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Reproductive biology and growth of Lesser Spotted Dogfish *Scyliorhinus canicula* (Linnaeus, 1758) in Western Algerian coasts (Chondrichthyes, Scyliorhinidae)

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ABSTRACT Elasmobranch fishes have a large distribution. At the level of the Mediterranean fisheries, a low density of elasmobranchs is noted at the assemblages, these fisheries appearing near to the point of best efficiency or even to over-exploitation. Indeed, a general decline of shark populations was observed over the last decade on the Mediterranean coast. The aim of this work was to evaluate different biological characteristics of the species *Scyliorhinus canicula* (Linnaeus, 1758). A sampling of 461 specimens was realized between September 2009 and August 2010 from the western coast of Algeria. The oviduco-somatic index OSI, the hepato-somatic index (HSI) and the condition factor (Kn) were estimated monthly for 249 females to identify the reproduction period. Obtained results show a rapid maturation from September to November and from February to April when the Kn values are very low.

KEY WORDS biology; fishery; western Algerian coasts; *Scyliorhinus canicula*; sentinel species.

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INTRODUCTION

The Lesser Spotted Dogfish *Scyliorhinus canicula* (Linnaeus, 1758), a species of Chondrichthyens fish studied in several areas of the globe, oviparous, abundant and frequently observed along the coasts of Europe in the Atlantic and Mediterranean (Halit & Taşkavak, 2006), is very abundant on the Algerian coast.

Recently, *S. canicula* was shown to be a good indicator to evaluate the level of exploitation of the marine ecosystem by its vulnerability to the fishing impact due to its slow growth, late reproduction and very low fertility rates (Rodriguez-Cabello et al., 1997; Massutí & Moranta, 2003) and by its association with other noble species frequenting the same habitat.

Taking into account that length at maturity, fecundity and sex-ratio are some of the most important parameters in studying reproductive dynamics of elasmobranch population, this study was carried out by examination of annual changes of the oviduco-somatic index (OSI), hepatosomatic index (HSI) and condition factor (Kn) in order to evaluate the level of the exploitation in the Algerian coasts.

In fact, on southern Mediterranean coast, the knowledge on *S. canicula* is still fragmentary, being limited to some remarks about Algerian waters.

Therefore, the aim of the present paper was to study the population dynamics, reproduction, condition, age and growth of this species. This is the first paper with a complete analysis of the biology of *S. canicula* in south-western Mediterranean.

MATERIAL AND METHODS

A-Reproduction study

A series of biological samples was conducted on specimens of *S. canicula* caught by the commercial trawlers in the sampling area of Oran and Arzew (Fig.1). Specimens' total length was measured and both sex and maturity were reported for females which represent the focus of our study. Three different maturity stages were defined (Table 1) according to Rodriguez-Cabello et al. (2007) and Capapé et al. (2008).

Stage	Microscopic aspect (color and eggs' texture)
I immature	No eggs and no Capsules
II Beginning of maturation	Ovaries small, light brown, egg-capsules rigid
III Advanced maturation	Ovaries enlarged, dark brown, egg-capsules rigid

Table 1. Different stages of maturity of *Scyliorhinus canicula* females.

Sex-ratio analysis was performed studying global sex-ratio, sex-ratio by length classes and sex-ratio by seasons using the logistic model STATISTICA Software (StatSoft Inc., 2001) and calculating the heterogeneity test χ^2 with one degree of freedom, $p < 0.05$. The value of the reduced distance (Schwartz, 1983) was also estimated; it is a homogeneity test which compares the average sizes of males and females, in case of large samples, by the following equation:

$$\varepsilon = \frac{\left|\overline{X}_1 - \overline{X}_2\right|}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

With reference to the work of Capapé et al., (2008) and to define the beginning and the extent of spawning period, oviduco-somatic index (OSI) was calculated using the following equation OSI= (OW/TW)*100, where OW is capsules' weight and TW is total weight of the specimens.

Hepatosomatic index (HSI) was calculated using the following equation: HSI= (LW/TW)*100, where LW is liver weight and TW is total weight of the specimens. Variation of OSI and HSI related to sexual maturity stages and seasons was examined in *S. canicula* females.

Finally, to monitor morphological variations, the condition index was calculated to assess the degree of overweight consecutive to genital development and repletion state of the target species. Condition factor was studied in females in order to show differences of Kn (Le Cren, 1951) related to time, according to the formula: $Kn = W/W_{th}$ with $W_{th} = aL^b$ where "W" is the total weight, "W_{th}" is the theoretical weight, "a" and "b" are coefficients of the relative growth between weight and length and "L" is total length.

B-Growth Study

The objective of this part of the study was to define several biological characteristics, such as structure of population size, growth and age of *S. canicula* in the study area.

