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Research Article
Reproductive Biology of *Sardinella* sp. (*Sardinella aurita* and *Sardinella maderensis*) in the South of Morocco

[1]Ayoub Baali, [1]Hajar Bourassi, [1]Samira Falah, [2]Wahbi Abderrazik, [3]Khalid Manchih, [3]Khadija Amenzoui and [1]Ahmed Yahyaoui

[1]Laboratory of Zoology and General Biology, Faculty of Science, Mohammed V University, Rabat, Morocco
[2]Laboratory of Environment and Aquatic Ecology, Faculty of Science Ain Chock, Hassan 2 University, Casablanca, Morocco
[3]Fishery Research National Institute, Casablanca, Morocco

Abstract

Background and Objective: *Sardinella* sp. has gained much attention lately because of its biomass increase, which might be the result of climatic changes occurring across the Atlantic sea. Little information is known about reproduction of these species particularly in the Moroccan Atlantic area. The objective of the this study was to explore some aspects of the reproductive biology of *Sardinella* in the South of Atlantic Moroccan coast. **Materials and Methods:** Monthly samples were collected during the period between February, 2015 and January, 2016 in the area between Cape Boujdor and Cape Blanc. The data collected concerned the measure of the total length, the weight, the gonad weight as well as the sex and maturity stages. The χ^2 test was used to compare the differences between both sexes and the ANOVA test was adopted to analyze the data variation. **Results:** *Sardinella* sp. is a gonochoristic fish. The overall female to male ratio was not statistically different for both species ($\chi^2 = 0.68$ for *Sardinella aurita* and $\chi^2 = 1.04$ for *Sardinella maderensis*), although it varied seasonally and according to the length of the fish. The monthly changes in the gonadosomatic index and the macroscopic characteristics of gonads showed that round *Sardinella* in the South of Morocco spawns between February and July and between November and December with a spawning peak on April. For the flat *Sardinella*, it spawns between February and March and in July with a spawning peak on July. Females round *Sardinella* reach first sexual maturity at a smaller size than males (26.17 and 26.78 cm, respectively). Concerning the flat *Sardinella*, it was the opposite. Males reaching sexual maturity are smaller than females (20.75 and 21.76 cm, respectively). **Conclusion:** It is concluded that the size at first maturity revealed that mature females in the South of Moroccan Atlantic Ocean were smaller than males for the round *Sardinella* and the opposite was observed for the flat *Sardinella*. The spawning of *S. aurita* presented a pick in April and for *S. maderensis* in July. As a shared stock these findings will be used for stock assessment in the North West Africa area.

Key words: *Sardinella aurita*, *Sardinella maderensis*, sex-ratio, reproduction, gonadosomatic index

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Corresponding Author: Ayoub Baali, Laboratory of Zoology and General Biology, Faculty of Science, Mohammed V University, Avenue Ibn Battouta, B.P. 1014, Rabat, Morocco Tel: +212 623-755-804

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Fish had developed reproductive strategies and traits that ensure the survival of the species under variable and often unfavourable conditions[1]. The reproductive strategy of each of these species was expressed by certain characteristics such as age and size fecundity, time duration and frequency of spawning, size at first maturity and reproductive behaviour[1,2]. All these characteristics are useful for managing fisheries[3], particularly for pelagic fishery species.

The *Sardinella* 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[4]. It is a key species inhabiting the ecosystem of the Northwest African upwelling region[5]. The biomass of *Sardinella* had known fluctuations last years. Production of *Sardinella* during the period 1990-2014 varied from year to year. Those fluctuations were especially linked to the migrations of the species. The average catch during the last 5 years was around 73 340 t. The South of Cape Boujdor area represented 90% of the average catch of *Sardinella*[6]. The *Sardinella* represented as the second pelagic species caught in this area after the Sardine (*Sardina pilchardus*), the round *Sardinella* represented the most dominant species in the studied area.

The identification of spawning period and spawning frequency were important prerequisites for understanding the dynamics of these resources, thus providing a basis for rational exploitation[7]. The reproductive biology of round *Sardinella* has been thoroughly studied in the Western[8,9] and Eastern Atlantic[10,11].

In contrast, information were limited for the Atlantic Moroccan coast and it has been studied across its Mediterranean distribution. Such as the study of reproduction of *Sardinella aurita* in Algerian[12,13], Tunisian waters[14] and Egyptian[15] waters. Previous studies on *Sardinella maderensis* included those on the fishery by Longhurst[16], Tobor[17] in Cameroon by Djama *et al.*[18], in Senegal by Postel[19] and in Congo by Rossignol[20]; on food and feeding habits by Facade and Olaniyan[21,22]; on breeding age and growth by Marcus[23] and on reproduction patterns by Youmbi *et al.*[24].

However, the study of stock dynamics of these species exploited was rarely initiated. The lack of study was rather surprising given the considerable catches of *Sardinella* and the strong contributions in the total catch in the Southern of Moroccan Atlantic coast[25]. The aim of the present study was to investigate the following aspects of the reproductive biology of *Sardinella aurita* and *Sardinella maderensis* in the Southern Moroccan Atlantic: The time and duration of the spawning, the annual reproductive cycle, in terms of monthly changes in maturity stages, the sex-ratio, the sex-ratio variation on the size and the size at first sexual maturity.

MATERIALS AND METHODS

A total of 580 specimens of *Sardinella aurita* and 96 of *Sardinella maderensis* were collected monthly from February, 2015 to January, 2016 in the area between Cape Boujdor and Cape Blanc (zone C) from artisanal catches and in Al Amir Moulay ABDELLAH research ship (Fig. 1). Sampling frequency depended on the availability of *Sardinella* because it was not always present in fishing areas especially the flat one. Catches were sorted, identified, inventoried and weighted. The data collected concerned the measure of the Total Length (TL), the Total Weight (TW), the Gonad Weight (GW) (0.01 g), sex and maturity stages.

Sex ratio: The sex ratio was defined as the proportion of each sex, determined by macroscopic observation of gonads in a given population. The principal hypothesis supposed that there were equal sex ratios. This was evaluated with a chi-square test.

Sexual maturity: The macroscopic sexual maturity included five stages[26] is shown in Table 1.

Table 1: Five-point maturity scale for partial spawners[26]

Stages of maturity	States	Gonads features
Stage I	Immature	Ovary and testis about 1/3rd length of body cavity. Ovaries pinkish, translucent; testis whitish. Ova not visible to naked eye
Stage II	Maturing virgin and recovering spent	Ovary and testis about 1/2 length of body cavity. Ovary pinkish, translucent; testis whitish, more or less symmetrical. Ova not visible to naked eye
Stage III	Ripening	Ovary and testis about 2/3rd length of body cavity. Ovary pinkish yellow colour with granular appearance, testis whitish to creamy. No transparent or translucent ova visible
Stage IV	Ripe	Ovary and testis from 2/3rd to full length of body cavity. Ovary orange-pink in colour with conspicuous superficial blood vessels. Large transparent, ripe ova visible. Testis whitish-creamy, soft
Stage V	Spent	Ovary and testis shrunken to about 1/2 length of body cavity. Walls loose. Ovary may contain remnants of disintegrating opaque and ripe ova, darkened or translucent. Testis bloodshot and flabby

