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Research Article

Growth and Biometry Analysis of the Atlantic Bonito (*Sarda sarda* (Bloch, 1973)), in the Southern Coast of Morocco

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Abstract

A total of 112 specimens were sampled from Southern Atlantic of Morocco in the period from April to June 2016. Sixty-two dorsal fin spines were analyzed for ageing and growth studies, and all samples (112) were used for biometric studies. The length of the aged individuals ranged from 440 to 704 mm. Fish ages ranged from 1 to 4 years old and the mean length by age were calculated for males and females. The standard von bertallanfy growth function was used to fit length at age data. The growth parameters are L∞= 73.01, K=0.3075 and to=-2.4469. Also, a biometry analysis of Atlantic bonito was conducted in this paper. Relative growth was studied by comparing changes in morphological characters with growth fork length. Length weight relationship is presented as well.

Keywords: Atlantic Bonito; Age Determination; Biometry; Growth; Length at Age; Morocco

Introduction

Atlantic bonito (*Sarda sarda* (Bloch, 1793)) which is a member of Scombridae is distributed in both sides of the tropical and subtropical Atlantic Ocean, in the Gulf of Mexico, and in the Mediterranean and Black Seas. In the Eastern Atlantic, it is distributed from Oslo (Norway) to Port Elizabeth (South Africa), including the Mediterranean and Black Sea. In the western Atlantic off the east coast of the United States and Canada its usual northern limit is Cape Ann but also has been recorded along Nova Scotia [1]. Atlantic bonito is a small tuna species that feeds on small fishes, especially clupeoids such as anchovy, sardine, and sprat, and also on crustaceans [2]. Maximum length in the Atlantic is 91.4 cm fork length (LF) and 5.4 kg and in the Black Sea is 85 cm and 5 kg weight [3]. Common size is 50 cm fork length and about 2 kg. Maximum published weight is 11.0 kg [4].

In Morocco, this species is distributed along the Atlantic Coasts, especially in the southern part of the Atlantic coast [5]. Coastal fishing units, using gill net as the main gear, mainly exploit the Atlantic bonito.

Knowledge of biometric variations is necessary in species descriptions. Collette., *et al*. 1975 [6], using a morphometric approach, described *S. sarda* from different areas. Pujolar., *et al.* (2001) and Vinas., *et al*. (2004) [7,8] studied the patterns of differentiation in two sub-populations of Atlantic bonito inhabiting the Mediterranean.

In addition, the growth parameters studies are necessary for stock status and stock assessment. Also, determination of age is an important task in all studies population dynamics. In addition, knowledge of the age and growth process constitutes a

fundamental aspect for knowing the chronology of the different phases of the cycle of life of a species. For the early stages of life, the information obtained can help to understand the factors that determine recruitment success. For adults are used to understand vital events such as age at first maturity, but also to determine the effect of fishing on stocks, improve their management and optimize the catch effort in order to achieve maximum balanced production.

This document presents an analysis of growth parameters and biometry of Atlantic bonito catches in the southern Atlantic coast of Morocco, being said that the knowledge regarding this parameter are very limited in this area.

Material and Method

Study area

Samples were collected in 2016 at the ports of Dakhla. The geographical coordinates are 23°39'33'' N, 15°56'47'' W (Figure 1).

Figure 1: Location of the study area.

This region of the Kingdom of Morocco is among the most important fishing areas in the world, due to the phenomenon of upwelling, which is almost permanent [9]. In the area north of Cap Boujdour, the surface temperature is between 18.4 and 20°C. In south of Cap Boujdour, temperatures between 18.4 and 21.6°C are recorded. The distribution of surface salinity corresponds to the temperature distribution, with 36.2-36.4 ppm in Upwelling zone and 36.5-36.8 ppm in deeper waters (Figure 2).

Figure 2: Distribution of the surface temperature in °C (left) and salinity in Ppm (right) (Source: Atlantida 2007).

The Atlantic bonito can adapt to temperatures ranging from 12 to 27°C and at salinities from 14 to 39 ppm [10].

Data sources

One hundred and twelve specimens of Atlantic bonito were collected from long-liners commercial catches from April to June 2016. Body lengths were measured to the nearest millimeter and total weight to the nearest 0.01g.