Basic principle of the growth equation of Von Bertalanffy.

There are several mathematical models to express the growth in elasmobranchs. A detailed review was made by Beverton & Holt (1957), Ursin (1967), Gulland (1983), Sparre & Venema (1996) and Pauly & Moreau (1997). The most popular model is Von Bertalanffy (1938) growth equation: $Lt = L\infty\,[1-e^{-k\,(t-to)}]$.

ELEFAN method (ELECTRONIC LENGTH FRENQUENCY ANALYSIS).

In this study, we used a numerical method, the method ELEFAN (Pauly & Moreau, 1997). For mathematical modeling, the LFDA software (Kirkwood et al., 2001) was used. Analyses were made for males and females, separately.

RESULTS

A-Study of reproduction

1) Sex–ratio

After sexing of 461 specimens we found a sampling rate of 54.01% of femininity significantly more important than males sex ratio (45.99%). These results are consistent with other studies carried out in different parts of the Mediterranean at depths ranging between 200 and 500 m (Rodriguez-Cabello et al., 1998; Capapé et al., 2008) (Table 2).

The length abundance curve is shown in figure 2. Figure 3 shows a variation of the percentage of females per month. The females percentage is still dominant during the end of summer and at the beginning of autumn up to winter, declining in the spring period.

Results were compared with theoretical ε (1.96) at a rate of 95% confidence (Table 3). The calculated value of ε = 0.33 is less than the value (1.96) given by the table of the z-score; this finding indicates that males are, on average, significantly larger than females. As regards the sexual maturation of females, different stages of maturation of the gonads during different months of the year are shown in figure 4.

Sex	Total	Percentage
Females	249	54.01%
Males	212	45.99%
Total	461	* 100%

Table 2. Percentage of sexes in *Scyliorhinus canicula* (*p<0,05).

Sex	Males	Females
Total	212	249
X (cm)	37.02	35.10
σ^2 $(cm)^2$	1943.02	1965.25
ε	0.33	
Difference	significant	

Table 3. Different size parameters of males and females of *Scyliorhinus canicula*.

2) Indices of fish condition

In our study we have used three indeces to determinate the spawning period of the species in the study area: the oviduco-somatic index (OSI) specific to Elasmobranchs, hepatosomatic index (HSI) and condition index (Kn). These allowed to quantify morphological changes of the specimens and to identify reproduction period by studying the evolution of maturity stages of the ovary.

Hepato-Somatic Index (HSI) and Oviduco-Somatic Index (OSI) and condition factor (Kn).

Monthly averages of OSI and HSI calculated from 249 females are plotted in figure 5. Three peaks were observed corresponding to the maximum annual spawning period of the population. The highest values of OSI were found in December, February, June and August and the lowest values in October, January, April, May and July.

The highest values of the HSI occurred in December, February, March, the lowest fall in October, January and April (Fig. 5). Figure 6 shows the condition factor Kn by seasons in both sexes. The values of Kn resulted overweight, thus revealing breeding events and confirming a rapid maturation occurring from September to November and from February to April when the values of Kn are very low with irregular variations.

3) Length at maturity

For the statistical method, the L50 point estimated the body size at sexual maturity at 36 cm (Fig. 7). All data are combined in Table 4. Our results confirmed values reported for Mediterranean

Author	Area	Males (cm)	Females (cm)
Ford (1921)	English Channel	50-60	57-60
Fauré-Frémiet (1942)	Atlantic	52-60	52-60
Leloup & Olivereau (1951)	Atlantic	52-60	52-60
Leloup & Olivereau (1951)	Mediterranean Sea	37-44	37-44
Zupanovic, 1961	Adriatic Sea	34	34
Collenot,1966	English Channel	60-68	60-68
Capapé and al., 1991	Mediterranean	44	41-47
Present work *	Algeria (west)	---	36

Table 4. Summary of first sexual maturity length (L50) of *S.cyliorhinus canicula* females and males from different areas (* only females were studied to determine the size at maturity).

fisheries which differ from those from the North Atlantic where specimens length at maturity is longer than that found in the Mediterranean Sea. Total individuals' length of the monthly samples ranged from a minimum of 20 centimeters to a maximum of 50 cm. Minimum sizes correspond to females and maximum sizes correspond to males (Table 5).

Sex	Females	Males
specimens caught	249	212
Maximum size (cm)	47.4	50
Minimum size (cm)	20.1	22.2

Table 5. Size of *Scyliorhinus canicula* females and males analysed in the present study.

