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Reproductive biology and growth of greater forkbeard *Phycis blennoides* (Brünnich, 1768) in Western Algerian Coasts (Osteichthyes, Gadidae)

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Abstract

The Great forkbeard, *Phycis blennoides* (Brünnich, 1768), is a species widely distributed throughout the Mediterranean Sea and although it is of great importance for fishing industry, little is known about its reproductive characteristics. This study provides first data on reproductive characteristics of this species in the south western Mediterranean, important for management and stock assessment. For this purpose a total of 461 individuals ranging from 17.5 to 43.5 cm in total length were collected monthly in a period of one year using trammel nets. Sex ratio of males to females was 1:0.91. The estimated length where 50% of analyzed individuals were sexually mature was 24.73 cm for females. The peak value of gonad somatic index was recorded in September and continued throughout the October, indicating the highest spawning activity when the Kn values are low.

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Introduction

The greater forkbeard, *Phycis blennoides* (Brünnich, 1768) is a common gadoid occurring in the Mediterranean and in the North-eastern Atlantic, from Iceland to Morocco (Tortonese, 1975; Fisher *et al.,* 1987; Davis & Edwards, 1988; Whitehead *et al.,* 1989). It is usually found on muddy or sand bottoms in depths of 100-650 m, but occasionally is captured in shallower depths, close to shore (18 m) (Bello & Rizzi, 1988). The total length at first sexual maturity for males and females are 18-20 cm and 22-23 cm respectively (Gallardo-Cabello & Gual-Frau, 1984). In the Mediterranean, *P. blennoides* spawns from June to August (Gallardo-Cabello & Gual-Frau, 1984).

The estimation of age and growth of fish are essential to the study of biology and population dynamics as well as for the management of fisheries resources, they provide a basis for the knowledge of longevity, age recruitment, age of sexual maturity, spawning periods, migration and mortality. They are also used to study the demographic population structure and dynamics.

Taking into account that length at maturity, fecundity and sex-ratio are some of the most important parameters in studying reproductive dynamics of gadoids population, this study was carried out by examination of annual changes of the gonado-somatic index (GSI), hepato-somatic index (HSI), condition factor (Kn), asymptotic length L∞, growth coefficient (K) and length-weight relationship in order to evaluate the level of the exploitation in the Algerian coasts.

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 *P. blennoides* in south-western Mediterranean.

Material and methods

A-Reproduction study

A series of biological samples was conducted on specimens of *P. Blennoides* caught by the commercial trawlers in the sampling area of Oran and Mostaganem (Fig.1). Specimens' total length was measured and both sex and maturity were reported for females which represent the focus of our study. Four different stages were defined (Table 1) according to (ICES, 2007).

Table 1. Different stages of maturity of *P. Blennoides* females

MATURITY STAGES	DESCRIPTION
1. Imature/Resting	Small ovaries, with firm consistence and minimal vascularization, transparent or pink grey, without opaque or hyaline oocytes.
2. Developing/Maturing	Medium or large ovaries, pink or yellow to orange, with vascularization variable, present and obvious. Opaque oocytes present but without hyaline oocytes.
3. Spawning	A-Hydrated-Large ovaries, with firm consistence and vascularization, pink or reddish orange. Opaque and hyaline oocytes present.
4. Post-spawning	Small or medium ovaries, flaccid, dark pink, orange or purple. Opaque and hyaline oocytes absent or residual.

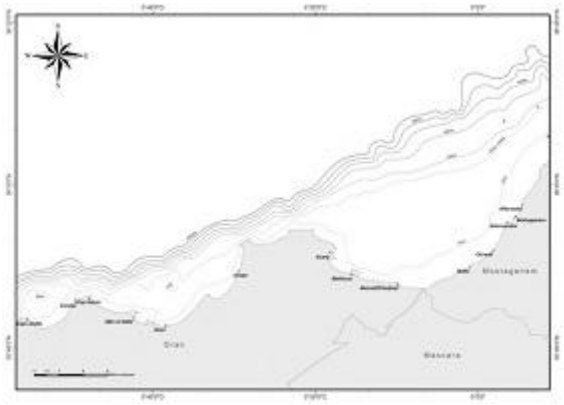

Fig. 1. Study Area.

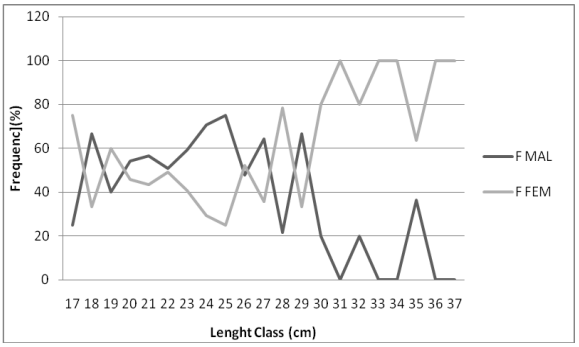

Fig. 2. Abundance curve. Results of X 2 test show a predominance of one sex over the other by length of specimens (* $p<0.05$).