For the biometry analysis, eleven morphometric characteristics were examined. Total length (LT), fork length (LF), standard length (LS), length from head to anal fin (LPA), pelvic fin length (LP), length of first dorsal fin base (LD1), length of second dorsal fin base (LD2), first pre-dorsal length (LP1), second pre-dorsal length (LP2), pre-ventral length (LPV), pre-pectoral length (LPP). These parameters were relative to fork length and the significance between males and females was tested by Pearson test.

Length weight relationship of the fish was estimated using the equation:

$W=aLFb$ [11]-----(1)

Where W is the weight of the fish, LF is the fork length, a and b are constants.

For the determination of age and the study of growth, the first dorsal spine was taken. The removal of the spines was carried out according to the following protocol:

The first spine of the first dorsal fin is collected from each specimen. The spine is pulled out whole from the base. Using a knife, we cut the membrane joining the first and second dorsal fin rays. Then, five spines of each size class of 1cm of sampled individuals are randomly selected [12], and finally, the spine is stored in a paper envelope labeled at room temperature.

The first ray of the dorsal fin is taken from each individual, cleaned with running water, and cleared of Flesh, which can adhere to it. The total length (Lb) of each spine was measured in mm and fine sections (2 or 3 per radius) of 500 microns are produced slightly above the joint and perpendicular to the axis of the radius [13] using a saw rotating at slow speed.

The study of growth can be described by an asymptotic curve, and the model more used is that of Von Bertalanffy (1938).

The relation expresses the model of Von Bertalanffy

$$Lt = L\infty(1 - e^{-k(t-to)})\text{-------}(2)$$

With Lt is the length of fish at time t, L∞ is the asymptotic size, which is considered, according to Thiam (1990) [14], Such as the average size of a fish whose growth would continue indefinitely and k is the rate at which fish reaches maximum theoretical size; Its value is all the greater as the growth of the species is faster. A phi-premium (Ø') test [15] is conducted to compare the curves of linear growth of the same species, the same stock or different stocks.

All statistics analysis are done with R software.

Results

Length frequency distribution

The distribution of size frequencies during the study period covers a wide range of sizes (between 392 and 642 mm), with a dominance of sizes between 450 and 500 mm (Figure 3).

The distribution of sizes by sex is presented in the figure 4. The modal class 450-500 mm is dominant in both sexes, with sizes smaller than 400 mm observed in females only (Figure 4).

Length weight relationship

The allometric regression performed on the individuals sampled gives the expressions that are summarized in table 1. Graphically, clouds of points are established, linking the length to the fork to the weight of the individual.

Figure 3: Length (LF) frequency distribution.

Figure 4: Length (LF) frequency distribution by sex.

Port	a	b	Equation	R^2	N
DAKHLA	$5X10^{-05}$	2.7852	$Y=5^{E}\text{-}05X^{2.7852}$	0.9139	112

Table 1: The parameters a and b of the relation weight size in *S. Sarda*.

A good correlation (r^2=0.9139) was found between the weight and the size of the species (i.e., 1), with an allometric coefficient close to 3, indicating the isometric growth between fork length and weight in *Sarda sarda* (Figure 5).

Figure 5: Relationship between fork length and weight of Atlantic bonito.

Biometry analysis

Descriptive statistics are presented in table 2, in total 112 specimens were measured with 55 males and 57 females.

	Sex	F	M	Both
LPV (mm)	Mean	139.43	140.96	140.1875
	sd	14.64	17.95	16.29
LPP (mm)	Mean	127.14	150.32	138.52
	sd	11.38	16.15	11.35
LT (mm)	Mean	539.54	547.24	543.32
	sd	57.22	62.42	59.69
LPA (mm)	Mean	322.79	323.85	323.31
	sd	35.78	46.07	40.97
LF (mm)	Mean	486.23	496.15	491.10
	sd	55.42	57.96	56.65
LS (mm)	Mean	451.28	458.98	455.06
	sd	49.62	51.08	50.26
LP (mm)	Mean	60.14	60.25	60.20
	sd	6.74	7.98	7.34
LP1 (mm)	Mean	135.95	141.49	138.67
	sd	12.38	25.51	20.04
LP2 (mm)	Mean	281.88	285.73	283.77
	sd	33.29	43.99	38.78
LD1 (mm)	Mean	142.19	144.05	143.11
	sd	16.42	21.51	19.03
LD2 (mm)	Mean	52.09	50.96	51.54
	sd	15.69	11.51	13.74

Table 2: Morphometric characters of Atlantic bonito from the southern coast of Morocco by sex and total (SD: Standard deviation; F: female; M: male).