B- Growth study

The values of growth parameters were calculated using the software LFDA (subroutine ELEFAN) (Kirkwood et al., 2001). Tables 6 and 7 report values of L∞ (asymptotic length), K (coefficient of growth), to (the theoretical age at which the size is zero), also for Φ (growth index). These values, once estimated for *S. canicula* specimens, were then replaced in the equation of Von Bertalanffy. Parameters obtained from the equation of Von Bertalanffy did not differ significantly between the two sexes; but asymptotic length, growth rate and growth index resulted slightly different in males.

Biometric relations observed by analysis of relative growth are shown in Table 8. This relationship indicates an upper bound of allometry (b greater than 3) for females in all months of the year.

We can say that the weight of the species grows faster than the cube of length. Such an allometric relationship was observed also in males. In fact, the upper bound also appeared in the allometry of males, except for males sampled in December and February when the values of allometry were reduced. The fitting of a and b ($W_{th}= aL^b$) was employed as input data in stock assessment models.

Sex	Females	Males
Parameters	K L∞ to ϕ	K L∞ to ϕ
Result	0.57 47.70 -0.76 3.39	0.57 47.70 -0.76 3.39

Table 6: Growth parameters for *Scyliorhinus canicula* females and males.

Sex	Von Bertalanffy Equation
Females	$Lt= 47.7 [1-e^{-0.57 (t+0.76)}]$
Males	$Lt =49.23 [1-e^{-0.51 (t+0.39)}]$

Table 7. Von Bertalanffy Equation.

Sex	$W_{th}= a L^b$
Females	$W_{th}= 0.00578 L^{3.176}$
Males	$W_{th}= 0.01675 L^{3.0215}$

Table 8. Biometric relation in *Scyliorhinus canicula*.

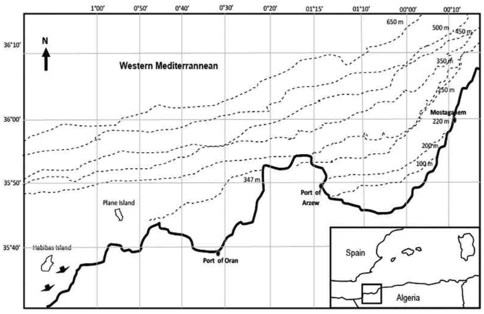
DISCUSSION

In our study (covering 12 months) a sample of 461 individuals of *Scyliorhinus canicula* was observed, resulting that females were more important than males. More information were obtained through the study of sex ratio based on different parameters and specimens size during the year.

We noted a fluctuation in the rate of femininity with a significant dominance during autumn and winter, which seems to correspond to a strong and early maturation period of the ovaries.

We also observed a clear statistically significant decrease in the rate of femininity tending to reach a numerical equality with males at the beginning of spring, i.e. in March and April, which could correspond to sexual rest or post-spawning periods; regarding the correlation between sex and body size, one can observe that size classes between 20 and 43 cm of total length are almost significantly dominated by females.

Large individuals are represented by males with a total length of 44-50 cm. This difference in size in favor of males was also reported by other authors in the Mediterranean, including Capapé et al. (1991) in the Gulf of Lions, De La Gándara et al.

1


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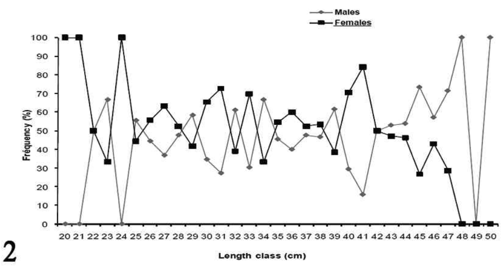

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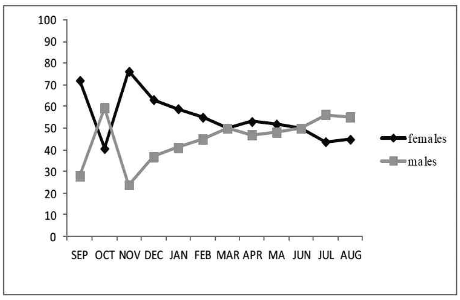

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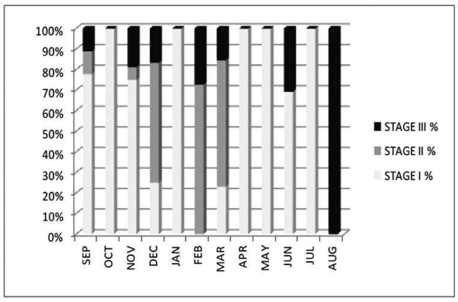

