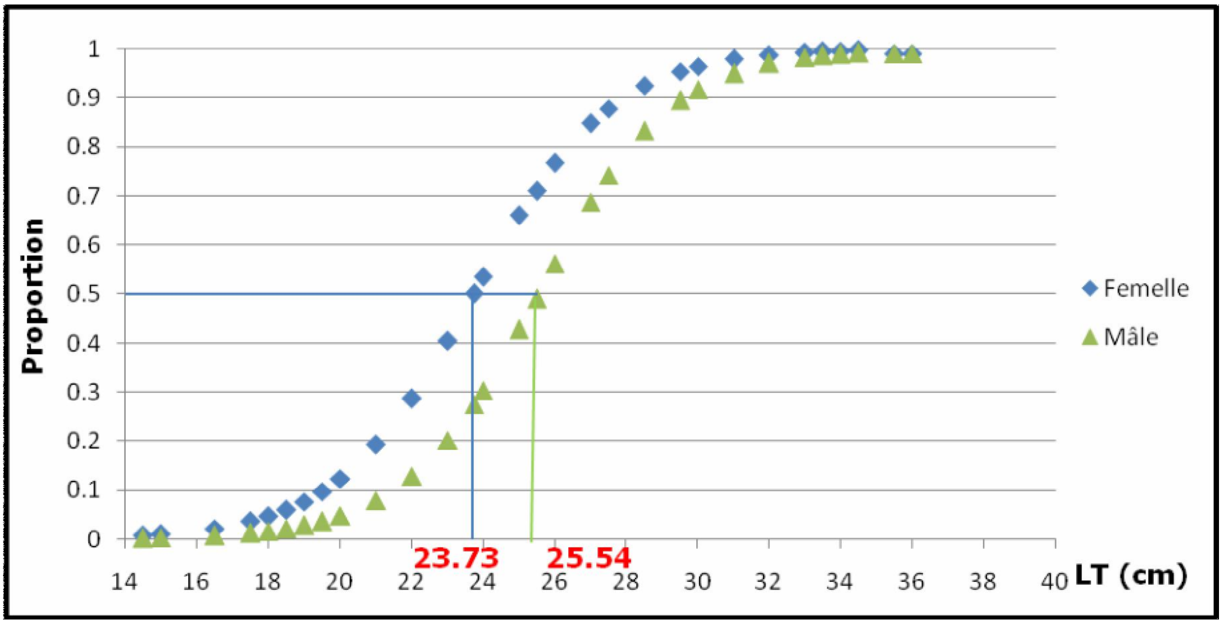


Figure 4. The size at first sexual maturity of *S. aurita* (male and female) of the campaign June-July, 2015.

Age and growth. 144 pairs of otolithe of *S. aurita* were examined. The counting of slowing growth rings on otoliths was used to estimate the age of fish and establish the relevant age-length keys. The age-length keys were established for the two sexes and the average sizes were calculated for each age. According to the age-length keys, age groups show that the age of *S. aurita* does not exceed 5 years. The age 1 is the most dominant for females. Concerning the males, there was a slight dominance of the age group 3, 1 and 2 (Table 2.)

Table 2

Key size-ages for *S. aurita* of campaign June-July 2015 for both sexes

	Age of males					
LT (cm)	0	1	2	3	4	5
N	1	14	14	16	5	3
LT (average)	15.5	19.93	28.36	29.75	31.9	33.83
	Age of females					
LT (cm)	1	2	3	4	5	
N	48	12	16	9	6	
LT (average)	19.11	27.91	29.87	32.5	34.25	

Linear growth. The growth parameters were added to the model of Von Bertalanffy by Vonbit (2005) program.

The analysis of growth parameters by the direct method of Von Bertalanffy for each sex shows that the males have a high growth rate k = 0.97 ($year^{-1}$) than females k = 0.83 ($year^{-1}$) and that these, therefore, reach a final size (asymptotic length) $L\infty$ = 33.72 cm higher than males $L\infty$ = 33.66 cm (Figure 5 & Table 3).

