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Study of the age and growth of the *Sardina pilchardus* in the north area of the Moroccan Atlantic coast

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Abstract

This work aims to analyze some aspect of biology of sardina pilchardus sampled during the time period between November 2014 and October 2015 in North Atlantic morocco.

The study of the age and growth of *Sardina pilchardus* showed that the sex-ratio is in favor of females. The sardines sampled during the period of study present different age. Growth parameters were estimated using the direct method of Von Bertalanffy, gave asymptotic length, L_{∞} 23.26 and 23.03 cm and curvature parameter, K of 0.41 and 0.37 per year for females and males respectively. The study of the regression of fish size otolith weight of *Sardina pilchardus*, showed significant relationships with positive correlation coefficients. During the first year of their lives, this species shows high and rapid growth, weight gain, increased in size and the linear and weight growth is slightly different between males and females in the North area of the Moroccan Atlantic coast.

Keywords: *Sardina pilchardus*, growth, age

1. Introduction

Sardina pilchardus (Walbaum, 1792) is one of the most popular sea fish sources in Morocco. The total amount of sardine production in the year 2015 was 850 000 tons ^[1]. These species were defined as fish living in the sea between the surface and 200 meters deep and characterized by significant horizontal and vertical migration in coastal waters.

The sardine is the most important species in terms of catch and biomass. Morocco is the first world producer of the sardine of superior quality and a leader in the international market of the sardine canned.

This species have been chosen because of its socioeconomic importance and its abundance along the Atlantic coast of Morocco. Also, it can play a structural role in the dynamics of the ecosystem in the control that it could exert on other species of pelagic fish.

Despite the significant economic importance of this species along the North African Atlantic coast, little information is known either on its ecology or biology. Populations of small pelagic fish, such as sardine and anchovy, show evidence of important natural fluctuations in their abundance ^[22, 23]. These fluctuations seem to be related, among other factors, to climate variability ^[24] or habitat conditions ^[25]. Growth and reproduction are two important parameters in fish population dynamics.

Biology of *Sardina pilchardus* 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 sardine and the strong contributions in the total catch in particular in the northern Moroccan Atlantic.

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

2. Material and Methods

A total 284 sardines were collected monthly, covering the period from November 2014 through October 2015 in the north Atlantic morocco (Figure 1). Catches were sorted, identified, inventoried and weighted. The data collected concerned the measure of the Total Length (LT), the Total Weight (TW), the Otolith Weight (OW) and Otolith Length (OL).

Otoliths are taken and fixed on black plates by resine EUKITT type.

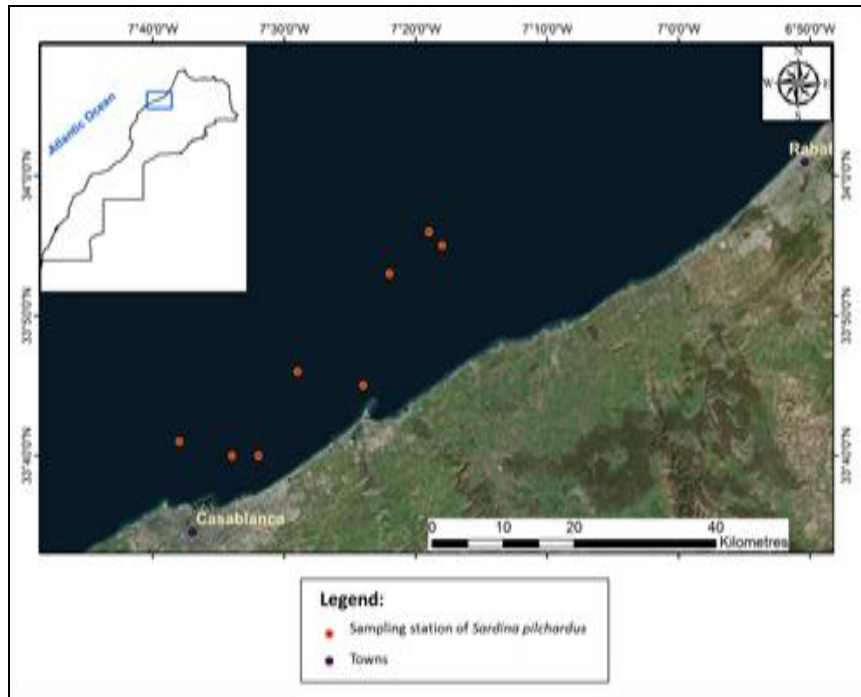


Fig 1: Sampling stations of *Sardina pilchardus* in the north of the Moroccan Atlantic coast.

2.1 Length-weight relationship

The relationship of size-weight is generally used for the estimate of the weight of the catch in fisheries biology as well as for the identification of stocks [2]. This relationship of allometric type allows you to convert the sizes measured in weight data. It is in the following form: $W(t) = a L^b$

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.

If $b = 3$: the weight believes in proportion to the size, it is a perfect isometry.