For each fish, total length (TL) was measured using a simple calliper to the nearest 0.1 cm and weighed (Wt) to the nearest 0.1 g. Fishes were gutted, and gonads were removed and weighed (Wg) with three decimal accuracy. Sex was determined by macroscopic observation of the gonads (Macer, 1974). Sex ratio was examined using χ^2 (Chi-square) test with a probability level of 0.05 to test differences in relation to the expected ratio 1:1. The gonadosomatic index (GSI) was estimated as: GSI = Wg / Wt x 100. To estimate size at first sexual maturity, the data were fitted in equation: $P = 1/(1+e^{(a}bxL))$; where P is probability that individuals are sexually matured and L is their length. The length when 50% of analysed individuals were mature was calculated according to Sparre and Venema (1998): L50%=a/b.

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:

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

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: $Kn = W/Wth$ with $Wth = aL^b$ where "W" is the total weight, "Wth" 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 *P. blennoides* in the study area.

Basic principle of the growth equation of Von Bertalanffy.

There are several mathematical models to express the growth in Gadidae. 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: $Lt = L\infty\,[1\text{-}e\text{-}k^{(t\text{-}to)}]$.

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

Sex–ratio

After sexing of 461 specimens we found a sampling rate of 51.30% of Males significantly more important than females sex ratio (48.70%) the sex ratio (male: female) is 1:0.91 (Table 2).

Table 2. Percentage of sexes in *P. Blennoides* (*p<0,05).

Sex	Total	Percentage
Females	225	48.70%
Males	236	*51.30%
Total	461	100%

The length abundance curve is shown in Fig. 2. Fig. 3 shows a variation of the percentage of females per month. The female's percentage is dominant during fall and spring season, declining in the winter and summer period.

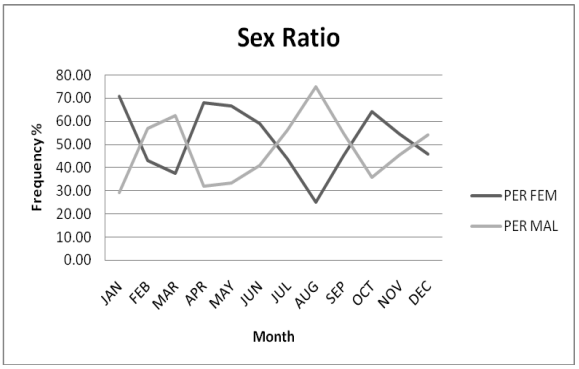

Fig. 3. Distribution of males and females of *Phycis blennoides* by season. *X* 2 test results show a prevalence of one sex over the other per sampling month.

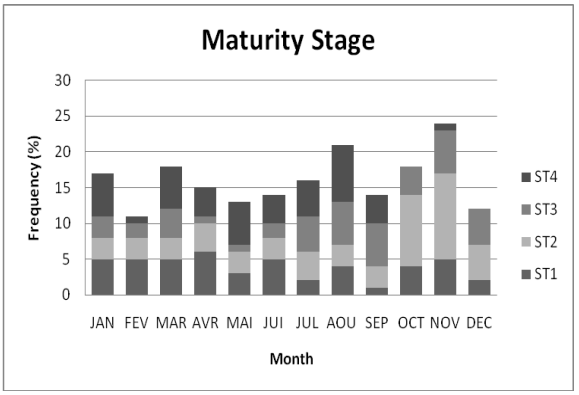

Fig. 4. Percentages of different stages of sexual maturity in *Phycis blennoides* females per month.

Results were compared with theoretical ε (1.96) at a rate of 95% confidence (Table 3). The calculated value of ε = 0.87 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 Fig. 4.

Table 3. Different size parameters of males and females of *P. blennoides*

Sex	Males	Females
Total	236	225
X (cm)	23.32	25.13
σ2 (cm)²	145.44	781.14
ε	0.87	Difference significant

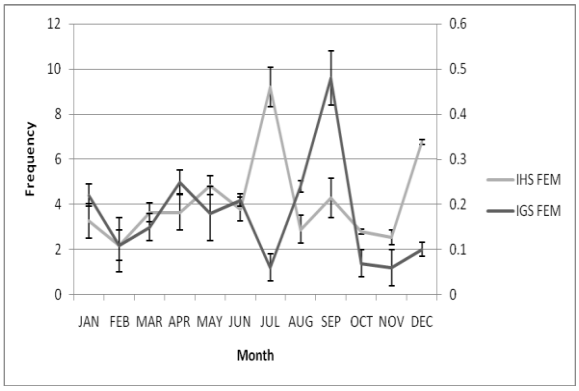

Fig. 5. Monthly trend of GSI and HSI with standard errors in *Phycis blennoides*.