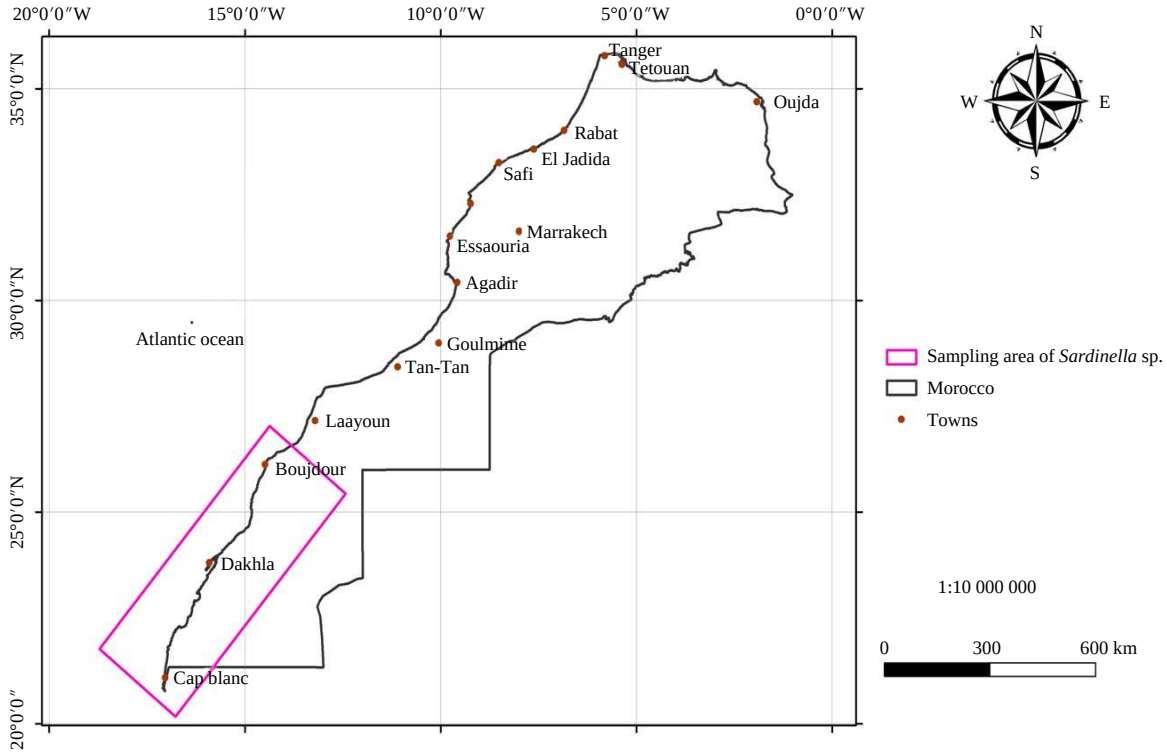

Fig. 1: Sampling area of *Sardinella* sp., in the South of Moroccan Atlantic ocean

Size at first sexual maturity (L_{50}): The total length at which 50% of specimens attains maturity (stage 3 was retained as the point at which the fish is considered mature) was deduced using theoretical maturity curve which corresponded to the regression between P parameter depending on the fish size ($P = 1/(1+e^{-(a+b\times L)})$[27]; where, P is the 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 gave:

$$-\ln((1-P)/P) = a+b\times TL$$

The regression between Ln (P/1 - P) and Total Length (TL) made finding the parameters a and b. So:

$$L_{50} = -a/b$$

Gonadosomatic index: Variations in the gonad were almost estimated with parameters such as the length of the body, the total body weight or the somatic weight[28]. The expression used in this study was the gonadosomatic index (GSI), equals both gonads weight divided by the total weight of the body. It expressed the gonad weight as a percentage of body weight[29]:

$$GSI = GW\times 100/TW$$

Condition factor: The condition factor (K) reflected the ecological and physiological conditions[30]. In this study, it was calculated using the formula[31]:

$$K = (TW/TL^3)\times 100$$

Statistical analysis: One way analysis of variance (ANOVA)[32] was applied to test the differences between sex, sizes and seasons using STATISTICA software version 6.1.

RESULTS

Sex-ratio: *Sardinella* was a gonochoristic fish. External morphological and colour differentiations were not observed at any stage of its life cycle (monomorphism). In overall, 52% of *Sardinella aurita* sexed were females and 48% were males. Also, 45% of *Sardinella maderensis* sampled in the Southern Moroccan Atlantic area during the study period were males and 55% were females. The F:M ratio was 0.93 for *S. aurita* and 0.81 for *S. maderensis* and did not differ significantly (Table 2).

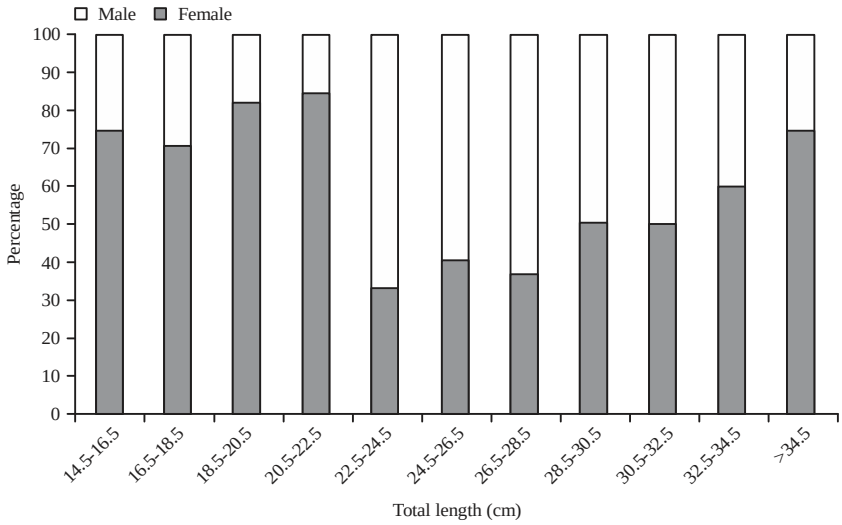

Fig. 2: Sex-ratio (%) as a function of total length for round *Sardinella*, South of Moroccan Atlantic ocean

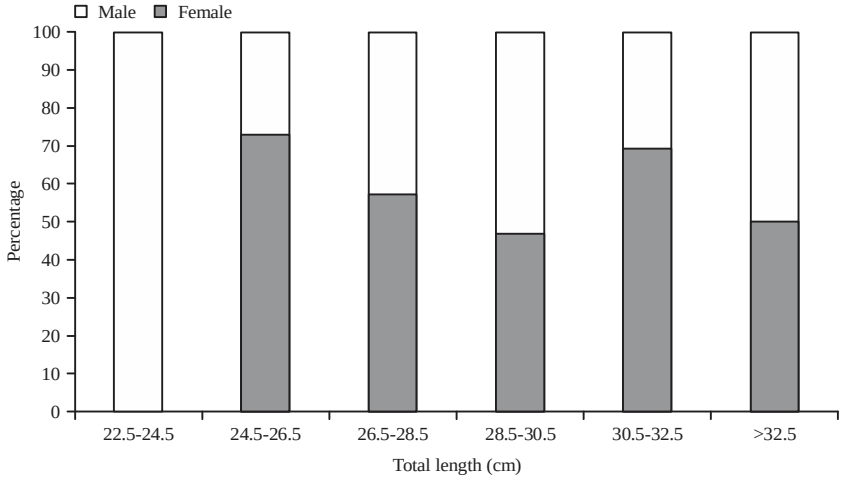

Fig. 3: Sex-ratio (%) as a function of total length (TL ranges (cm)) for flat *Sardinella* Males (M) and Females (F), South of Moroccan Atlantic ocean

Table 2: Comparison of proportions of males and females of *Sardinella* sp., during the period February, 2015 and January, 2016

	Males		Females			
Species	No.	%	No.	%	χ^2_{obs}	$\chi^2_{(1, 0.05)}$
Sardinella aurita	257	48	276	52	0.68	3.84
Sardinella maderensis	43	45	53	55	1.04	3.84

Sex-ratio depending on the size: The size-specific sex-ratio of *Sardinella aurita* showed that the number of females was higher for sizes (length) lower than 22.5 cm, whereas, the number of males was higher for sizes between 22.5 and 28.5 cm. The percentages of males and females were equal for size ranged between 28.5 and 32.5 cm. Females generally were dominant at sizes greater than 32.5 cm (Fig. 2). The sex-ratio differed statistically between the size classes ($p = 0.001$). For *Sardinella maderensis*, the size-specific sex-ratio showed that the number of males was higher for sizes lower than 24.5 cm. Females generally dominated the sizes greater than 24.5 cm (Fig. 3). The sex-ratio differed statistically between the size classes ($p = 0.009$).