The results of the correlation analysis between the different morphometric characters are presented in figure 6 and 7.

Figure 6: Correlation between LF and all morphometric parameters for Atlantic bonito.

Figure 7: Correlations between morphometric characters for Atlantic bonito, (*) 5%; (**) 1%; (***) 0.1%.

The most important correlations (r^2=0.9) are between LF/TL (r^2=0.95), LF/LP2 (r^2=0.90), LF/LS (figure 6). It should be noted that for the majority of these determined linear relationships, the correlation coefficient is greater than 0.75 and all parameters are statistically significant at least in 5% degree in relationship with fork length (figure 7).

Growth parameters

The relationship between the fork length and the first spine length is shown in Figure 8 and the relationship is presented in table 3. It is important to note the strong linear correlation between the two types of length, which shows that the length of the spine increases proportionally with the size of the individual.

Figure 8: Relationship between fork length of fish (LF) and the length of the first spine Of Atlantic bonito (combined sex).

N	Equation	R^2
57	Y=11.737X0.9918	0.8104

Table 3: relationship between fork length and first pine of Atlantic bonito.

Age-length key (ALK)

The lengths recorded in the age-length table (Table 4 and 5) correspond to the average lengths calculated for individuals of the same age. We also took care, when establishing the ALK, to eliminate outliers.

Pictures A and B: Cross section of the first dorsal spine fin (A = Female, LF = 39.2 cm, catch date: April 2016, 1 ring, age = 1 years, B = Female, LF = 50.6 cm, Catch date: June 2016, 3 rings, age = 3 years).

Length (cm)	1	2	3	4
39	1			
40	2			
41	4			
42	3			
43	3			
44	3			
45		2		
46		3		
47		1	2	
48		3		
49			3	
50		1	2	
51			3	
52			3	
53			1	
54			3	
55			2	
56			1	
57			3	
58			3	
59				2
60				1
61				3
64				1
Lt (moy)	41.88 ± 1.54	46.9 ± 1.60	52.92 ± 3.44	60.71 ± 1.70

Table 4: ALK of Atlantic bonito sampled in the port of DAKHLA (Example pictuare A and B).

Von bertallanfy growth parameters

We have adjusted the theoretical equation of Von Bertalanffy in order to calculate the mathematical relationship between age and fish size (i.e., 2). This analysis made it possible to demonstrate a regression of logarithmic type.

The growth curve of Von Bertalanffy is represented graphically in figure 9 (Table 6).

The growth equation according to the Von Bertalanffy model is then written as follows:

$$Lf = 73.0146\ (1- e^{-0,3075(t + 2.4469)})$$

Age	LF (cm)	Age	LF (cm)	Age	LF (cm)	Age	LF (cm)
1	39	2	45	3	51	3	58
1	40	2	46	3	52	4	59
1	40	2	46	3	51	4	59
1	41	2	46	3	52	4	60
1	41	3	47	3	52	4	61
1	41	2	47	3	53	4	61
1	41	3	47	3	54	4	61
1	42	2	48	3	54	4	64
1	42	2	48	3	54		
1	42	2	48	3	55		
1	43	3	49	3	55		
1	43	3	49	3	56		
1	43	3	49	3	57		
1	44	3	50	3	57		
1	44	3	50	3	57		
1	44	2	50	3	58		
2	45	3	51	3	58		

Table 5: ALK (Age in year, Length in cm).

Figure 9: Von Bertallanfy growth curve of Atlantic bonito.

Species	L ∞ cm	K	t0	R^2
S. sarda	73.01	0.3075	-2.4469	0.96

Table 6: Growth parameters of Atlantic bonito.