Table 3

Growth parameters of *S. aurita* with Ø' correspondent

	L_∞ (cm)	*K ($year^{-1}$)*	*t_0 (year)*	*Ø'*	*N*
Females	33.72	0.83	-0.34	2.97	91
Males	33.66	0.97	-0.02	3.04	53

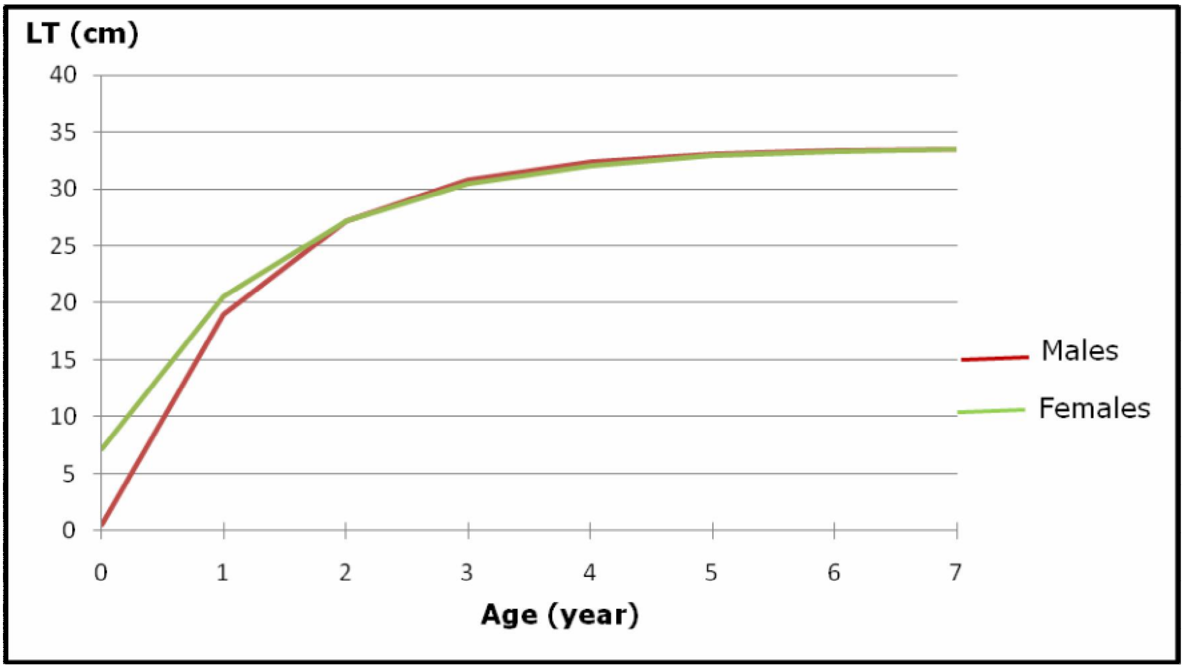


Figure 5. Linear growth curve of *S. aurita* (males and females) in the southern of Atlantic Moroccan area campaign June-July 2015.

Length-weight relationship and weight growth gain. Length-weight relationship of *S. aurita* was established for each sex and the asymptotic weights were calculated by combining the asymptotic sizes of parameters to the parameters of the corresponding length-weight relationship (Table 4 & Figure 6).