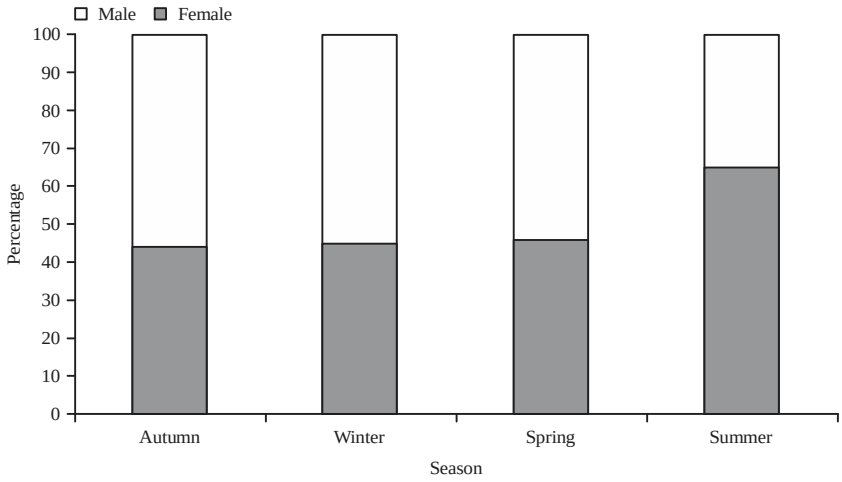

Fig. 4: Seasonal variability of the sex ratio of *Sardinella aurita* Males (M) and Females (F)

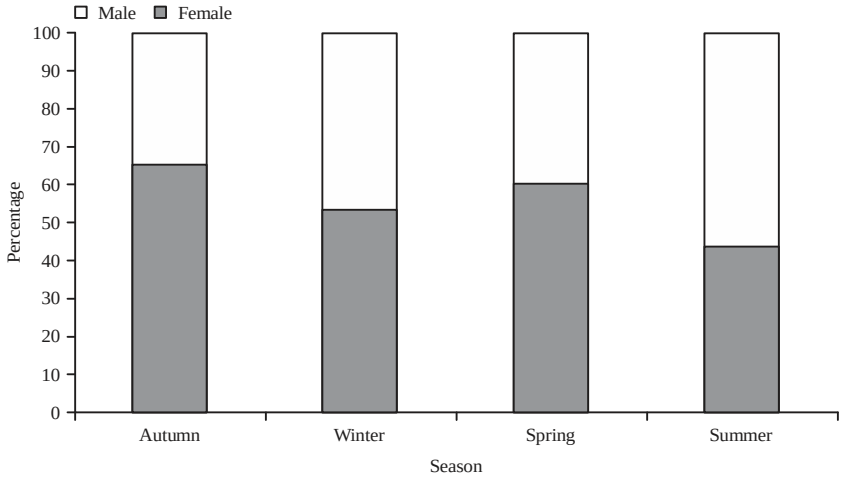

Fig. 5: Seasonal variability of the sex ratio of *Sardinella maderensis* Males (M) and Females (F)

Sex-ratio depending on the season: During the year, the population of *Sardinella aurita* was constituted of a slightly higher percentage of males from autumn to spring, while in summer the sex ratio was in favour of females (Fig. 4). The sex-ratio did not vary significantly with seasons ($p = 0.18$). In contrast, *Sardinella maderensis* presented a higher percentage of females from autumn to spring. While in summer, males were slightly dominant (Fig. 5). The sex-ratio for this specie also didn't vary significantly with seasons ($p = 0.5$).

Gonad stages and time of spawning: The sexual maturity stages were determined by the Food and Agriculture Organization (FAO) scale, 5 stages were identified for *Sardinella*[26]. Fish with gonads at stage greater than or equal to 3 were considered mature[33]. The monthly changes of different maturation stages are shown in Fig. 6 and 7. For *Sardinella aurita*, immature individuals were dominant from September-December and absent in April and June. Whereas, for *Sardinella maderensis*, the immature stages were present only for males and during February and November. The mature individuals of the two species were present along the year except in September and October for the round *Sardinella*. Although, the reproductive cycle was characterized by intense gonadal activity during February, March and April for *S. aurita*, while for *S. maderensis* during March, April and July. The GSI monthly values for both sexes are presented in Fig. 8 and 9. Males and females of *S. aurita* showed a maximum GSI of 5.11 and 3.78, respectively in April and a minimum GSI of 0.01 for males and 0.06 for females in October. For *S. maderensis* the maximum of GSI was observed in July for males (3.06) and females (3.23) and a minimum in November for both sexes.

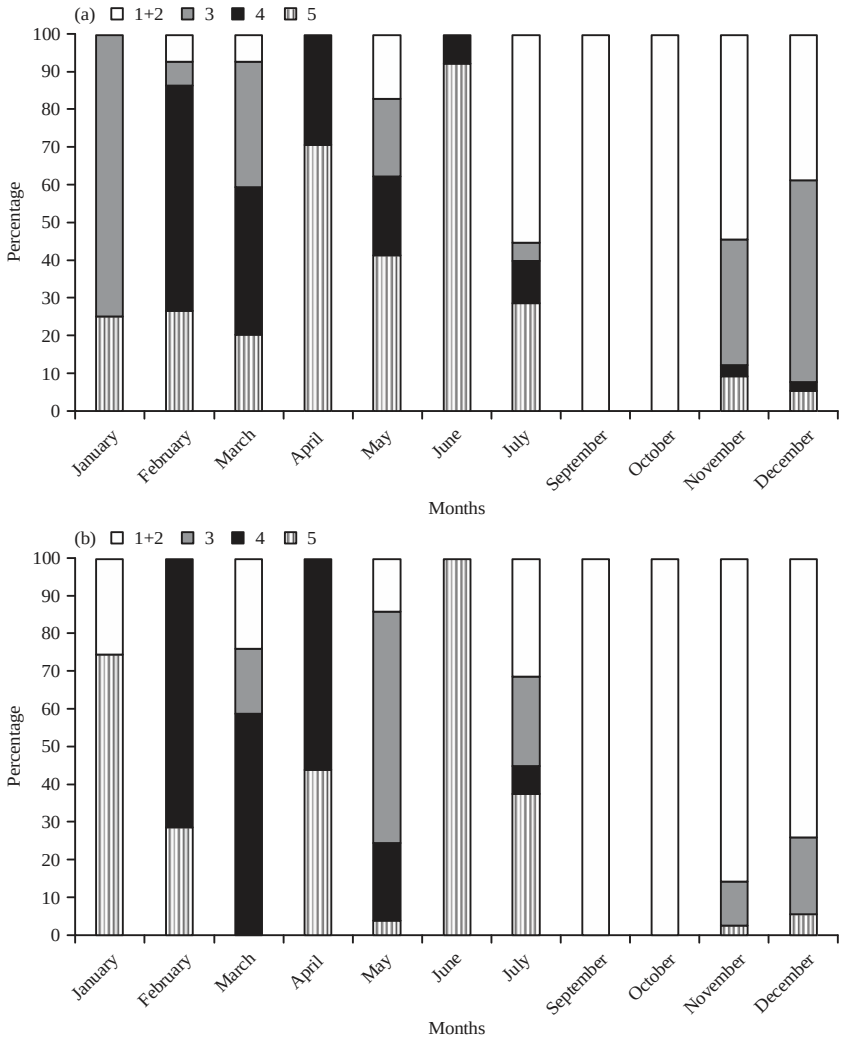

Fig. 6(a-b): Monthly percentage of maturity stages of (a) Female and (b) Male round *Sardinella*, South of Moroccan Atlantic ocean

Condition factor: The mean monthly changes in the condition factor are shown in Fig. 10 and 11 for both sexes. Overall, there were no significant differences between the months studied. For *Sardinella aurita*, the lowest value of condition factor was recorded for males in December (0.89) and the highest value in July (1.03). The lowest value of condition factor for females occurred in January (0.88) and the peak value (1.03) in April. For *Sardinella maderensis,* the lower value for males was recorded in July (0.87) and the highest value in March and December (0.97). For females, the lower condition factor was occurred in July (0.89), while the peak value in April (1.07).

