Morphology and sexual dimorphism of the Salema *Sarpa salpa* (Linnaeus, 1758) on Annaba coasts

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ABSTRACT

This work deals with the biometrics of the Salema *Sarpa salpa* from the coasts of eastern Algeria. Using metric and meristic criteria, the morphology of the species is characterized and compared to other individuals from different localities in the Mediterranean and the Atlantic. The Salema of the Annaba coasts show an isometry of growth of the majority of the metric characters considered (9 out of 16), both in females and in males, but it is not always the same characters. Two characters show sexual morphological dimorphism: the length of the maxilla and the diameter of the eye. Females are said to have a larger maxilla and orbital diameter. Regarding the numerical criteria, we note their greater extent in the Salema of the Annaba coast compared to the other Mediterranean and Atlantic populations studied.

Introduction

The prerequisite for any study of a group of living organisms, animal or otherwise, is the identification of the individuals that compose it. The morphological concept considers that the morphological distinction is the decisive criterion of the rank of the species. This typological concept is sometimes misleading because it overestimates the strictly secondary role of differences in shape which are often the result of different environmental conditions. The main criterion of the rank of the species of a natural population is in fact only represented by reproductive isolation.

In fish, meristic (or numerical) and morphometric characters, and currently morphogeometry, are still used to detect signs of genetic divergence within species, although their use for this purpose has certain drawbacks: (1) their expression generally results from complex interactions between environmental factors and the animal's genetic program, (2) their heritability is polygenic and of variable intensity. This is why the use of this tool is supplemented, whenever possible, by more precise molecular genetic techniques.

The characterization of the morphology is useful in the context of the search for possible different populations within the species, data necessary for the correct management of the stocks present. Indeed, a geographically structured species cannot receive the same modes of management and fishery exploitation, given the differences that can characterize the life history traits (growth, sexual maturity, fertility, etc.) of its different species constituent populations.

The primary objective of this study was therefore to characterize the morphology of the Salema *Sarpa salpa* before addressing other aspects of its biology and dynamics. For this, we used meristic and metric criteria. The goal is to have a regional biometric reference useful for current and future research on the possible differentiation of populations of this species (LENFANT & PLANES, 1996; GONZALEZ-WANGUEMERT et al., 2004). In particular, the influence of sex on morphology will be sought.

1. Materials and methods

1.1. Origin of the samples

Obtaining a representative sample of a population is one of the main problems in the study of the dynamics of animal communities. This study is carried out on samples of fish collected monthly from wholesalers and fishmongers in the city of Annaba during an annual cycle, from March 2010 to March 2011. Their fishing was carried out by means of trawls and gillnets on the coasts from Annaba (fig. 1). A total of 586 fish, with a total length of between 3.9cm and 31.3cm and a total weight ranging from 0.78g to 550g were obtained. The sample used in this morphological study is composed of 128 males: 16.2 <Lt (cm) < 27.8; 60.73< Pt (g) < 324.61 and 94 females: 17 < Lt (cm) < 31.3; 60 < Pt(g) < 550.