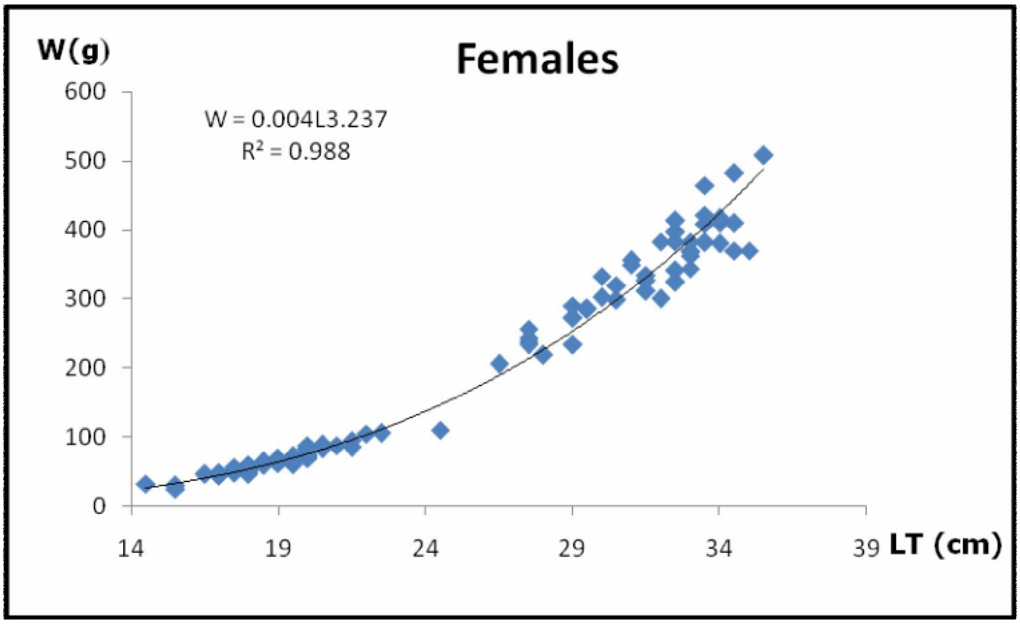
These results show that we have a good correlation between size and weight for both sexes (Figure 6). The allometry coefficient b is higher than 3 reflecting that growth is a majorant allometric. So, the weight is growing faster than the length for males and females.

Comparing the asymptotic weight of males and females showed that males have the asymptotic weight higher than females (Table 4).

Table 4

Length-weight relationship and asymptotic weight of *S. aurita* in the southern Atlantic Moroccan area campaign June-July 2015

	a	*b*	R^2	t_{obs}	t_{the}	*Allometry type*	W_∞ *(g)*	*Effective*
Males	0.004	3.25	0.98	4.19	1.67	Majorant allometry	362.3	58
Females	0.004	3.24	0.99	6.68	1.66	Majorant allometry	353.05	103



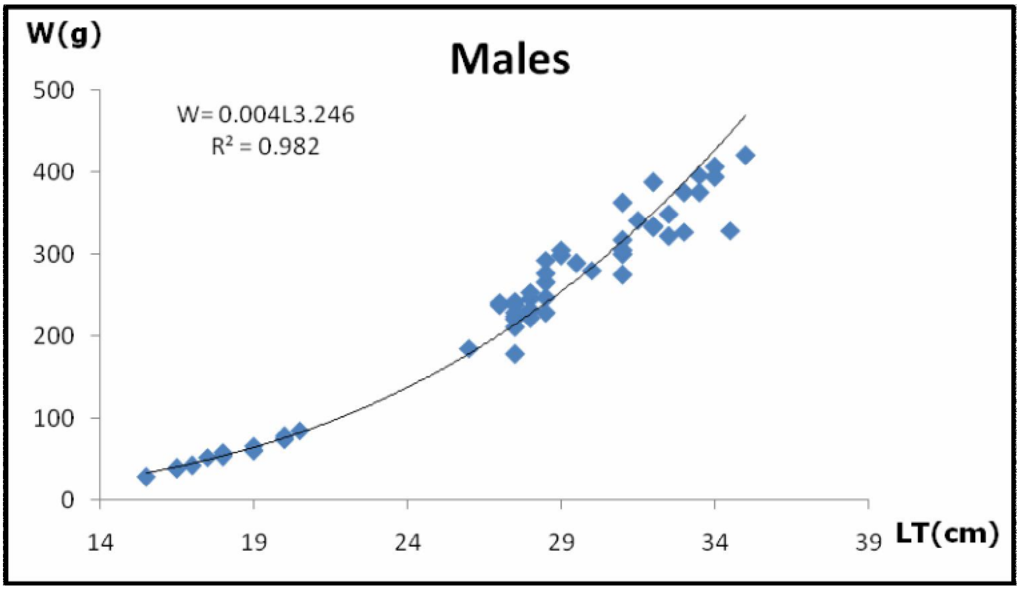


Figure 6. Length-weight relationship of *S. aurita* (males and females) campaign June-July 2015.

The analysis of growth gain curves shows that for small individuals of age 0 and 1 the females have a higher weight than those of males; and from age 2, males have higher weights than females (Figure 7).