Size at first sexual maturity (L_{50}): The L_{50} was 26.78 cm for males and 26.17 cm for females of *S. aurita* (Fig. 12), whereas, *S. maderensis* males have an L_{50} lower than the females (20.75 cm for males and 21.76 cm for females) (Fig. 13).

DISCUSSION

The sex-ratio is in favour of females for both species (52% for *Sardinella aurita* and 55% for *Sardinella maderensis*). These results are in agreement with those found by Bensahla-Talet *et al.*[13] on Algeria and Lawson and Doseku[34] on Nigeria. The dominance of females must be due to its rise to the spawning site that is usually later than males[28,35]. The determining of sex proportions is very helpful for a better understanding of demographic structures. Thus, Boely[36] points out that for Clupeidae, females often slightly outnumbered males. Dahel *et al.*[37] in the Algerian Eastern coasts, Conand[38] and Boely[39] on the Senegalese coast and Cheibany[40] in the Mauritanian Exclusive Economic Zone (EEZ) noted a significant predominance ($p<0.05$) of females, especially during the breeding season.

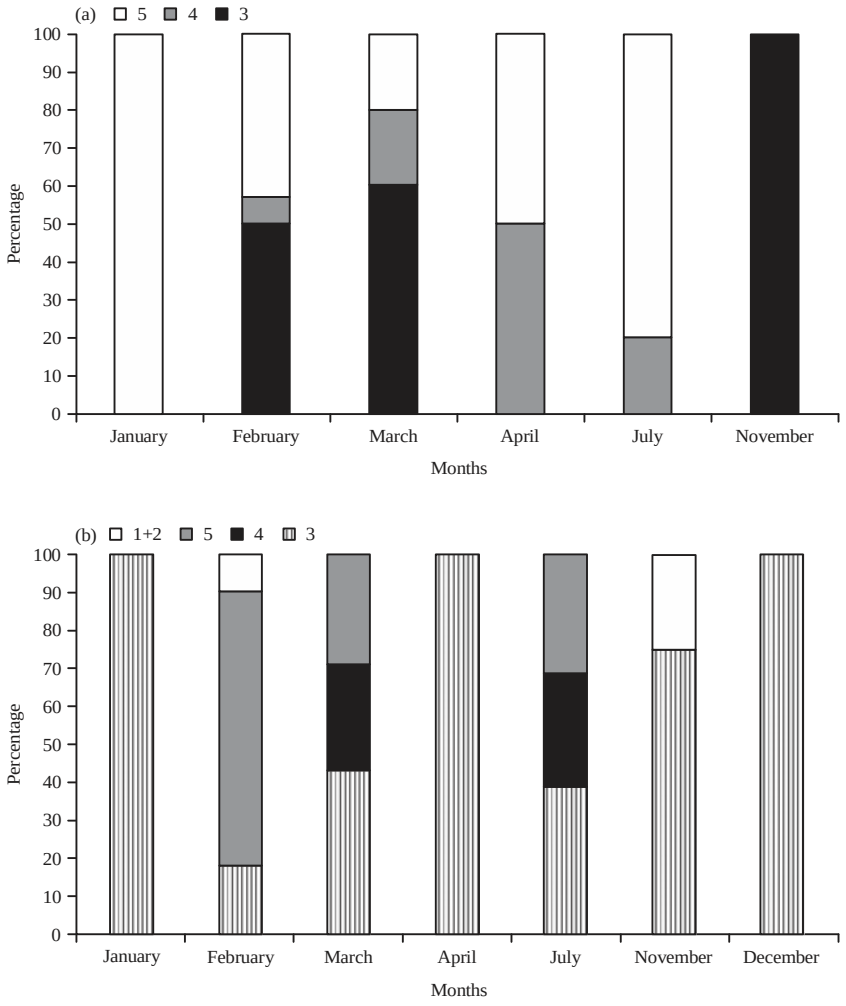

Fig. 7(a-b): Monthly percentage of maturity stages of (a) Female and (b) Male flat *Sardinella*, South of Moroccan Atlantic Ocean

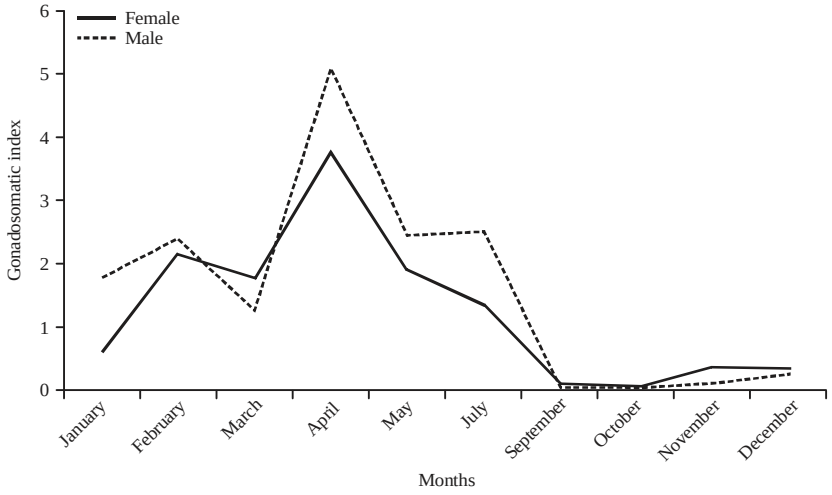

Fig. 8: Mean monthly changes in gonadosomatic index for both sexes of *Sardinella aurita*

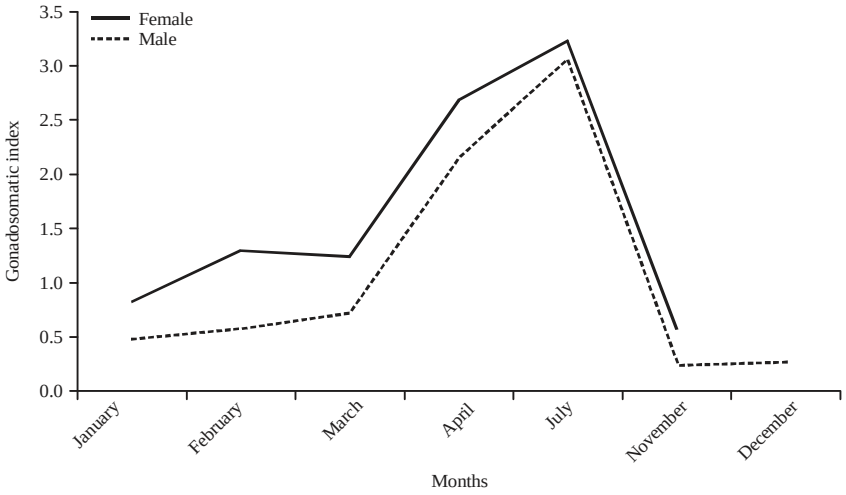

Fig. 9: Mean monthly changes in gonadosomatic index for both sexes of *Sardinella maderensis*