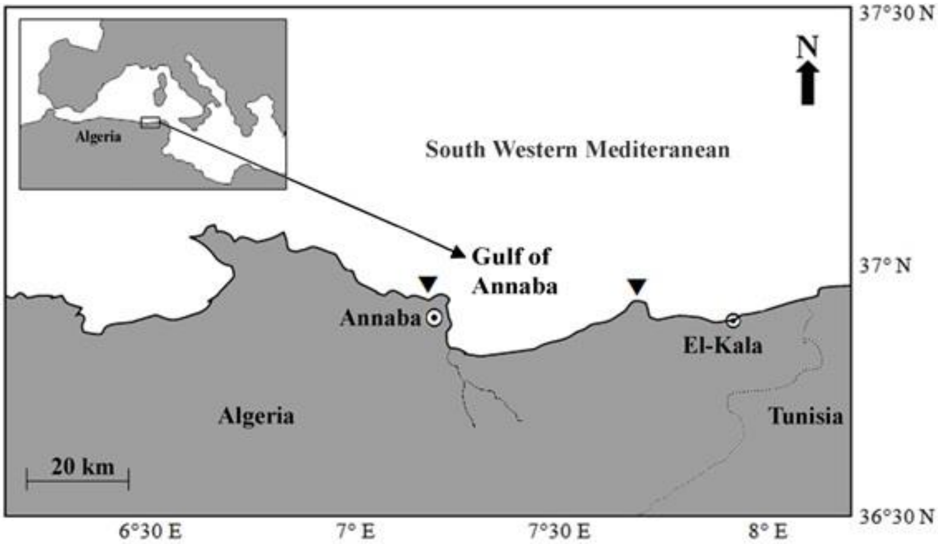

Figure 1. Geographic boundaries of *S. salpa* sampling sites on the coast of Annaba.

1.2. Somatic morphometry

The morphology of each individual is characterized by two types of data: the dimensions of the different parts of the body (metric characters) and the numerical or meristic characters. The combination of these two types of criteria makes it possible to characterize the biometrics of the population considered.

1.2.1. Meristic characters

Seven meristic characters were studied:

- The number of gill rakers: it is counted on the lower and upper part of the first left gill arch under a binocular magnifying glass, except for large specimens. To be considered, a gill rakers must be able to retain a mounted needle, pressed along the gill arch.
- The number of scales on the lateral line: for small specimens, counting is facilitated by the use of a magnifying glass. The limit of the fleshy part of the caudal peduncle (limit of the measurement of the standard length) marks the end of the counting, because the counting of the very last scales is random.
- The number of hard and soft rays of the dorsal fin.
- The number of hard and soft anal fin rays.

Hard rays are easily distinguished from soft rays by their ossified and pointed structure at their distal end. To avoid possible counting errors, the soft rays were counted from their base.

1.2.2. Metric characters

Sixteen metric characters are retained in this study to describe the morphology of *Sarpa salpa*. These are measured on each individual to the nearest millimetre (figure 2). These are: the total length (Lt), the standard length (Ls), the fork length (Lf), the pre-pectoral length (LPp), the post-pectoral length (Lpp), the diameter of eye (Do), pre-orbital length (LPo), post-orbital length (Lpo), body height (Hc), caudal peduncle height (Hpc), body thickness (Ec) , pre-dorsal length (LPd), pre-anal length (LPa), maxillary length (Lm), inter-orbital diameter (Dio) and cephalic length (Lc). The total length is measured using an ichthyometer. The standard (Ls), cephalic (Lc), pre-dorsal (Pd) and pre-pectoral (Pp) lengths are assessed using a Plexiglas graduated ruler. The identification of the limit points is done by transparency. All other measurements are made using a dry-point compass.

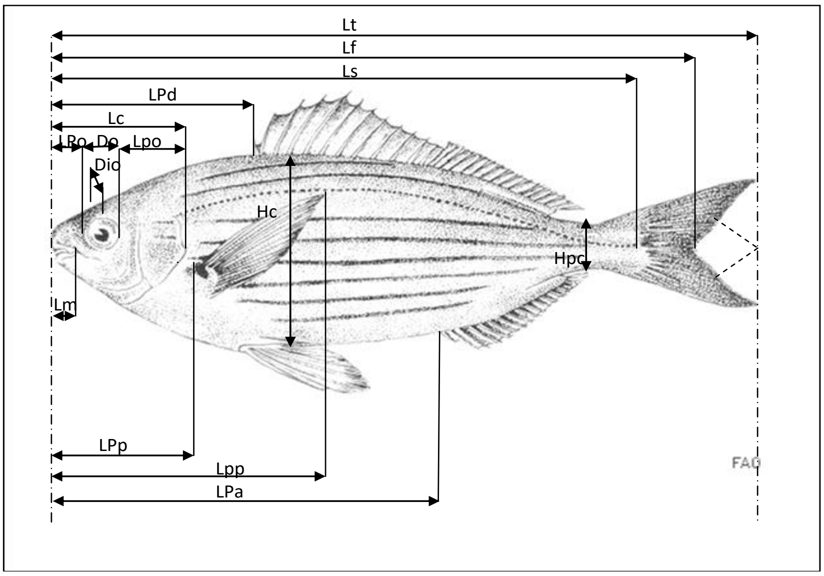

Figure 2. Measurements taken on examined specimens of *Sarpa salpa* from the eastern coasts of Algeria.