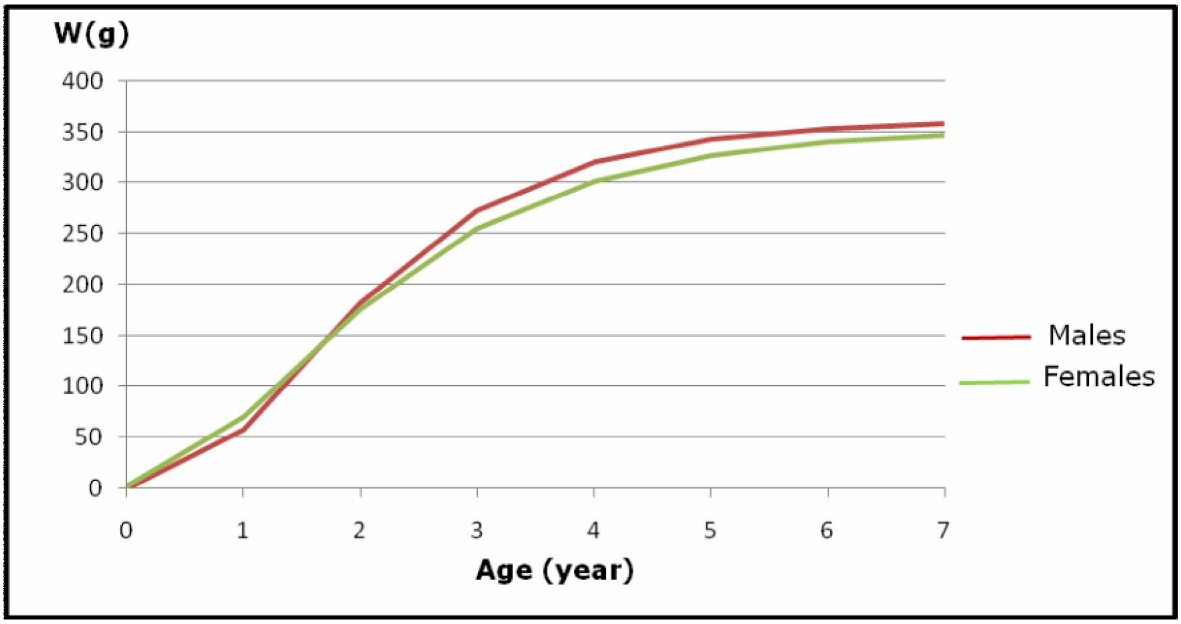


Figure 7. Growth gain curve of *S. Aurita* (Males and females) in the southern Atlantic Moroccan area campaign June-July 2015.

Discussion. The determining of sexes proportions is very useful for a better understanding of demographic structures.

The sex-ratio is in favor of females (63.98 %). This result is in agreement with the results of several authors. Indeed, Boëly (1980) points out that from Clupeidae, females often slightly outnumber males. Andreu & Rodriguez-Roda (1952) in the Balearic Islands also note a significant predominance of females, especially during the species breeding season. Conand (1977a), on the Senegalese coast, reports a sex-ratio slightly in favor of females (52.20 %). Boëly (1979) notes, in the same region, that the sex-ratio is globally balanced with a slight predominance of females among young and older individuals. In the EEZ Mauritanian, Cheibany (1990) observes that the sex-ratio is in favor of females (51.55 %).

It should be noted that the sex-ratio varies according to size ranges. According to Kartas & Quinnard (1984), the predominance of females could also be explained by the migratory nature of this species.

Indeed, from migratory species, the rise of the females to the spawning site is usually later than those of males. There is a predominance of males among the first individuals arrived, followed by a numerical inequality of females and males, and a female predominance in late migration (Diouf et al 2010).

The results of the study realized by Diouf et al 2010 about *S. aurita,* sampled monthly in the period between 1995 and 2007 in the Senegalese coast, show an average sex-ratio lower than those carried out by others authors on the same species in Senegal and Mauritania. These differences are likely due in part to the peculiar sampling each fishery and the average size of samples. In addition, the relative distribution of sexes and fisheries in time and space may explain the observed difference in the results.

Size at first sexual maturity observed is slightly beyond 25.54 cm for males and 23.73 cm for females. It is almost the results achieved by Diouf et al in 2010 in Senegal.