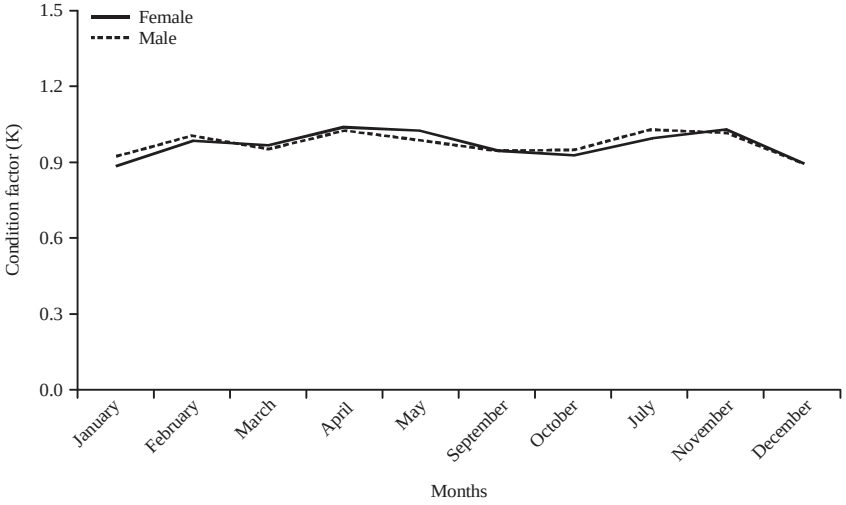

Fig. 10: Mean monthly changes in condition factor (K) for both sexes of *Sardinella aurita*

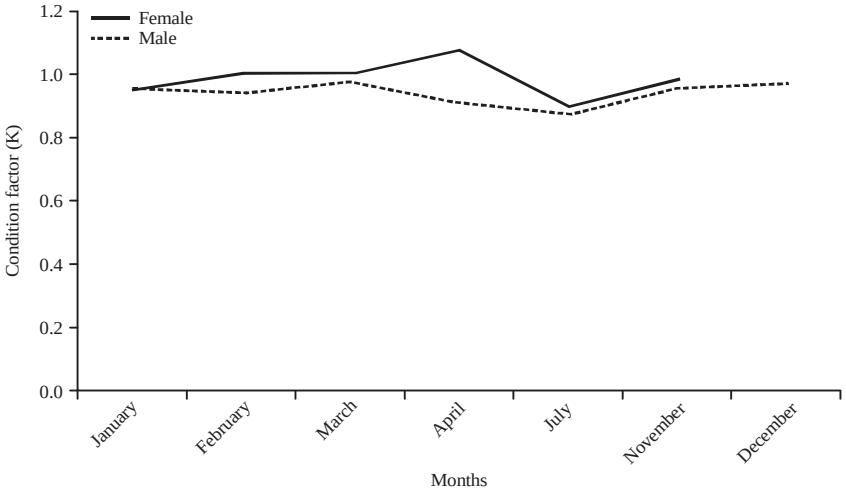

Fig. 11: Mean monthly changes in condition factor (K) for both sexes of *Sardinella maderensis*

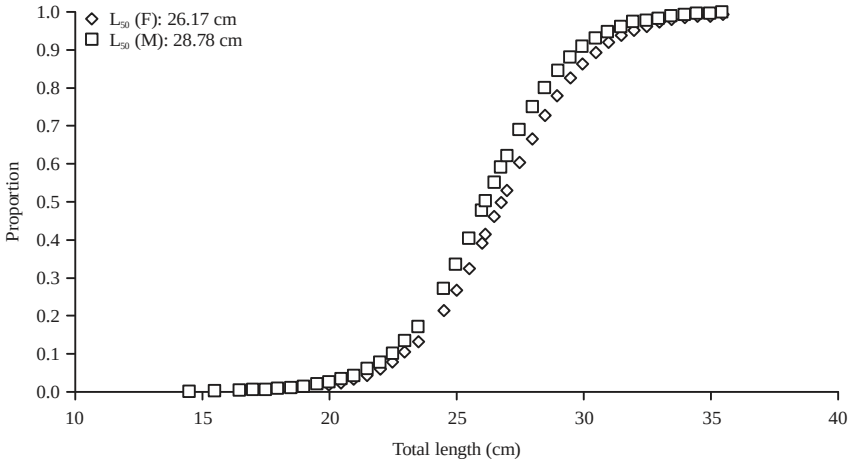

Fig. 12: Size at first sexual maturity of *Sardinella aurita* males (M) and females (F) in the South of Moroccan Atlantic Ocean

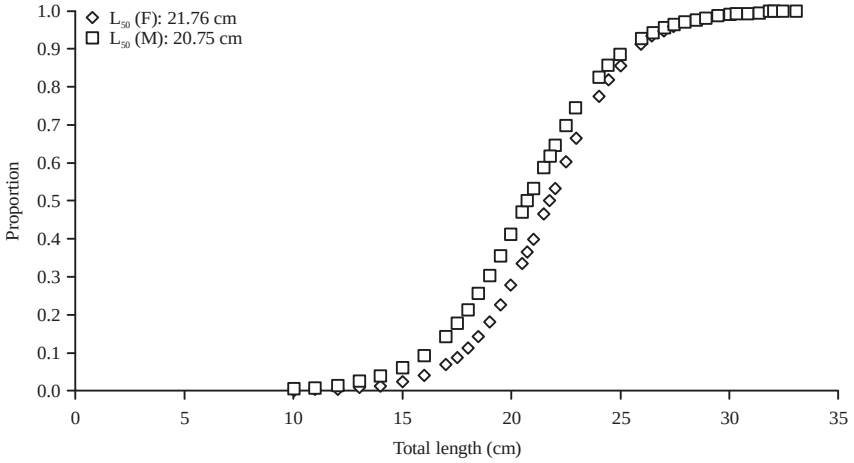

Fig. 13: Size at first sexual maturity of *Sardinella maderensis* males (M) and females (F) in the South of Moroccan Atlantic Ocean

Table 3: Average values of the sex ratio found by different authors

Species	Sex-ratio	Areas	References
Sardinella aurita	1.20	Senegal	Luhrs[55]
	0.98	Senegal	Diouf *et al.*[35]
	1.56	Mauritania	Lawal and Mylnikov[62]
	0.93	Morocco	Present study
Sardinella maderensis	1.00	Senegal	Boely[39]
	0.78	Senegal	Diouf *et al.*[35]
	1.48	Mauritania	Lawal and Mylnikov[62]
	0.81	Morocco	Present study

It should be noted that the sex-ratio varies according to size ranges. 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[35]. For Libyan waters, Pawson and Giama[41] had reported differences in the sex-ratio depending on the size that were related to sexual differences in growth, mortality or energetic cost of reproduction. In the Northern Aegean, Algerian and Tunisian waters females generally dominated the higher size classes[13,14]. Fairly significant seasonal variation ($p<0.05$) in sex ratio is also observed in *Sardinella* but it's more pronounced in the flat one. The comparison of the average values of the sex ratio found in Senegal and Mauritania are shown in Table 3.

The results of the study realized by Diouf *et al.*[35] about *Sardinella aurita* and *Sardinella maderensis* sampled in the Senegalese coast during the period between 1995 and 2007, showed an average sex-ratio lower than those carried out by other authors as presented in Table 3 on the same species in Senegal and Mauritania. These differences were likely due, in part, to the peculiar sampling of 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 differences in the results.

Table 4: Reproduction periods of round *Sardinella* (*S. aurita*) by country

		Months											
Zones	References	1	2	3	4	5	6	7	8	9	10	11	12
Mauritania	Wague and M'bodj[63]									+	+	+	
Mauritania	Chavance *et al.*[53]	+						+	+				+
Mauritania	Pascual-Alayon *et al.*[54]						+	+	+			+	+
Senegal	Conand[38]					+	+				+	+	
Senegal	Cury and Fontana[47]		+	+	+	+	+			+	+	+	
Senegal	Diouf *et al.*[35]			+	+	+					+		
Senegal	Samba[51]										+	+	+
Africa Northwest	Thuoc and Szypula[11]					+	+	+	+	+	+	+	
Morocco Cape Verde	Boely and Freon[64]					+	+	+	+	+	+	+	
North-west African coast	Fontana[10]	+	+	+	+	+	+	+	+	+	+	+	+
Morocco	Present study		+	+	+	+	+	+				+	+

Table 5: A review of the reproductive periods of flat *Sardinella* (*S. maderensis*) by country