Lt: total length, Ls: standard length, Lf: fork length, LPp: pre-pectoral length, Lpp: post-pectoral length, Do: eye diameter, LPo: pre-orbital length, Lpo: post length -orbital, Hc: height of the body, Hpc: height of the caudal peduncle, Ec: thickness of the body, LPd: pre-dorsal length, LPa: pre-anal length, Lm: length of the maxilla, Dio: inter-orbital diameter, Lc: cephalic length.

In order to better describe the possible changes in the relative growth of the different parts of the body of the fish during its somatic growth, the metric criteria are expressed in terms of total length or cephalic length. Thus, in order to put in a more expressive way the relative changes of these dimensions, we used the regression equation of the reduced major axis type, recommended by TEISSIER (1948) for the studies of allometry and whose formula is:

$Y = a X^b$

with

a: constant

b: allometric coefficient

The statistical comparison of the allometry coefficient of this relation to the value 1 is carried out using the Student t test (DAGNELIE, 1998). It is a test of equality of standard deviations or variances of two possibly correlated random variables, according to the formula:

$$t\ obs = \frac{[(|b^2 - 1|).\sqrt{n-2})]}{2b.\sqrt{1-r^2}} \qquad (1)$$

where:

n: number of data pairs

r: correlation coefficient

b: allometric coefficient (slope)

The value of t_{obs} is compared with that of theoretical t $t_{1-\alpha/2}$ of the Student distribution, where α represents the confidence threshold at the risk of error of 5% for n-2 degrees of freedom. Two cases can arise:

- If $t_{obs} \leq t_{1-\alpha/2}$, we accept the hypothesis. The difference is not significant and the value of b = 1. There is therefore an isometry (or simple allometry) between the two parameters studied.
- If $t_{obs} \geq t_{1-\alpha/2}$, we reject the hypothesis. The difference is significant. There is therefore a decreasing (negative) allometry if b < 1, or increasing (positive) if b > 1.

Statistical analyses are performed using the Microsoft Excel program (V. 2007).

1. 3. Comparison of the morphology of males and females

To detect a possible sexual dimorphism, we compared for each metric character, the equations of the regression lines between the two sexes. For this, we used the Student's "t" test adapted to reduced major axes (MAYRAT, 1959). We first compare the slopes of the two axes by comparing a difference to its standard error:

$$tpe = \frac{|a_1 - a_2|}{\sqrt{Var(a_1 - a_2)}} \qquad (2)$$

at n - 4 degrees of freedom where:
a_1 and a_2: slopes of the two regression lines.
n: total number of pairs.
If the difference in slope is not significant, then the position of the two straight lines is compared over their entire length and not simply at their origin. The two experimental straight lines are replaced by two parallel “auxiliary straight lines” passing through the centers of gravity of the samples, but with a common intermediate slope. A common variance is calculated around these parallels; this is a combined "tpo" regression:

$$tpo = \frac{Y_{1P} - Y_{2P}}{\sqrt{Var(Y_{1P} - Y_{2P})}} = \frac{\left|\overline{Y}_1 - \overline{Y}_2\right| - a_P(\overline{X}_1 - \overline{X}_2)}{\sqrt{S^2 y_P\left[\left(\frac{1}{n_1} + \frac{1}{n_2}\right) \times \left(\frac{2}{1 + R_P}\right) + \frac{(\overline{X}_1 - \overline{X}_2)^2}{NS^2 X_P}\right]}} \qquad (3)$$

where:

$\overline{Y}_{1P} - \overline{Y}_{2P}$: Distance between auxiliary lines.