According to Boëly (1982), the size at first sexual maturity (L50) of females of *S. aurita* is about 18.5 cm in Senegal. However, the size can vary from one year to another or within one year following the current quarter (Boëly 1982). The size differs according to gender (Diouf et al 2010; Samba 2011).

In the EEZ Mauritanian, Cheibany (1990) reports a size at first sexual maturity at 21 cm, while Chavance et al (1991) notes the appearance of an earlier sexual maturity for females (20 cm). In the sub-region, it varies considerably from one area to another.

The size reaches 21 cm in Congo (Fontana & Pianet 1973) and 2 cm for populations of the Sahara coastal sector in Cape Verde (Boëly 1979).

Like most Clupeidae, the higher size at first sexual maturity in females is justified by slower growth of males. For *S. aurita,* the size varies from each year and during different seasons.

Note that Wague & M'bodj (2002) worked on catches of Dutch industrial units that target Sardinella adults. The sizes of the individual samples of the study varied between 20 cm and 33 cm fork length.

Table 5 shows the different values of the size at first sexual maturity found in the Senegal-Mauritanian area.

Table 5

Size at first sexual maturity (L50) of *S. aurita* found in the Senegal-Mauritanian area

Areas	*Sexes*	*L_{50} (cm)*		*Reference*
		LF	LT	
Senegal	F	20	23	Conand (1977b)
	F	18.5	21.5	Boëly (1982)
	F	18	21	Camarena (1986)
	F	20	23.6	Diouf et al (2010)
	M	21	25	
Mauritania	F	22.5	26	Samba (2011)
	M	18	21	
	F	21	26	Cheibany (1990)
	M	20	23	Chavance et al (1991)
	F	29	34	Wague & M'bodj (2002)
	M	29	34	
	F	17	20	Pascual-Alayón et al (2008)
	M	19	22	

The length-weight relationship is for describing the nature of individual growth. In our study, there is a majorant allometry. This is consistent with the results of the work done in Senegal (Camarena 1986; Boëly 1979), in Congo (Ghéno & Fontana 1981) and in Mauritania (Holzlöhner el al 1983; Wagué & Mbobj 2002; Diouf et al 2010; Samba, 2011). They showed an allometric (slightly) majorant since the parameter b is higher than 3. It is important to note that the authors used different sizes and units of measurement ranges (fork length and total length). This could explain the difference between the obtained values (Table 6).

Table 6

Parameters of length-weight relationship of *S. aurita* from literature and the corresponding size ranges

Areas	*Size ranges*	*a*	*b*	*Reference*
Mauritania	22-37 (LT)	0.0024471	3.375	Holzlohner et al (1983)
	15-32 (LF)	0.00794	3.227	Lawal et Mylnikov (1988)
	23.6-37.5 (LT)	0.007	3.126	Pascual-Alayón et al (2008)
Senegal	5-32 (LF)	0.0061104	3.290	Camarena (1986)
		0.00000185	3.388	Boëly (1979)
	4-32 (LF)	0.006392	3.274	Freon (1988)
	7.7- 40 (LT)	0.000038	3.162	Diouf et al (2010)

Our study on the growth of *S. aurita* showed that this species has a rapid growth, with a maximum age observed in 5 years, reaching average 19 cm after one year.

Other studies showed that the growth of *S. aurita* is fast, reaching an average of 18 cm after one year (Camarena 1986; Cury & Fontana 1988). The size is growing rapidly in the Senegalese coast, reaching its maximum after 3 years of life.

The recent study of the growth of Sardinella from peninsula of Cape Verde, performed by Samba (2011), also shows very rapid growth of *S. aurita* with maximum observed morphological trait at years 4.

Table 7 summarizes the growth parameters of Von Bertalanffy of *S. aurita* from the literature.