		Months											
Zones	References	1	2	3	4	5	6	7	8	9	10	11	12
Mauritania	Boely[39]						+	+	+	+	+		
Mauritania	Pascual-Alayon *et al.*[54]						+	+					
Senegal	Boely[36]					+	+	+	+				
Senegal	Luhrs[55]						+	+	+	+	+		
Senegal	Diouf *et al.*[35]					+	+	+	+	+	+		
Senegal	Samba[51]					+	+	+	+		+	+	
Morocco	Present study		+	+	+			+					

In the Southern Morocco, the spawning starts in February and lasts until July for *Sardinella aurita*. While for *Sardinella maderensis*, it takes place in spring and summer. According to GSI monthly variations and maturation stages of the fish, a maximum of GSI for the round *Sardinella* is recorded in spring (April) and for the flat *Sardinella* in summer (July). As for most marine fish, to ensure the synchronization of larvae appearance and the peak of primary production, the time of spawning of *Sardinella* has evolved[42,43]. However, the yearly variation of the spawning season onset of *Sardinella* is owing to temperature differences and other factors such as population-related changes and food availability[44]. Furthermore, Ben-Tuvia[45] noted that the ideal water temperatures for a gonad maturation of round *Sardinella* are above 20°C. Ettahiri *et al.*[46] also related *Sardinella* spawning to high water temperatures. *Sardinella* might be a model species for understanding climate change mediated effects on fish populations due to the flexible strategy that results from its demographic plasticity[47] and its wide geographical range.

The reproductive period of round *Sardinella* in the present study was long, whereas in the Northern Aegean the reproductive period was short: Two months lasting. In other areas of its distribution (Table 4), the reproduction of round *Sardinella* is highly variable regarding the time and duration of spawning. Consequently, its reproduction lasts throughout the year in the North-west African coast[10], exhibiting intra-annual variations with one[10] or two[47] peaks of reproductive activity. At the sub-region, all the authors who have studied the monthly variation of females and males GSI of the round *Sardinella* or who have made larvae prospecting campaigns agreed on the existence of sexual activity vary over the year with two main spawning seasons separated by biological rest periods more or less marked[35,47-51]. In the Mauritanian area, spawning takes place from May to July[52]. Chavance *et al.*[53] also highlighted two breeding seasons, the first from July to August and the other from December to January. The study of Pascual-Alayon *et al.*[54] concluded that in the same area, there was a main spawning period from June to August and a second in November and December.

For *Sardinella maderensis*, the sexual activity is intense in March, April and July with a maximum in July. The peak of reproduction highly varied inter-annually[35,36,49,51,55,56]. The spawning period is minor in November-December[51,55]. The results obtained by Diouf *et al.*[35] show a continuous reproduction for *S. maderensis* throughout the year. The reproductive activity period shows less marked fluctuations with minimum values in the cold season (October, November, December and January) and maximum in the beginning of the warm season (March, April and May). Gonad maturation is more continuous for *S. maderensis* females. The results of Samba[51] also highlight two main breeding periods for *Sardinella maderensis,* the first occurs from May to August during the hot season and the other occurs in October and November during the cold season-warm season transition. So it seems that the dates and the importance of laying period peaks vary from one year to another (Table 5).

Table 6: Size at first sexual maturity (L_{50}) of *Sardinella aurita* found in different area

		L_{50} (cm)		
Areas	Sexes	FL	TL	References
Senegal	F	20.0	23.00	Conand[38]
	F	18.5	21.50	Boely[48]
	F	18.0	21.00	Luhrs[55]
	F	20.0	23.60	Diouf *et al.*[35]
	M	21.0	25.00	
	F	22.5	26.00	Samba[51]
	M	18.0	21.00	
Mauritania	F	21.0	26.00	Cheibany[40]
	M	20.0	23.00	Chavance *et al.*[53]
	F	29.0	34.00	Wague et M'bodji[63]
	M	29.0	34.00	
	F	17.0	20.00	Pascual-Alayon *et al.*[54]
	M	19.0	22.00	
Morocco	F	20.0	23.73	Baali *et al.*[25]
	M	22.0	25.54	
	F	22.5	26.17	Present study
	M	23.0	26.78	

L_{50}: Size at first sexual maturity, FL: Fork length, TL: Total length, (TL = 1.21×FL-0.857)[48], F: Female, M: Male

Table 7: Size at first sexual maturity (L_{50}) of *Sardinella maderensis* found in different area

		L_{50} (cm)		
Areas	Sexes	FL	TL	References
Senegal	F	16.5	20.00	Boely[36]
	F	17.0	21.00	Luhrs[55]
	F	18.0	22.00	Diouf[61]
	M	17.0	21.00	
	F	22.0	27.00	Diouf *et al.*[35]
	M	19.0	23.00	
	F	18.0	22.00	Samba[51]
	M	18.0	22.00	
Guinea Bissau (Rio Grande Buba)	F	12.0	15.00	Kromer[65]
	M	12.0	15.00	
Morocco (South of Atlantic)	F	18.0	21.76	Present work
	M	17.0	20.75	

L_{50}: Size at first sexual maturity, FL: Fork length, TL: Total length, FL conversion to TL by the relationship (FL = 0.843×TL)[50], F: Female, M: Male

In the South of Moroccan Atlantic Ocean, round *Sardinella* females were smaller at maturity than males. Indeed, maturation usually occurs at the end of the first year of life for short-lived species[57]. Bimaturism, which is common in species with promiscuous mating, external fertilization and indeterminate growth[58], was also observed for other round *Sardinella* populations[14]. Besides the environmental and genetic factors[2,59], size at first maturity can be influenced by other factors such as long-term fishing pressure[3]. This may pose severe impacts on size at first sexual maturity forcing the population to mature at a smaller size in order to ensure the survival of the species[60]. The size at first sexual maturity (L_{50}) has been reported for Atlantic stocks of round *Sardinella* (Venezuelan waters, Ghana waters, Table 6). In the Mediterranean, however, round *Sardinella* reaches sexual maturity at a smaller size (Table 6).

For the flat *Sardinella*, the total length at which 50% of specimens attain maturity were estimated by logistic regression as 20.75 and 21.76 cm for males and females respectively. In Senegal, the work performed by Boely[36] and Levenez[50] showed that the L_{50} in this area was 20 cm. More recent studies in Senegal give annual average sizes of first sexual maturity of 23.6 cm (TL) and 25 cm (TL) for females and males, respectively[36] and 22 cm (TL) for both sexes[51] (Table 7). Note that the sizes of first sexual maturity found in Senegal and Morocco were slightly higher than that observed in Guinea Bissau. This could be explained by the higher growth rate observed in Senegalese waters[39]. The small size at first sexual maturity found in the Rio Grande de Buba (Guinea Bissau) could be linked to increased salinity conditions that can lead to the size reduction[61].

CONCLUSION

It is concluded that the sex-ratio of *Sardinella* sp. was in favour of females for both species. The size at first sexual maturity of *Sardinella aurita* was determined as 26.78 cm for males and 26.17 cm for females, while for *Sardinella maderensis* the L_{50} was about 20.75 cm for males and 21.76 cm for females. In line with the GSI, the spawning peak for *S. aurita* occurred in April, while for *S. maderensis* it was in July.

The results of the size at first maturity showed that mature females in the South of Moroccan Atlantic Ocean were smaller than males for the round *Sardinella* and the opposite was observed for the flat *Sardinella*.

SIGNIFICANCE STATEMENTS

- This study discovers that results will be used for the stock assessment and fishery management of *Sardinella* sp.
- The identification of spawning period and spawning frequency will provide a framework for better understanding the reproductive patterns of *Sardinella* sp.