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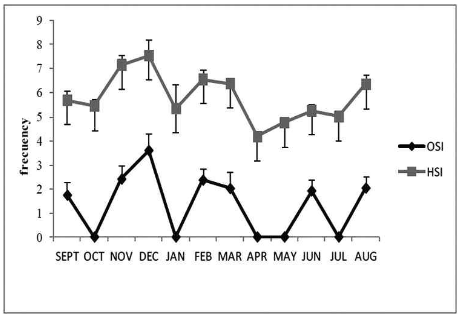

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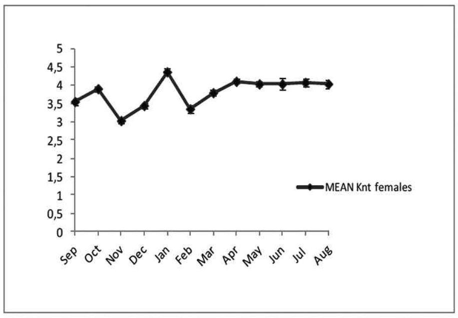

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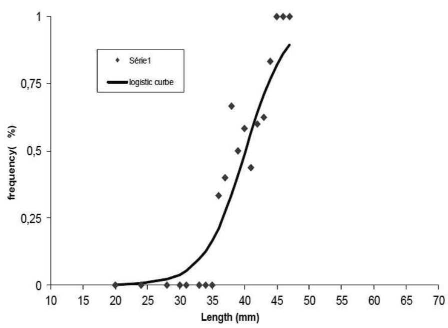

Figure 1: Study area.
Figure 2: Abundance curve. Results of χ^2 test show a predominance of one sex over the other by length of specimens (* p<0.05).
Figure 3: Distribution of males and females of *Scyliorhinus canicula* by season. χ^2 test results show a prevalence of one sex over the other per sampling month.
Figure 4: Percentages of different stages of sexual maturity in *Scyliorhinus canicula* females per month.
Figure 5: Monthly trend of OSI and HSI with standard errors in *Scyliorhinus canicula*.
Figure 6: Condition index (Kn) with standard error according to the season in *Scyliorhinus canicula* females.
Figure 7: Size of first maturity in *Scyliorhinus canicula*.

(1994) and Rodriguez-Cabello et al. (1998) along the Spanish coast; they all pointed out the size difference between females and males, which could be explained by the fact that large females are likely to be less accessible to fishing gear as they move to specific reproduction areas (Rodriguez-Cabello et al., 1998).

From the three indexes studied (OSI, HSI and Kn) we determined the spawning period of the species. Moreover, by a macroscopic approach we studied the sexual cycle of the species, the breeding of which appears to be annual (see also Capapé et al., 2008) with maximum phases of maturation occurring in December, February and March (during the laying period) and interruptions in October, January and April, corresponding to a state of sexual rest or repletion.

Similar observations were reported by Capapé (1977) however, we found periods of high ovarian maturation that differ from those reported in that paper, probably due to changes in environmental conditions as fluctuations in ocean water masses (Harris, 1952; D'Onghia et al., 1995; Mouffok et al., 2008). Ford (1921) reported that, in southern England, there were a peak in August and a minimum in September and October. While in the paper of Fauré-Fremiet (1942) these peaks were in June and January. Lo Bianco (1909), Leloup & Oliverau, (1951) and Capapé et al., (1991, 2008), maintained that this period can last all year round, without interruptions. In line with further studies on endocrine control of reproductive cycle by Sumpter & Dodd (1979), we support the idea that, although the spawning period of *S. canicula* could be quite long, it should have a maximum peak of spawning in spring and winter.

To accurately determine the period of breeding and spawning of benthic or demersal species, several indicators are generally used. Referring to ISRA-IRD (1979), it is recommended to use at least two indices when studying the reproduction of a target species. Please note that, in the present study, OSI and HSI vary in parallel and the evolution of these values is opposite to that of Kn.

We estimated the size at first maturity (L50) at 36 cm. According to Rodriguez-Cabello et al., (1998) the size at first maturity of females in the Mediterranean is smaller than that found in North Atlantic; this difference (also found in males) was explained by suggesting a possible relationship between maturity of the species and latitude (Lam, 1983). Our results confirm and support findings obtained by different authors mentioned above suggesting that reproductive parameters of *Scyliorhinus canicula* differ from one region to another, probably under the influence of various environmental and geographic parameters (Leloup & Oliverau, 1951; Relini & Orsi-Relini, 1987; Capapé et al., 1991; Demestre & Martin, 1993; Guijarro et al., 2007) such as the passage of the Atlantic currents entering the Mediterranean through the Strait of Gibraltar rich in organic matter providing an ideal enrichment of Algerian deep waters (Cartes et al., 2002).

Finally, our results for growth curves (in line with those reported by Rodriguez-Cabello et al., 1997), strongly suggest a slow growth rate and an important longevity, up to 10-20 years, for *S. canicula* specimens.

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