$\overline{Y}_1$ et $\overline{Y}_2$: mean of the Y of the experimental lines.

$\overline{X}_1$ et $\overline{X}_2$: average of the X of the two experimental straight lines.

a_P : Slope of the auxiliary line.

R_P : Mean correlation coefficient.

$\frac{1}{n_1}\left(S^2 Y_P\right)$ et $\frac{1}{n_2}\left(S^2 Y_P\right)$: variance of $\overline{Y}_{1P} - \overline{Y}_{2P}$ considered as averages of $Y_{1P} - Y_{2P}$.

$NS^2 X_P$: Covariance of X_P.

N : Total number of pairs.

2. Results

2. 1. Meristic characters

The statistical data concerning the distribution of seven specific meristic characters for *Sarpa salpa* are specified in Table 1, independently of the sex or the size of the fish.

Table 1. Statistical distribution of the different meristic characters studied for *Sarpa salpa* from the Algerian eastern coasts (N = 586).

Numeric characters	Mean	Standard deviation	Mode	Extreme values
Number of gill rakers (lower part)	12.483	0.935	12	9-16
Number of gill rakers (upper part)	4.470	0.778	4	3-7
Number of scales on the lateral line	75.462	2.663	75	66-85

Number of hard dorsal fin rays	10.992	0.097	11	10-12
Number of soft dorsal fin rays	15.521	0.903	16	10-18
Number of hard anal fin rays	3	-	3	-
Number of anal fin soft rays	13.794	0.682	14	10-15

From the point of view of meristic characters, the left gill arch of the Salema from the eastern coasts of Algeria has 9 to 16 lower gill rakers (mode = 12) and 3 to 7 upper gill rakers (mode = 4). The dorsal fin has 10 to 12 ossified rays (mode = 11) and 10 to 18 soft rays (mode = 16). The anal fin has 3 spines (mode = 3) and 10-15 soft rays (mode = 14). The number of scales on the lateral line varies between 66 and 85, giving a modal value of 75 scales.

2. 2. Metric characters

The allometry relationships of the different metric characters as a function of total length (Lt) or cephalic length (Lc) and their correlation coefficients are recorded in Table 2 in the case of the total population. All the parameters measured are significantly correlated with total length ($0.774 \leq r \leq 0.999$; $P \leq 0.001$) or cephalic length ($0.689 \leq r \leq 0.985$; $P \leq 0.001$). The weakest correlation is that which links the length of the maxilla to the length of the head ($0.689 \leq r \leq 0.907$; $P \leq 0.001$).
In the total population, growth isometry concerns three characteristics of the sixteen measured: LPa/Lt, Hpc/Lt, Lpo/Lc. A minor allometry is demonstrated in seven cases (Lf/Lt, Lc/Lt, LPd/Lt, LPp/Lt, Lpp/Lt, Lm/Lc, Do/Lc), whereas the major allometry is verified only in five cases (Ls/Lt, Ec/Lt, Hc/Lt, Dio/Lc, LPo/Lc). In males, the regression equations show that Lf/Lt, Ls/Lt, LPd/ Lt, Lpp/Lt, LPa/Lt, Hpc/Lt, Lm/Lc, Dio/Lc, Lpo/Lc exhibit isometric growth. The cephalic and pre-pectoral lengths present a lower allometry compared to the total length, similarly a lower allometry is observed for the Do/Lc ratio. An increasing allometric growth is noted for the following characters: Ec/Lt, Hc/Lt, LPo/Lt. In females, the growth isometry concerns nine characters as for males, but not the same. These are: Lf/Lt, Ls/Lt, Lc/Lt, LPp/Lt, LPa/Lt, Hpc/Lt, Lm/Lc, Dio/Lc, Lpo/Lc. The pre-dorsal length, the thickness of the body, the height of the body present an increasing allometry compared to the total length. The pre-orbital length shows the same allometry compared to the cephalic length, whereas the minor allometry is verified only in two cases (Lpp/Lt and Do/Lc).