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REFERENCES

1. Tsikliras, A.C. and E. Antonopoulou, 2006. Reproductive biology of round sardinella (*Sardinella aurita*) in North-Eastern Mediterranean. Sci. Mar., 70: 281-290.
2. Smith, C. and R.J. Wootton, 2016. The remarkable reproductive diversity of teleost fishes. Fish Fish., 17: 1208-1215.
3. Tsikliras, A.C., K.I. Stergiou and R. Froese, 2013. Editorial note on reproductive biology of fishes. Acta Ichthyol. Piscatoria, 43: 1-5.
4. Froese, R. and D. Pauly, 2017. FishBase. World Wide Web Electronic Publication, France.
5. Tsikliras, A.C., E.T. Koutrakis and K.I. Stergiou, 2005. Age and growth of round sardinella (*Sardinella aurita*) in the northeastern Mediterranean. Scientia Mar., 69: 231-240.
6. INRH., 2015. Etat des stocks et des pecheries marocaines. Doc. Tech. INRH., Cape Bojador, pp: 140-213.
7. Hernandez, O., P. Lehodey, I. Senina, V. Echevin, P. Ayon, A. Bertrand and P. Gaspar, 2014. Understanding mechanisms that control fish spawning and larval recruitment: Parameter optimization of an Eulerian model (SEAPODYM-SP) with Peruvian anchovy and sardine eggs and larvae data. Prog. Oceanogr., 123: 105-122.
8. Dias, D.F., L.P. Pezzi, D.F.M. Gherardi and R. Camargo, 2014. Modeling the spawning strategies and larval survival of the Brazilian sardine (*Sardinella brasiliensis*). Prog. Oceanogr., 123: 38-53.
9. Freon, P., M. El Khattabi, J. Mendoza and R. Guzman, 1997. Unexpected reproductive strategy of *Sardinella aurita* off the coast of Venezuela. Mar. Biol., 128: 363-372.
10. Fontana, A., 1969. Etude de la maturite sexuelle des sardinelles *Sardinella eba* (Val.) et *Sardinella aurita* (C.V.) de la region de Pointe-Noire. Cah. ORSTOM, Ser. Oceanogr., 7: 101-114.
11. Thuoc, P. and J. Szypula, 1973. Biological characteristics of gilt sardine, *Sardinella aurita* Cuv. et Val. 1847, from Northwest African coast. Act. Ichth. Pisc, 3: 19-37.
12. Bouaziz, A., A. Bennoui, B. Brahmi and R. Semroud, 2001. Sur l'estimation de l'etat d'exploitation de la sardinelle (*Sardinella aurita*, Valenciennes, 1847) de la region centre de la cote algerienne. Rapp. Comm. Int. Mer Medit., 36: 244-244.
13. Bensahla-Talet, A., Y. Mortet and J.A. Tomasini, 1988. Length-weight relationship, sex ratio and reproduction (spawning period, fecundity) of *Sardinella aurita* from the Oranaises, Alger). Rapp. Comm. Int. Mer Medit., 31: 14-14.
14. Gaamour, A., H. Missaoui, L. Ben-Abdallah and A. El Ahmed, 2001. Parametres Biologiques de la Sardinelle Ronde (*Sardinella aurita* Valenciennes, 1847) dans la Region du Cap Bon (Canal Siculo-Tunisien) (Biological Parameters of Round Sardinella in the Region of Cap Bon (Tunisia Sicilian-channel)). GFCM., Kavala, Greece, pp: 26-30.
15. Wassef, E., A. Ezzat, T. Hashem and S. Faltas, 1985. Sardine fishery by purse-seine on the Egyptian Mediterranean coast. Mar. Ecol. Prog. Ser., 26: 11-18.
16. Longhurst, A.R., 1961. Report on the fisheries of Nigeria. Ministry of Economic Development, Federal Fisheries Service, Lagos, pp: 30.
17. Tobor, J.C., 1966. Meristic counts of some important marine fishes found in Lagos. Bulletin of Institute of Fondam Africa, Noire, Vol. 1, pp: 259-275.
18. Djama, T., C. Gabche and O. Njifonju, 1989. Growth of *Sardinella maderensis* in the Lobe estuary, Cameroon. Fishbyte, 7: 8-10.
19. Postel, E., 1955. Resume des connaissances acquiesce sur les clupeides de l'Ouest Africain-Rapp. Cons. Explor., 137: 14-17.
20. Rossignol, N., 1955. Premiere observations sur la biologie des Sardinelles dans la region de Pointe Noire (*Sardinella eba*, *Sardinella aurita*). Rapp. Cons. Explor., 137: 17-21.

21. Facade, S.O. and C.I.O. Olaniyan, 1972. The biology of the West African shad *Ethmalosa fimbriata* (Bowdich) in the Lagos Lagoon, Nigeria. J. Fish Biol., 4: 519-533.
22. Facade, S.O. and C.I.O. Olaniyan, 1973. The food and feeding interrelationship of the fishes in the Lagos Lagoon. J. Fish Biol., 5: 205-225.
23. Marcus, O., 1989. Breeding, age and growth in *Sardinella maderensis* (Lowe 1839) Pisces: Clupeidae from coastal waters around Lagos, Nigeria. J. Sci., 23: 1-5.
24. Youmbi, J.T., T. Djama and C. Gabche, 1991. Reproductive patterns of *Sardinella maderensis* (Lowe, 1841) off Cameroon. J. Applied Ichthyol., 7: 60-63.
25. Baali, A., A. Yahyaoui, K. Amenzoui, K. Manchih and W. Abderrazik, 2015. A preliminary study of reproduction, age and growth of *Sardinella aurita* (Valenciennes, 1847) in the Southern of Atlantic Moroccan area. AACL Bioflux, 8: 960-974.
26. Holden, M.J. and D.F.S. Raitt, 1974. Manuel des sciences halieutiques. Deuxieme partie. Methodes et recherches sur les ressources et leur application. Doc. Tech., Vol. 115, FAO., Peches Rev., pp: 223.
27. Pope, J.A., A.R. Margetts, J.M. Hamley and E.F. Akkyuz, 1983. Manual de metodos poblaciones de peces-Parte 3. Slectividad del arte de pesca. FAO Doc. Tech., Vol. 41, Pesca, pp: 1-56.
28. Kartas, F. and J.P. Quignard, 1984. La Fecondite des Poissons Teleosteens. Masson, Paris, ISBN: 9782225804557, Pages: 121.
29. Bougis, P., 1952. Rapport hepatosomatique et rapport gonadosomatique chez *Mullus barbatus* L. Bull. Soc. Zool., 74: 326-330.
30. Belveze, H., 1984. Biologie et dynamique des populations de sardine (*Sardina pilchardus* Walbaum) peuplant les cotes atlantiques marocaines et propositions pour un aménagement des pecheries. [Biology and population dynamics of *Sardina pilchardus* Walbaum living on the Morocco Atlantic coasts and propositions for a fisheries management]. Ph.D. Thesis, University of Bretagne Occidentale, Brest.
31. Freon, P., 1979. Relation taille-poids, facteur de condition et indice de maturité sexuelle: Rappels bibliographiques, interpretation, remarques et applications. Doc. Sci. Cent. Rech. Oceanogr. Dakar-Thyaroye, ORSTOM., 68: 143-171.
32. McDonald, J.H., 2014. Handbook of Biological Statistics. 3rd Edn., Sparky House Publishing, Baltimore, Maryland, USA., Pages: 299.
33. Fontana, A., 1979. Etude du stock demersal cotier congolais. Biologie et dynamique des principales especes exploitees. Propositions d'amenagement de la pecherie. Ph.D. Thesis, Universite Pierre et Marie Curie, Paris.
34. Lawson, E.O. and P.A. Doseku, 2013. Aspects of biology in round Sardinella, *Sardinella aurita* (Valenciennes, 1847) from Majidun Creek, Lagos, Nigeria. World J. Fish Mar. Sci., 5: 575-581.
35. Diouf, K., B. Samb and M. Sylla, 2010. Contribution a la Connaissance de la Biologie des Sardinelles (*Sardinella aurita* et *Sardinella maderensis*) du Littoral Senegalais. In: Science et Amenagement des Petits Pelagiques. Symposium sur la Science et le Defi de l'Amenagement des Pecheries de petits Pelagiques sur les Stocks Partages en Afrique Nord-Occidentale, 11-14 Mars 2008, Casablanca, Maroc, FAO Comptes Rendus des Peches et de l'Aquaculture, No. 18, Dans Garcia, S., M. Tandstad and A.M. Caramelo (Eds.)., FAO., Rome, 39-56.
36. Boely, T., 1980. Etude du cycle sexuel de la sardinelle plate: *Sardinella maderensis* (Lowe, 1841) des cotes senegalaise. Cybium, 8: 77-88.
37. Dahel, A., M. Tahri, M. Bensouilah, R. Amara and B. Djebar, 2016. Growth, age and reproduction of *Sardinella aurita* (Valenciennes, 1847) and *Sardina pilchardus* (Walbaum, 1792) in the Algerian Eastern coasts. AACL Bioflux, 9: 1172-1181.
38. Conand, F., 1977. Oeufs et larves de la sardinelle ronde (*Sardinella aurita*) au Senegal: Distribution, croissance, mortalite, variations d'abondance de 1971 a 1976. Cahiers ORSTOM. Serie Oceanographie, 15: 201-214.
39. Boely, T., 1979. Biologie de deux especes de sardinelles (*Sardinella aurita* Valenciennes, 1847 et *Sardinella maderensis* Lowe, 1841). Ph.D. Thesis, Universite de Paris, VI et Museum National d'Histoire Naturelle, Paris.
40. Cheibany, A., 1990. Methodes d'etude des Parametres Biologiques. Rapp. Stage fin d'etudes CNROP., Nouadhibou, Mauritania.
41. Pawson, M.G. and M.S. Giama, 1985. A biological sampling problem illustrated by the population structure and growth patterns of *Sardinella aurita* at Tripoli, Libya. Environ. Biol. Fish., 12: 143-154.
42. Cushing, D.H., 1975. Marine Ecology and Fisheries. Cambridge University Press, London, Pages: 278.
43. Blaxter, J.H.S. and J.R. Hunter, 1982. The biology of the clupeoid fishes. Adv. Mar. Biol., 20: 1-223.
44. Roy, C., P. Cury, A. Fontana and H. Belveze, 1989. Spatio-temporal reproductive strategies of the clupeoids in West African upwelling areas. Aquat. Living Resour., 2: 21-29.
45. Ben-Tuvia, A., 1960. Fluctuations in the stock of *Sardinella aurita* and its dependence to temperature and rain. Proceedings of the World Scientific Meeting on the Biology of Sardines and Related Species, September 14-21, 1960, Rome, pp: 1193-1203.
46. Ettahiri, O., A. Berraho, G. Vidy and M. Ramdani, 2003. Observation on the spawning of Sardina and Sardinella off the South Moroccan Atlantic coast (21-26°N). Fish. Res., 60: 207-222.