If $b \neq 3$: growth is allometric

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 the verification of the isometry ($b=3$) or of allometry ($b \neq 3$) of the relationship between size and weight is the Student's t test after linearization of this relationship by logarithmic transformation [3-4].

This test consists in the comparison of the slope of the regression line (b) with a theoretical slope equal to 3.

The main hypothesis (H_0) proposes that there is no significant difference between the slope (b) and the value 3.

The alternative hypothesis (H_1) implies that there is a significant difference between the slope (b) and the value 3.

If $t < 0.05$ the main hypothesis is accepted.

If $t > 0.05$ the main hypothesis is rejected.

2.2 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 mathematical 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:

$$L(t) = L_{\infty} (1 - \exp -K(t-t_0))$$

Where $L(t)$ is the total length at age t , L_{∞} is the asymptotic length, K is a growth coefficient,

t_0 is the theoretical age at which predicted mean length is zero.

2.3 Weight growth

The combination of the model of linear growth of von Bertalanffy and the relationship of size-weight allows to deduct the growth model weight of von Bertalanffy.

2.4 Use of the morphometry and otolith weight in the study of the growth

In total 110 pairs of otoliths were weighed. It is to be noted that it was considered both otoliths forming each pair of otolith to share. In cases where the otolith is broken on one side of its surface, it was not the object of the corresponding surveying.

3. Results

3.1 Relationship of size and weight

The allometric regression carried out by the sampled individuals of separate sex gives the expressions which are summarized in the Table 1. From the spectrum of the Sizes This last between 11 and 22.5 cm for females, between 13 and 21.5 cm for males.

	A	b	R ²	T obs	T the	Type of allometry
Female	0.007	3.009	0.946	1.65	0.05	Isometry
Male	0.004	3.215	0.923	1.66	0.06	Allometry majorante

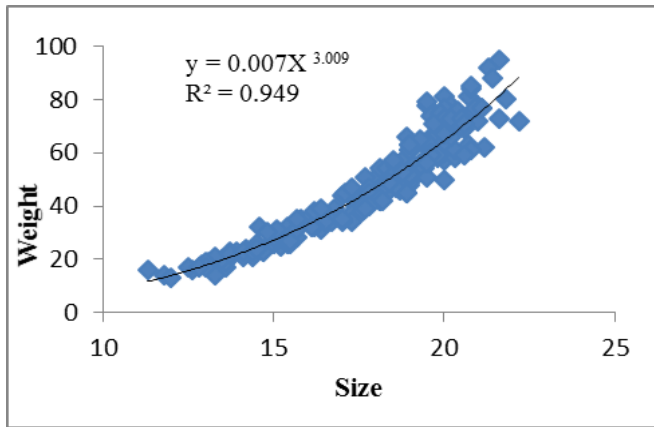


Fig 2: Relationship of size-weight of female.

These results show that there is a good correlation between the size and the weight. For females the allometric coefficient is equal to 3, it is an isometry, therefore the weight increase in proportion to the size (figure 2). For males, the allometric coefficient *b* is greater than 3, which indicates that it is an allometric increase, that is to say that the weight increases faster than the length (Figure 3).

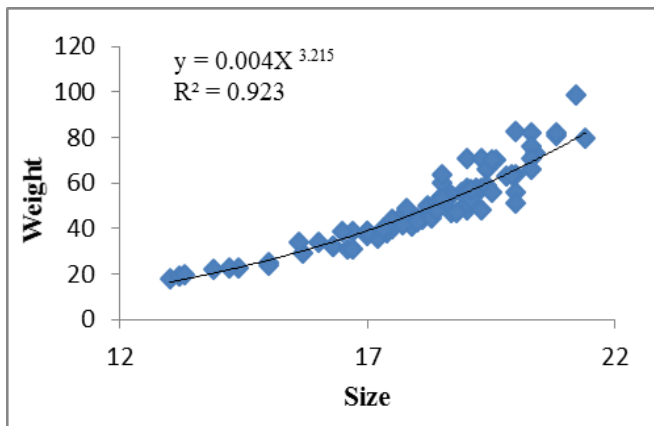


Fig 3: Size-weight relationships of male.

3.2 Key size-age

In total 110 pairs of otolith from *Sardina pilchardus* have been examined. The counting of the rings of judgments of growth on the otoliths, has allowed estimating the age of the fish. For males and females separately. The key size-age shows that the age group 3 is the most dominant in males as well as the average size is 18.25 cm. By contrast, for females age group 2 is more dominant and that the average size is 16.13 cm.

Male				
Age	1	2	3	4
Staff	15	17	21	13
Average size	13.25	18.25	18.25	20.25
Female				
Age	1	2	3	4
Staff	38	88	63	29
Average size	14.33	16.13	18.91	20.6
Combined sex				
Age	1	2	3	4
Staff	53	105	84	42
Average size	14	16.46	18.75	20.5

3.3 Weight growth

The analysis of curve of growth in weight has shown that the age between 1 and 2 as well as between 3 and 4 males have an

average weight slightly higher than those of females, for the age between 2 and 3 females have an average weight slightly higher than those of males (Figure 4).