2. 3. Sexual dimorphism

The equality of the residual variances between the males and the females is confirmed by the F test. The "tpe" values show a significant difference ($P < 0.001$) in slopes for 5 parameters: fork length, standard and pre-anal lengths, body thickness and caudal peduncle height, while "tpo" values show that the positions of these straight lines are significantly different ($P < 0.001$) in the case of maxillary length and orbital diameter (tab. 3). The length of the maxilla (Lm) and the orbital diameter (Do) grow more rapidly in females than in males. The seven characters above highlight the existence of a sexual dimorphism in *Sarpa salpa*.

Table 2. Correlation coefficients and allometric relationships between the different lengths measured in the total population of *S. salpa* from the eastern coasts of Algeria (N = 586).

Function	R	Regression equation	Allometric relationship	Allometry	Limit values
Lf = f (Lt)	0.999	Lf = 0.974 Lt – 0.02	Lf = 1.954 $Lt^{0.974}$	t_{obs}=14.776 (-)	3.9 ≤ Lt ≤ 31.3 3.7≤ Lf≤ 27.9
Ls = f (Lt)	0.998	Ls = 1.012 Lt –0.105	Ls = 0.785 $Lt^{1.012}$	t_{obs}=4.559 (+)	3.9 ≤Lt ≤31.3 3.3 ≤ Ls ≤26,1
Lc =f (Lt)	0.993	Lc=0.841 Lt – 0.49	L= 0.323 Lt $^{0.841}$	t_{obs}=35.757 (-)	3.9 ≤ Lt ≤ 31.3 1 ≤ L_c≤ 6.2
LPd= f (Lt)	0.979	LPd = 0.917 Lt – 0,474	LPd = 0.335 $Lt^{0.917}$	t_{obs}=10.336 (-)	3.9 ≤ Lt ≤ 31.3 1.4≤LPd ≤ 8.9
LPp= f (Lt)	0.991	LPp = 0.848 Lt – 0,457	LPp = 0.349 $Lt^{0.848}$	t_{obs}=29.911 (-)	3.9 ≤ Lt ≤ 31.3 1.2≤ LPp ≤ 6.8
Lpp= f (Lt)	0,986	Lpp = 0.930 Lt – 0,313	Lpp = 0,486 $Lt^{0,930}$	t_{obs}=10.6 (-)	3,9 ≤ Lt ≤ 31,3 1.7≤ LPp ≤ 12.1
LPa= f (Lt)	0.989	Lpa = 1,006 Lt - 0,268	Lpa = 0,539 $Lt^{1,006}$	t_{obs}=0.973 (=)	3,9≤ Lt ≤ 31,3 2,1≤ Lpa ≤ 18
Ec= f (Lt)	0.962	Ec=1.354Lt–1,382	Ec=0,041$Lt^{1,354}$	t_{obs}=27.239 (+)	3.9≤ Lt ≤ 31.3 0.2≤ Ec ≤ 4.6

Hc= f (Lt)	0.971	Hc = 1.208 Lt – 0,82	Hc = 0,151Lt ^{1,208}	t_{obs}=19.157 (+)	3.9≤ Lt ≤ 31.3 0.7≤ Hc ≤ 10,7
Hpc= f (Lt)	0.950	Hpc =1.006 Lt– 1,193	Hpc = 0,064 Lt ^{1,006}	t_{obs}=0.459 (=)	3.9≤ Lt ≤ 31.3 0.2 ≤Hpc ≤ 2.2
L_m=f(L_c)	0.907	L_m =0.872 L_c –0,529	L_m =0,295 $Lc^{0,872}$	t_{obs}=7.900 (-)	1 ≤ L_c ≤ 6,2 0.3 ≤ L_m ≤ 1.7
Do =f (L_c)	0.940	Do =0.721 L_c – 0,398	Do =0,399 $Lc^{0,721}$	t_{obs}=23,576 (-)	1 ≤ Lc ≤6,2 0.4 ≤ Do≤ 1.5
Dio =f (L_c)	0.981	Dio =1.255 L_c – 0,574	Dio =0,266 $Lc^{1,255}$	t_{obs}=28,590 (+)	1 ≤ Lc≤ 6,2 0.2 ≤ Dio ≤ 2.6
LPo= f (L_c)	0.977	LPo = 1.097 L_c – 0,54	LPo = 0,288 $Lc^{1,097}$	t_{obs}=10,458 (+)	1 ≤ Lc≤ 6,2 0.3≤ LPo ≤ 2.3
Lpo= f (L_c)	0.985	Lpo = 1.007 L_c – 0,386	Lpo = 0,411 $Lc^{1,007}$	t_{obs}=0,971 (=)	1 ≤ Lc≤ 6,2 0.4≤ Lpo ≤ 2.7