47. Cury, P. and A. Fontana, 1988. Competition et strategies demographiques comparees de deux especes de sardinelles (*Sardinella aurita* et *Sardinella maderensis*) des cotes ouest-africaines. [Competition and comparative life-history strategies of two sardinella species (*Sardinella aurita* and *Sardinella maderensis*) of the West-African coasts]. Aquat. Living Resour., 1: 165-180.
48. Boely, T., 1982. Etude du cycle sexuel de la sardinelle ronde (*Sardinella aurita* Val. 1847) au Senegal. [Sexual cycle of the round sardinella (*Sardinella aurita* Val.1847) in Senegal ocean waters]. Oceanogr. Trop., 17: 3-13.
49. Freon, P., 1988. Reponses et adaptation des stocks de clupeides d'Afrique de l'Ouest a la variabilite du milieu et de l'exploitation-Analyse et reflexion a partir de l'exemple du Senegal. Ph.D. Thesis, Universite d'Aix-Marseille II, Paris.
50. Levenez, J.J., 1993. Synthese Bibliographique des Connaissances sur la Biologie de Quelques Especes de Poissons Concernant le Symposium. In: L'Evaluation des Ressources Exploitables par la Peche Artisanale Senegalaise, Barry-Gerard, M., T. Diouf, A. Fontenau (Eds.). ORSTOM., France, pp: 121-141.
51. Samba, O., 2011. Nouvelle Evaluation des Caracteristiques Biologiques de *Sardinella aurita* (Valenciennes, 1847) et *Sardinella maderensis* (Lowe, 1841) - Memoire de Diplome d'Etudes Approfondies. Institut Universitaire de Peche et d'Aquaculture, Universite Cheikh Anta Diop, Dakar, Senegal, pp: 45.
52. Franqueville, C., 1980. Etude des Nurseries de Daurades *Pagellus coupei* le Long de la Cote Ouest-Africaine Entre 10 et a 20&Deg;N. Centre de Recherches Oceanographiques de Dakar-Thiaroye, Dakar, Senegal, pp: 15.
53. Chavance, P., I. Ba and S. Krivospichenko, 1991. Les ressources pelagiques de la ZEE mauritanienne. Bulletin of the Centre National Rech Oceanogr Et des Peches, Nouadhibou, Vol. 23, pp: 28-72.
54. Pascual-Alayon, P., M.T.G. Santamaria and E. Hernandez, 2008. Spanish report on the activity of European pelagic trawlers fishing in Mauritania and landing in the port of Las Palmas de Gran Canaria. Proceedings of the Spain 9th Meeting of the FAO Working Group on the Assessment of Small Pelagic Fish off Northwest Africa Nouakchott, Volume 23, (ASPF'08), Mauritania, pp: 20-30.
55. Luhrs, T.C., 1986. La croissance de *Sardinella maderensis* (Lowe, 1841) au Senegal. Oceanogr. Trop., 21: 143-151.
56. Conand, F. and E. Fagetti, 1971. Description et distribution saisonniere des larves de sardinelles des cotes du Senegal et de la Gambie en 1968 et 1969. Cah. ORSTOM, Ser. Oceanogr., 9: 293-318.
57. Beverton, R.J.H., 1963. Maturation, growth and mortality of clupeid and engraulid stocks in relation to fishing. Rapport Proces-Verbaux Reunions Counseil Int. l'Exploration Mer, 154: 44-67.
58. Stearns, S.C., 1992. The Evolution of Life Histories. Oxford University Press, New York.
59. Sampson, D.B. and S.M. Al Jufaily, 1999. Geographic variation in the maturity and growth schedules of English sole along the US West coast. J. Fish Biol., 54: 1-17.
60. Olsen, E.M., M. Heino, G.R. Lilly, M.J. Morgan, J. Brattey, B. Ernande and U. Dieckmann, 2004. Maturation trends indicative of rapid evolution preceded the collapse of Northern cod. Nature, 428: 932-935.
61. Diouf, P.S., 1996. Les peuplements de poissons des milieux estuariens de l'Afrique de l'Ouest: L'exemple de l'estuaire hyperhalin du Sine-Saloum. Ph.D. Thesis, Universite de Montpellier II, ORSTOM., Paris.
62. Lawal, H.S. and N. Mylnikov, 1988. Contribution a l'etude de la relation taille-poids de la reproduction et du sex-ratio des principales especes pelagiques en Mauritanie. Proceedings of the Rapport du Groupe de Travail CNROP/CRODT/ISRA sur les Ressources Pelagiques Cotieres (Mauritanie-Senegal) Nouadhibou, Juin 8-16, 1988, Mimeo, Nouadhibou, pp: 82-97.
63. Wague, A. and O.B. M'bodj, 2002. Etude de quelques aspects de la reproduction chez la sardinelle ronde *Sardinella aurita* (Valencienne, 1847) pechee le long des cotes mauritaniennes. Bulletin of Scientifique de l'Institut Mauritanien de Recherches Oceanographiques et des Peches, Vol. 29, pp : 13-18.
64. Boely, T. and F. Freon, 1979. Les ressources pelagiques cotieres. FAO Fisheries Tech. Paper No. 186, FAO., Rome, pp: 13-78.
65. Kromer, J.L., 1994. Grande de Buba-Bio-ecologie et parametres environnementaux. UICN/Ministere des Peches de Guinee-Bissau, pp: 119.