Indices of fish condition

In our study we have used three indexes to determinate the spawning period of the species in the study area: the gonado-somatic index (GSI), 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 Gonado-Somatic Index (GSI) and condition factor (Kn).

Monthly averages of GSI and HSI calculated from 225 females are plotted in Fig. 5. Only one peak were observed corresponding to the maximum annual spawning period of the population. The highest value

of GSI were found in September and the lowest values in October and November

The highest values of the HSI occurred in July and the lowest fall in November (Fig. 5). Fig. 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 July to September when the values of Kn are very low with irregular variations.

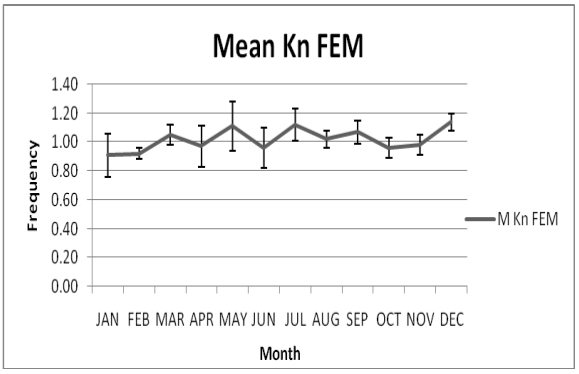

Fig. 6. Condition index (Kn) with standard error according to the season in *Phycis blennoides* females.

Length at maturity

For the statistical method, the L50 point estimated the body size at sexual maturity at 24.73 cm (Fig. 7). All data are combined in Table 4. Our results confirmed values reported for Mediterranean.

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 **17.50** centimeters to a maximum of **43.5** cm. Minimum sizes correspond to females and maximum sizes correspond to males.

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 *P. blennoides* 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.

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

Authors	Area	Males (cm)	Females (cm)
Cohen *et al.*, 1990	Atlantic	18	33
Rotllant *et al.*, 2002	Mediterranean	19.32	20
Present work 2014	west Algeria	*	24.73

Table 5. Growth parameters of *Phycis blennoides* females and males.

Sex	Females	Males
Parameters	K L∞ to ϕ	K L∞ to ϕ
Result	0.94 41 - 0.70 3.199	0.81 42.14 - 0.71 3.158

Biometric relations observed by analysis of relative growth are shown in Table 6. 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. The fitting of a and b ($W_th = aL^b$) was employed as input data in stock assessment models.

Table 6. Biometric relation in *Phycis blennoides*.

Sex	$W_th = a L^b$	
Females	$W_th = 0.004$	$L^{3.150}$
Males	$W_th = 0.002$	$L^{3.332}$

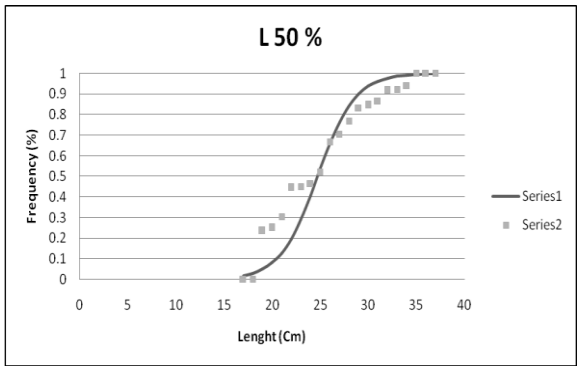

Fig.7. Size of first maturity in *Phycis blennoides*.

Discussion

This study presents first data of reproductive characteristics of forkbeard in the south-western Mediterranean Sea and therefore results were compared with other gadiform species common for this area.

Sex-ratio

In the 12 months that lasted our study we observed and analyzed a sample of 461 individuals Phycis blennoides. This allows us to see that the males are slightly larger than females. More information was obtained through the study of the sex ratio, according to different parameters and sample size during the year.

We found a change in the rate of femininity with a significant dominance during the fall, which seems to correspond with the period when we recorded the maximum peak of the GSI which could correspond to a strong and early maturation of the ovaries.

The sex ratio showed a predominance of males, the catch rate (48.70%) for females (51.30%) for males, the sex ratio (female: male) is 1:0.91 In fact, this value is not significantly different ($\chi 2$ = 0.01, df = 11, p> 0.05) of the 1:1 theoretical value. The study of sex ratio depending on the size shows the dominance of male individuals up to size 26 cm, and that beyond this size the proportions of females are dominant, to the size where females reach sexual maturity. These results are in agreement with the different regions of the Mediterranean (Gordon *et al*, 1995. Rotllant *et al*, 2002) . This predominance of females in older individuals could be explained by several authors by availability or larger female catchability; is a higher natural mortality in males. These studies showed that the females grow faster than males: in four years (Cohen *et al*, 1990).