Table 7

Growth parameters of Von Bertalanffy of *S. aurita* and the methods used in the northwest African coast and Mediterranean Sea

Areas	*Reference*	*Method*	*L_∞ (cm)*		*t_0*	*K*	*Ø'*
			LF	*LT*			
Mauritania	Pham-Thuoc & Szypula (1973)	Scales	34.35	40.7	0.33	-0.63	2.73
	Chesheva (1998)	Scales	35.12	41.63	0.26	-0.87	2.66
	Santamaria et al (2008)	Scales and otoliths	32.92	38.97	0.32	-1.78	2.69
	Pascual-Alayón et al (2008)	Otoliths	31	36.6	0.39	1.46	2.72
Senegal-Mauritania	Maxim & Maxim (1987-1988)	Scales	38.1	45.22	0.36	-0.69	2.72
Senegal	Boëly (1979)	Scales and length frequency	31.23	36.92	0.97	0.21	2.97
	Krzeptowski (1981)	Scales	36.25 34.34 35.52	43 40.69 42.12	0.3 0.27 0.28	-0.95 -0.99 -0.99	2.75 2.66 2.7
	Boëly et al 1982)	Scales and length frequency	30.6	36.2	1.21	-0.06	3.05
	Fréon (1986)	Scales	30.63	36.2	1.21	-0.06	3.03
	Samba (2011)	Otoliths	26.7	31.45	1.79	0.55	3.6
Algeria (Centre of the Algerian coast)	Bouaziz (2007)	-	-	29.82	-	0.41	-
Tunisia	Kartas (1981)	-	-	28.99	-	0.36	-
Spanish (Balearic island)	Oliver & Navarro (1952)	-	-	27.4	-	0.41	-

The interpretation of the results is complicated by the existence of two relatively long breeding seasons and migrations carried out by this fish. The difference concerning, in particular, the growth rate may be fast for some, or relatively slow for others. The comparative study of age reading from scales and otoliths on the basis of a sample of 1873 otoliths and 1162 scales shows that the reading based on otoliths tends to overestimate the growth rate K due to reading difficulties and the presence of fake brands (Santamaria et al 2008). Similarly to the method of reading scales, the difference between different authors can be explained by completely different interpretation of scales. Indeed, Pham-Thuoc & Szypula (1973) results seem to show an underestimation of the growth rate of juveniles and youth. Age reading is difficult from the year 3.

Thus, the difference noted could be explained by the type of fishery sampled by the authors. Indeed, there may arise a problem of representation of a class size in the samples used for the study of growth according to the authors (a segment of the stock may be absent for under sampled).

The same analysis reveals the superiority in sizes for different ages of Atlantic Sardinella compared to those of the Mediterranean. *S. aurita* like authors Clupeidae is characterized by short-lived, with maximum durability reported by all studies conducted in different regions of eight years (Beverton 1964; Froese & Pauly 2007).

This characteristic is typical of small pelagic warm and temperate waters and Clupeidae who spent a lot of energy in their lives and their coveted position at the marine food chain.

Asymptotic weight of the stock of *S. aurita* in the southern Moroccan Atlantic area is higher than that found in different regions of the Mediterranean (Table 8).

This can be explained by several reasons. Whether the exploitation of Sardinella in south of Morocco targets individuals with high body weight, or the local environmental conditions enable faster growth of Sardinella in this region compared to other regions of the Mediterranean.

For this, knowledge of size or weight asymptotic is important to have a preliminary idea about the mean state of fish stock component. Annual monitoring of these indicators can be very useful and can be considered a sign of the health of the stock. Indeed, the different fishery studies agree to affirm that the decrease in the average size of individuals caught is a sign of a probable overfishing.

Table 8

Asymptotic weight $W\infty$ of *S. aurita* from the literature

Reference	*Areas*	*W_∞ (g)*
Bébars (1981)	Egypt (Saloum Bay)	311.35
Kartas (1981)	Tunisia	198.18
Bouaziz (2007)	Algeria (Centre of the Algerian coast)	220.24
Baali et al (present work)	Morocco (Southern Atlantic area)	362.3 (male) 353.05 (female)

Conclusions. This preliminary study realized by the samples of the round Sardinella, *S. aurita,* in the southern Moroccan Atlantic area in the period between June-July 2015 has clarified some of the reproductive biology and growth. The sex-ratio is in favor of females, especially for larger sizes (>34 cm). The size at first sexual maturity was determined as 25.54 cm for males and 23.73 cm for females. The growth of *S. aurita* was studied using the direct method based on the estimation of age by counting the growth rings stops. During the first years of their lives, this species has a high and rapid growth. The size of 19 cm is reached after the first year of life, and the maximum age is of 5 years. The weight gain and the increase in size are larger, and the linear and weight growth have a slight difference between males and females throughout the area.

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