In addition, and according to the reversed model of Von Bertalanffy

t (L)= to-1/k ln (1-1/ L∞)------(3)

Allows to determine the age of fish corresponding to its length.

The parameters of growth thus estimated can provide indications on the longevity (tmax) of the species. This parameter indicates the age at which 95% of the asymptotic size L∞ is reached:

t max=5(ln2/k) [16]------(4)

Likewise, the age of the first maturity (tm) can be estimated by using the formula of Froese and Binohlan [17]:

Log (tmax) = 0.5496 + 0.957log (tm)

The comparison of the curves of linear growth of the same species, the same stock or different stocks is performed by the test Phi-premium (Ø') [15] provided according to the following expression:

Ø' =log (K) + 2*log (L∞)------(5)

This test is based on the work of Pauly (1979) which showed that the values of Ø' are very similar inside closed taxa and that they have narrow normal distributions [18].

According to the calculated growth parameters thus obtained: L∞= 73 cm, K=0.31/y the next table represents the results of tmax, tm and Ø'.

Biological indicators	Present study values	Fish base
tmax	4.89 years	5 years
tm	1.7 years	
Ø'	3.21	
Lmax	65.3 cm	91.4 cm
Lm	52.6 cm	37 cm

Table 7: Biological indicators of Atlantic bonito.

This table shows clearly that while tmax (i.e., (4)) calculated was the same as those cited in Fish base (tmax=5years), the Lmax (maximum length reached by the species) and Lm (i.e., (5)) (first maturity length) are quite different. This is probably linked to the studied area and methods.

Discussion and Conclusion

The sizes frequency analysis of Atlantic bonito at port Dakhla shows a dominance of mature individuals, whose size is larger than 40 cm. However, we observe sizes smaller than 40 cm only in females but in small percentage. Knowledge of the early life stages in tunas is very scarce, during the first life stages bonitos are not caught and juvenile life history is unknown [19].

Unpublished studies on selectivity conducted in the southern Atlantic coast of Morocco [20], suggest that Atlantic bonito is fully accessible to fishing only from the age of 4 (LF > 40 cm).

As seen in table 8, the length range of sampled specimens in this study was similar to those found in other studies: Gibraltar Strait: 40.0-55.0 cm [21] and 19- 72 cm LF [22]; the Spanish Mediterranean coasts: 41.0-48.0 cm [23] and 40.0-61.0 cm [24]; Tiran and Sicily coasts of Italy, respectively: 35.0-82.0 cm and 35.0-67.0 cm [25]; Adriatic Sea coasts: 33.0-67.0 cm [26]; the Turkish coasts of the Black Sea, the Sea of Marmara: 14.0-90.0 cm [27] and 23.0-66.0 cm [28] and 23.0-71.0 cm [29], the Northern Aegean Sea: 23.0-72.0 cm [30], the black sea 29.0-37.0 cm [31].

Authors	Area	N	Lmin-Lmax (cm)
Rodriguez-Roda (1966)	Strait of Gibraltar, Spain	165	40-55
Rey., *et al.* (1984)	Strait of Gibraltar, Spain	878	19-72
Macias., *et al.* (2005)	Spanish coast of the Mediterranean Sea	183	41-48
Valeiras., *et al.* (2008)	Spanish coast of the Mediterranean Sea	136	40-61
Di Natale., *et al.* (2006)	Tyrrhenian coast, Italy	240	35-82
Di Natale., *et al.* (2006)	Sicilian coast, Italy	109	35-67
Franičević., *et al.* (2005)	Coast of the Adriatic Sea	665	33-67
Kara (1979)	Turkish coasts of the Black Sea and the Sea of Marmara	1608	14-90
Oray., *et al.* (2004)	Turkish coasts of the Black Sea and the Sea of Marmara	1168	23-66
Ateş., *et al.* (2008)	Turkish coasts of the Black Sea and the Sea of Marmara	694	23-71
Cengiz (2013)	Northern Aegean Sea (Gallipoli Peninsula and Dardanelles)	238	23-72
Yankova., *et al.* (2013)	Black Sea, Bulgaria	411	29-37
Present study (2017)	Moroccan Atlantic coast	2688	39-64

Table 8: The length ranges of specimens for Atlantic bonito in different area.