Spawning periodThe GSI is a real coefficient of gonadal maturation. Its increase coincides with gametogenesis while its decrease indicates an active spawning (Lahaye, 1972). Tracking monthly changes GSI allowed us to know the times of sexual activity *P.blennoides* and its breeding season.

We observed the presence of gravid females with a maximum of 0.48 GSI September also, there are resting females in summer and winter; these observations could be explained by the fact that after spawning adult females would regain deep waters. Similarly, males have emissions of their sexual products with a maximum GSI 0.50 in September, this shows that the eggs are laid at the studied species could take place in autumn. Our results are almost similar to those obtained by other authors. They all define clearly the spawning period in autumn; this situation is common to all the Mediterranean coast (Gordon and Duncan, 1985) and in the Ionian Sea (Matarresse *et al*., 1998). Presence of ripe females indicated that spawning of *Phycis blennoides* occurs during early autumn to early winter. Rotllant *et al.* (2002) investigated population of *Phycis blennoides* in the western Mediterranean Sea. Mature females in their study were found only in autumn.

Parallel to the GSI, we studied the HSI since the energy required for gonad maturity comes from fat reserves stored in the liver. The observation of the temporal evolution of the hepato-somatic report *Phycis blennoides* females showing phases of hepatic synthesis and consumption phases of liver lipids. The largest decline HSI is during the autumn which synchronizes perfectly with the period of mass reproduction in females and coincides with the transfer of liver reserves to the gonad.The results of

the study of the condition index (Kn) in females, set and confirm the spawning period in the range from September to November, as from September, the value of Kn begins to decrease with a minimum in October, which could be explained by a loss of organic matter associated with the laying period.

Length of first sexual maturity

We estimated the size at first maturity (L50) to 24.73 cm. According to Rodriguez - Cabello *et al*, (1998), the size at first maturity of females of the Mediterranean is smaller than that found in the North Atlantic; this difference (also found in males) was explained by suggesting a possible relationship between the maturity of the species and latitude (Lam, 1983). Our findings and conclusions support obtained by various authors mentioned above suggests that the reproductive parameters of *Phycis blennoides* differ from one region to another, probably under the influence of various environmental and geographical parameters, as the passage of Atlantic currents entering the Mediterranean through the Strait Gibraltar rich in organic matter providing an ideal enrichment Algerian deep waters (Cartes *et al*., 2002), Silva (1986) calculated length at first maturity at 41 cm for females and 36 cm for males in Azorean waters and in this study that length was lower and equal to 24.73 cm for females.

Growth and length-weight relationship

Concerning the study of growth, we used the LFDA software (subroutine ELEFAN), and able to analyze the size frequency of this species which is largely untapped in Algeria, and calculate for the first time the growth parameters in the western basin of Algeria.Model Von Bertalanffy (1938) for linear growth was applied to both sexes. This study revealed that the relative growth rates of each sex decreases with age; they are maximum for small sizes because of the rapid growth of young species compared to older then they fall progressively as the size of the fish approaches the asymptotic size.

Our results are in agreement with many authors who have described the Gadidae in general and in particular Physic blennoides faster growth of females k = (0.94) compared to males (0.81) in the Mediterranean (Cohen *et al*., 1990 ; Massuti *et al*, 1996).

The adjustment of growth parameters in Von Bertalanffy model shows that the values differ significantly between the sexes, with higher values of growth coefficient (K) for females. Females grow faster, but reach the maximum size (37 cm) before the males which continue to grow beyond the asymptotic size of females (41cm).

In general, the various aspects discussed on the population dynamics of Phycis blennoides (Brünnich 1768) on the west coast of Algeria have shown the same pattern as other areas in the Mediterranean, France (Fancuilli *et al*., 1979), (Casas and Pineiro, 2000) in the north and north-west of the Iberian Sea. The different authors cited above have also observed this same pattern, but with lower values of growth coefficient (K), especially for females. In any case, the growth parameters estimated (which may overestimate or underestimate) the model parameters used in the study area are consistent with slow growth and high durability (between 10.5-20 years) considered for this Gadidae in the Mediterranean.

The results of the length-weight relationship showed a strong majoring allometry in females and males, that is to say that the weight of the species grows faster than the cube of the length. Adjusted for a and b (W = alb) serve as input data in the stock assessment models.

These results were previously observed in other Mediterranean areas (Fancuilli *et al*., 1979) in the Gulf of Lion in France (Romdhani *et al*., 2010) in the Tunisian coast.

In the conclusion, this study shows that Great forkbeard has group-synchronus ovarian

development and spawning season from early September to late November. The obtained results from this study are important input data for management and stock assessment of this commercially important fish species.

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