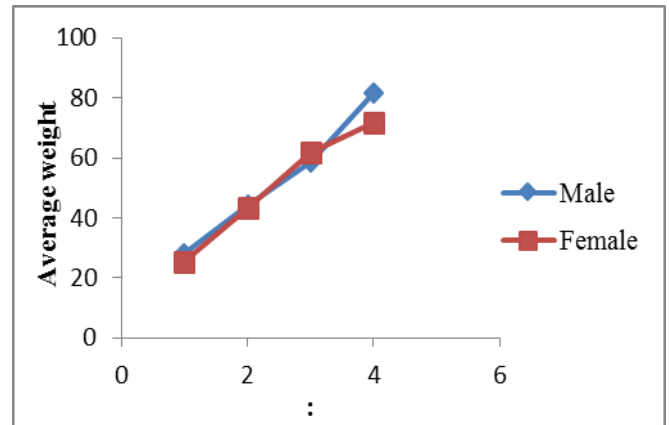


Fig 4: Average weight as a function of age.

3.4 The average size as a function of age

The analysis of growth by the direct method of von Bertalanffy shows that the *Sardina Pilchardus* in the north Atlantic Morocco has a growth rate *K*: 0.42 (year-1) for the two sexes combined with an asymptotic size L_{∞} : 23.08 cm.

The comparison of the curves of growth in length of *S. pilchardus* established for each of the sexes shows that females have a constant of higher growth *k*: 0.41 (year-1) that males *K*: 0.37 (year-1) and these latest therefore reach a final size (*L*: asymptotic size) L_{∞} = 23.09 cm lower than that of the female L_{∞} = 23.26 cm.

3.5 Relationship of size –weight of otolith

The results obtained show that there is a good correlation between the weight of otolith and the total size of the *S. Pilchardus*. The rate of growth of the otolith weight is low at the beginning of the growth, and then it increases progressively with the sizes the larger (Figure 6).

3.6 Relationship age-weight of otolith

The growth curves for the *S. Pilchardus*, was presented on the basis of the weight of the otoliths (Figure 7). The weight of otolith presents a good correlation with the age. The latter increases with the weight of the otolith.

4. Discussion

The growth of *Sardina pilchardus* has been studied according to the direct method based on the estimate of the age by counting rings of judgments of growth. This method remains the most appropriate for the study of the growth because it is more precise.

In temperate regions, two types of main factors synchronised the formation of the hyaline area: on the one hand, the external factors such as the temperature of the water, the availability of food and the migration, on the other hand the internal factors such as the reproduction and the internal rate of calcium metabolism and protein synthesis [6-7].

Among the Moroccan sardine the formation of the hyaline zone coincides well with the laying period maximum. However, the reproduction is not the only factor responsible for the formation of the hyaline zone since the latter has been observed in the individuals mature and immature. But other factors may intervene in synergy as the temperature of the water, the availability of food and the migration. These

factors are known for their impact on the condition of the fish.

The award of the first of January as the date of birth to the Moroccan sardines coincides well with their main season of Ponte [2, 8-10]. During the first years of their lives, this species presents a high growth and fast, the gain of the weight and the increase in the size are more important. The linear growth and weight shows a slight difference between males and females in the north Atlantic morocco.

The comparison of mean lengths by age group has shown that there could exist within the Atlantic different populations of sardines (Table 4).

These differences could be related to different adaptations of sardines in their environment [11]. However, these differences could result from the relationship genotype-phenotype. Individuals with strong growth have a genotype structure in particular.

Otolith growth is generally proportional to the growth of fish [16].

The study of the regression of the size of fish in relation to the weight of otoliths of *Sardina pilchardus*, showed significant relationships with correlation coefficients positive, which is consistent with the work of [17].

The growth of otolith continues during the life of individuals. The otolith is proving to be an indicator of growth among fish, although for the length and the width it note a kind of stabilization of the growth of otoliths, comparable to that observed in the size of the fish, at the end of a certain age. The weight of otoliths allows a better estimate of the age that the size of the fish, since it allows you to solve the problem of the stabilization of the size and therefore especially for major ages. This is in agreement with the results of several authors who have shown the close relationship between otolith weight and age of the fish for many species of tropical and temperate areas [18-21].

5. Conclusion

The species studied *Sardina pilchardus* possess an important value in the Moroccan fisheries on both coasts the Atlantic and Mediterranean, due to their significant commercial value.

The growth of *Sardine pilchardus* has been studied according to the direct method based on the estimate of the age by counting rings of judgments of growth. This method remains the most appropriate for the study of the growth because it is more precise.

During the first years of their lives, this species presents a high growth and fast, the gain of the weight and the increase in the size are more important. The linear growth and weight shows a slight difference between males and females in the area of north Atlantic Morocco.

The weight of the otoliths that remains a more convenient way, ensures a better estimate of the age of the *Sardina pilchardus*, since it allows you to solve the problem of the stabilization of the size and therefore especially for major ages.

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