Author	Region	N	LF (cm)	a	b	Sex
Hansen 1987 [33]	SW. Atlantic		33-77	0.0135	2.952	both
Giacchetta., *et al.* 1995 [34]	Gulf of Taranto	845		$0.0252x10^{-3}$	2.83	Both
Rey., *et al.* 1984 [22]	W. Mediterranean	878	19.71.5	0.00724	3.1644	Both
Kara 1979 [27]	Black Sea Aegean Sea Sea of Marmara	1608	14-90	0.02361	2.8703	Both
Rodriguez Roda 1966 [21]	W. Mediterranean	263	36-67.5	$1.4861x10^{-5}$	2.9719	Both
Franičević, 2005 [26]	E. Adriatic	665	33-67	0.0085	3.1230	Both
Present study, 2017	Atlantic	111	39.2-64.2	$0.05x10^{-3}$	2.7852	Both

Table 9: Comparison of relationship between fork length (LF) and weight (W) of Atlantic bonito from various regions of the Atlantic and Mediterranean W=aLFb.

The length-weight relationship was calculated for both sex. Correlation coefficients (r^2>0.9), shows high correlation between fork length and weight for this species. However, other authors reported different results in different area (Table 9). The observed difference could be due to several factors such as variability in environmental conditions (e.g., temperature and salinity), season habitat, fishing area, depth, sampling methodology, selectivity of fishing gear [32].

Atlantic bonito age determination and growth have been studied by means of different methodologies: otholiths, vertebrae, spines and size frequency. The maximum reported age is 5 years.

Most of studies are from Mediterranean stocks. There are several studies on growth biology of bonito in the Black Sea [35] and Western Mediterranean. Von Bertallanfy growth parameters are showed in table 10 for different areas. [22] studied otoliths, vertebrae, spines and length frequencies and developed a growth equation based on a large number of specimens from western Mediterranean and Atlantic area near Gibraltar strait.

Loo	Length	K	Vers (1/y)	Sexes	M (1/y)	Temp° C	Ø'	Region
62.5	LF	0.72					3.45	Spain
64.0	LF	0.69	-1.42		0.87	17.5	3.45	Morocco
64.0	LF	0.86				14.0	3.55	Turkey
67.8	LF	0.80				14.0	3.56	Turkey
68.0	TL	0.82	-0.39			17.0	3.58	Turkey
69.6	LF	0.44	-1.33	F			3.33	Turkey
69.8	TL	0.76					3.57	Turkey
80.6	LF	0.36					3.37	Italy
80.9		0.35	-1.70				3.36	
81.5	LF	0.53				14.0	3.54	Turkey
95.6	LF	0.24	-1.24			14.3	3.34	Bulgaria
103.0	LF	0.13	-1.80			14.3	3.15	Russia
73.01	LF	0.31	-2.45				3.21	Morocco (Present Study)

Table 10: Comparative of growth parameters obtained for Sarda sarda by the present study with other studies in different area according to www.fishbase.org [37].

Recently, [36] present an estimate of growth rate, based on otholith analysis of juvenile fish from Mediterranean Sea (18-110 days) were 5.83 mm per day (range= 4.85-6.81 mm per day) and 4.15 g per day (range= 1.88-6.42 g per day).

In spite of some small divergences in the growth parameters according the studied area, the calculation of the coefficient of performance (Ø') indicates that our results are globally similar to those obtained by different studies. The different Ø' gotten from the bibliography, vary from 3.15 to 3.58 [37] while the parameters of growth calculated in this study equals to 3.21 and appeared similar to the range the values previously obtained.

In this paper, results indicate that Atlantic bonito have diverged morphology and all correlation coefficients showed that all morphometric relationships increased with fork length. This is the same results found in Marijana, 2005 [26] work on Atlantic bonito in the Adriatic Sea. All former fishery surveys of this species focused on fork lengths of commercial specimens, except HANSEN, 1988 [38] who studied morphometric characteristics in relation to total length.

In this work, the juvenile phase is mainly missing from the samples.

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