=: isometry, +: majorant allometry, -: minorant allometry

Table 3. Comparison of the slope and the position of the regression lines in females and males of *Sarpa salpa* from the eastern coasts of Algeria.

Function	Regression equation		Homogeneity of variances		tpe		tpo	
	Females	Males	F_{obs}	$F_{1-\alpha/2}$ α=0.05	t_{obs}	$t_{1-\alpha/2}$ α=0.001	t_{obs}	$t_{1-\alpha/2}$ α=0.001
Lf=f(Lt)	Lf=1.015Lt -0.074	Lf = Lt -0.054	1 .33	1.37	3.75	3.337*	-	3.337
Ls=f(Lt)	Ls=1.030Lt -0.129	Ls =1.017Lt -0.112	1.22	1.37	6.5	3.337*	-	3. 337
Lc=f(Lt)	Lc=0.939Lt-0.619	Lc=0.928 Lt -0.606	1.01	1.37	1.83	3.337	2.967	3.337
LPd=f(Lt)	LPd=1.121Lt-0.744	LPd =1.071Lt - 0.676	1	1.37	2.5	3.337	-	3.337
LPp=f(Lt)	LPp=0.939Lt -0.576	LPp=0.910Lt -0.54	1.02	1.37	2.9	3.337	-	3.337
Lpp=f(Lt)	Lpp=1,924Lt-0,306	Lpp=1.053Lt -0.477	1.02	1.37	3	3.337	-	3.337
LPa=f(Lt)	LPa=1.045Lt -0.324	LPa= 0.964Lt - 0.209	1.11	1.37	8.1	3.337*	-	3.337
Ec=f(Lt)	Ec=1.378Lt-1.411	Ec=1.446Lt-1.499	1.05	1.37	3.4	3.337*	-	3.337
Hc=f(Lt)	Hc=1.196Lt -0.814	Hc=1.214Lt -0.827	1	1.37	0.58	3.337	2	3.337
Hpc=f(Lt)	Hpc=0.893Lt-1.046	Hpc=0.857Lt-0.999	1.01	1.37	3.6	3.337*	-	3.337
L_m=f(L_c)	L_m=1.080L_c-0.679	L_m=1.019L_c-0.619	1.06	1.37	1.84	3.337	7	3.337*
Do=f (L_c)	Do=0.806L_c-0.467	Do=0.807L_c-0.452	1.12	1.37	0.0 5	3.337	4.666	3.337*
Dio=f (L_c)	Dio=1.096L_c-0.475	Dio=1.076L_c-0.466	1.01	1,37	2	3.337	-	3.337
LPo=f(L_c)	LPo= 1.209L_c-0.615	LPo=1.153L_c-0.57	1.01	1,37	2.8	3.337	-	3.337
Lpo=f(L_c)	Lpo= 1.048L_c-0.41	Lpo=1.057L_c-0.415	1.01	1,37	0.3 7	3.337	0.333	3.337

*: significant difference

Discussion

The various morphometric characters considered have correlation coefficients close to 1, which express their strong relationship with total length or cephalic length. The character that seems the least related to size is the length of the maxilla (Lm). This phenomenon is classic in fish and reflects a slowing down and then a cessation of maxillary growth.

The regressions of the different parameters according to the total length or the cephalic length were defined in order to evaluate their allometric constants. The majority of these characters (44.46%) has a slower growth (minor allometry) than the total length or the cephalic length. Growth isometry is noted for only 20% of the traits examined, while 33.3% of the traits show an increasing allometry, indicating their faster growth in relation to total length or head length. Biometric relationships in saup were only addressed by BAYHAN and KARA (2015) in Izmir Bay in Turkey and only concerned standard and fork lengths. On 927 individuals, both sexes combined, these authors highlight an isometry (1.06) of growth in the case of Lf/Lt and a minor allometry (0.84) in the case of Ls/Lt. The same conclusions hold when the sexes are separated.

Depending on the sex, the relative growth evolves in a different way. In males, the isometry is verified for 60% of the characters considered and the same percentage, i.e. 20% of the parameters measured, show an allometric increase or decrease. In females, 60% of the parameters examined have an isometric growth as in males, 26.66% show an increasing allometry and 13.33% show a decreasing growth. The statistical analysis that we have applied shows that certain characters can be used to differentiate the sexes. It is the length of the maxilla and the orbital diameter which seem to be valid for the distinction of males and females. The latter would have a larger maxilla and orbital diameter. This sexual dimorphism is encountered in other teleost fish living in the Mediterranean, such as the sea bass *Dicentrarchus labrax* where the females have a shorter maxilla (KARA, 1997), while BARNABE (1973) finds in the same species other characters involved in sexual dimorphism, such as the lengths of the head, the pre-anal, the pre-dorsal and the height of the body which are greater in the female. In the baraccuda *Sphyraena sphyraena*, the length of the upper jaw is the only character involved in sexual dimorphism (BOUREHAIL, 2004).

Regarding numeric characters, Table 2.4 compares our results with those obtained in other localities in the Mediterranean and the Atlantic. The number of gill rakers on the lower (9-16) and upper (3-7) parts of the left first gill arch shows a different dispersion from that found by DE LA PAZ (1975), Whitehead et al. (1986) and FISHER et al. (1987) in different regions of the Mediterranean (9-12/ 6-9) and the Atlantic (15-21) (DE LA PAZ, 1975). The number of lateral line scales ranges from 66 to 85. This interval is wider than that observed by DE LA PAZ (1975), WHITEHEAD et al. (1986) and FISHER et al. (1987) in the Mediterranean (between 58 and 67) and in the Atlantic between (57 and 68) (DE LA PAZ, 1975). The number of hard fin rays dorsal (10-12) is constant, while that of the soft rays (10-18) is variable (12-16) (DE LA PAZ, 1975; WHITEHEADet al., 1986; FISHERet al., 1987). With 10 to 15 soft rays, the anal fin is distinguished by a wider extent than elsewhere in the Mediterranean and the Atlantic (12-14) (DE LA PAZ, 1975; WHITEHEADet al., 1986; FISHERet al., 1987). However, morphology alone cannot claim to lead to absolute certainty of the results in all cases, since for each species, the probability is not zero to encounter individuals whose characters deviate from the limit values specific to the species considered. Observed discrepancies in number of characters, such as number of gill rakers, lateral line scales or fin rays, may be due to methodology (counting limits) which often is not specified.

Table 4. Comparison of distribution of meristic characters of *Sarpa salpa* in different areas of the Mediterranean and the Atlantic.

Characters	Mediterranean*	Atlantic**		Present study
Lower gill rakers	9-12	15-21		9-16
Upper gill rakers	6-9			3-7
Lateral line scales	58-67	55-68	57-68	66-85
Hard dorsal fin rays	XI-XII	XI-XIII	XI-XIII	X-XII
Soft dorsal fin rays	12-15	12-16	12-16	10-18
Hard anal fin rays	III	III	III	III
Soft anal fin rays	12-14	12-14	12-14	10-15

*WHITEHEAD*et al*. (1986) ; FISCHER*et al*. (1987)
**DE LA PAZ, (1975)

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